Meat Science and Technology in Service of the Meat Industry

Seventh Meat Symposium
14 October 1992

Editors:
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Private Bag X2, Irene,
1675 Republic of South Africa
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E. & O. E.
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E.C. Webb, M.J.C. Bosman & N.H. Casey

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WELCOMING ADDRESS:
Seventh Meat Symposium - Meat Science and Technology in service of the Meat Industry

G.L. Nortjé

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WELCOME

Ladies and Gentlemen, a hearty word of welcome to the 7th meat symposium presented by the Meat Industry Centre, and especially to our keynote speakers from the US, dr Darrell Wilkes and dr Abraham Saloma-Orozco. We trust that they are enjoying their stay, and that they will be afforded time to acquaint themselves with the South African way of life and the wildlife and other assets our country has to offer.

This is the first meat symposium presented under the auspices of the ARC, and the newly defined mission of the MIC namely, meat research, technology development and - transfer. It is also noteworthy that this symposium celebrates the first decade of meat symposia - we sincerely hope that we managed to serve the meat industry according to their needs in the past and that we will be able to better our performance in this regard in future. To this end I call on industry to assist us.

I would also like to take this opportunity to thank all the sponsors, the staff of the Meat Industry Centre and others who were instrumental in making today possible, for their inputs.

Ladies and gentlemen, I certainly do hope that you will take part and enjoy deliberating the subjects under discussion today and that your visit will prove to be a worthwhile exercise.

Thank you for your attention.

I would now like to call on our first speaker of the day, dr Raymond Naudé to address us on the subject of “Promoting the production and quality of animals and animal products in the ARC”.

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Promoting the production and quality of animals and animal products in the ARC

R.T. Naudé

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INTRODUCTION

The Agricultural Research Council (ARC), one of the largest agricultural research institutions in Africa, became fully operative on the first of April, 1992. This new research council was created by the transfer of 12 research institutions, together with their equipment, experimental farms and staff of more than 4 500, including 1 000 researchers and 1 200 technologists from the Department of Agricultural Development to the ARC. In contrast to its parent organisation, the ARC is autonomous with regard to staffing and remuneration, and will be able to acquire funds from outside sources to supplement its grant from parliament.

The mandate of the ARC is to undertake research, development and technology transfer for the total agricultural community, viz. the large scale commercial farmer and the smallholder, including the subsistence farmer as well as all related animal product industries. Furthermore the national aim is to enhance the quality of life of the peoples of our country while protecting the environment. International co-operation of ARC scientists in South Africa with countries in Africa and abroad, based on mutual involvement and reciprocal exchange of expertise and experience, is regarded as being of utmost importance for optimal progress.

Animal Production Programme

Research, development and implementation regarding livestock production and products are conducted by two well-known and long established institutes of the ARC viz. the Irene Animal Production Institute and the Onderstepoort Veterinary Institute. More recently the Roodeplaat Grassland Institute was established. The mutual mission of these three institutes is as follows:

The creation of environmentally friendly technology for the promotion of the production and quality of animals and animal products.

IRENE ANIMAL PRODUCTION INSTITUTE

The Irene Animal Production Institute renders a comprehensive service to the dairy, meat, fibre and poultry industries in South Africa regarding the production, processing, and manufacturing of the products concerned. The institute conducts its activities through four centres of excellence.

The Animal Improvement Centre is responsible for the fields of animal genetics and breeding, animal physiology and biotechnology as well as the production improvement schemes performed at more than 5 000 breeding herds representing most species of production livestock. Superior genetic material, identified for increased reproduction and production performance, is then distributed throughout the country into the national livestock herd.

The Animal Nutrition Centre aims at improving production efficiency by studying the physiology of the animal, in relation to its metabolic and digestive processes, as well as the physical and nutritive traits of all available feedstuffs for feeding ruminants and monogastric farm animals under intensive and extensive feeding conditions.

At the Meat as well as the Dairy Industry Centres, the relevant industries are studied from conception to consumption in order to promote the supply of meat and dairy products of optimal quality to the consumer at affordable prices.

To meet the needs of the developed as well as the developing animal production and animal product industries of the subcon-
tinent of Africa, fundamental and applied research is undertaken from which the relevant animal and product technologies are developed, enabling animal, dairy, meat, poultry and other natural scientists to transfer this knowledge to primary producers,中间men in the manufacturing industries as well as consumers of animal products. Through a sound and well planned fundamental but always industrially orient-economic efficiency of the primary and secondary animal industries of the country, enabling them to produce sufficient food of adequate quality at affordable prices.

**PRODUCTION IMPROVEMENT SCHEMES**

The Production Improvement Schemes have contributed substantially to the level of production as well as the genetic quality of the animals of the more than 5 000 participating cattle, sheep, pig and poultry breeders in South Africa, during the past three to four decades. As much as 62 % of all the registered beef breeding cows in the country participate in the performance and progeny testing schemes and more than 10 000 of the estimated 30 000 breeding bulls annually required in beef production herds in South Africa are being performance tested for growth rate, feed conversion ratio, fertility and frame size. These tested animals comprise the genetic core at the top of the beef cattle pyramid influencing the more than 5 million beef cattle in South Africa (Figure 1). The traits measured in the scheme are highly heritable (ADG=60 %; FCR=35 %) hence the impact of the 1 800 tested breeding herds on the beef cattle population of South Africa. At the central bull performance testing centres (Phase C) for a particular prominent

![Diagram](https://via.placeholder.com/150)

**Fig. 1:** Meat industry pyramid: Transfer of genetic traits

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beef breed the genetic variation has been found to be as indicated in Table 1.

Table 1: Performance of Phase C bulls of a beef breed

<table>
<thead>
<tr>
<th>Breed</th>
<th>adg (g)</th>
<th>for kg/kg</th>
<th>scrotum circumference cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best 1%</td>
<td>1,507</td>
<td>5,83</td>
<td>42,2</td>
</tr>
<tr>
<td>Poorest 1%</td>
<td>800</td>
<td>10,80</td>
<td>27,5</td>
</tr>
<tr>
<td>Difference (%)</td>
<td>88 %</td>
<td>85 %</td>
<td>53 %</td>
</tr>
</tbody>
</table>

The variation of these traits and the high level of heritability ensures significant genetic improvement.

Table 2: Growth performance and carcass traits of performance tested pigs (86 kg live mass)

<table>
<thead>
<tr>
<th>Trait</th>
<th>1974</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days to 86 kg</td>
<td>148</td>
<td>145</td>
</tr>
<tr>
<td>FCR (kg/kg)</td>
<td>3,05</td>
<td>2,82</td>
</tr>
<tr>
<td>ADG (g)</td>
<td>850</td>
<td>900</td>
</tr>
<tr>
<td>P3 fat at 86 kg (mm)</td>
<td>21</td>
<td>20</td>
</tr>
</tbody>
</table>

During the past 3 decades the weaning mass of calves in tested herds has improved from 167 to 211 kg. At central testing centres the ADG has improved by 272 g/day and the FCR by 0.66 kg/kg gain, representing marked financial benefits to beef producers utilizing bulls with superior breeding values.

Table 3: Broiler performance in the randomized broiler test

Presently in South Africa approximately 365 million broilers are being produced per year.

**Breeding values**

One of the most powerful tools for genetic improvement of livestock is presently being adapted and applied in all the production improvement schemes, namely the mixed model BLUP (best linear unbiased prediction) analysis for calculating expected progeny differences (EPD) as well as estimated breeding values (EBV) of breeding herds and breeding sires. The sire model has been in use for a number of years in ranking promising young dairy sires in respect of breeding value for milk, butterfat and protein production. The animal model has just recently been adapted in a PC-programme rendering more accurate breeding value estimates. Genetic trends regarding production traits in breeding herds can now be identified, enabling breeders to improve less favourable traits in their animals by introducing breeding sires with positive breeding values for the identified deficiencies. In order to illustrate the importance of knowledge by the breeder of the genetic merit of his herd, the analysis of two dairy herds is depicted in Figures 2 to 5. The environmental trend over a ten year period for milk production in herd No 1 was uneven but positive. Less efficient management during certain years could be clearly identified. The genetic trend, with environmental influences removed, was however consistently positive, indicating a sound breeding programme in which bulls of superior genetic merit were used throughout. In herd No 2 the level of management has been excellent over the ten year period of the analysis even though the analysis identified a consistently negative genetic trend for milk production - hence good stockmanship masking a poor breeding programme. Such inefficiency can now be prevented by using the mixed model BLUP analysis separating genetic and environmental influences on production.

These programmes are now also being developed and adapted for beef cattle, sheep, pigs and poultry with the object of rendering a more comprehensive service to breeders as well as breed societies.

**Genetic probes**

In support of the pig progeny testing scheme the genetic services division has just introduced a new service by which pig breeding stock is tested with a DNA probe identifying the recessive gene for malignant hyperthermia. Using results of this test carrier animals may either be eliminated from breeding herds or due to the linked genetic response for lean growth, be utilized in planned terminal production systems. Animals carrying the malignant hyperthermia gene are also highly stress susceptible and pigs produced for slaughter may die as
a result of transport stress or may have poor meat quality (PSE) when slaughtered.

PRODUCTION AND PRODUCT TECHNOLOGY

Pigs

Uncastrated male pigs produce lean meat 15% more efficiently than castrates. However, due to the unpleasant odour emitted when the fat of certain uncastrated males is heated (sub-
stances called skatole, indole and androstenedione) while frying bacon or chops, males in South Africa and many other countries are castrated to prevent the hormones from being deposited in the fat. This practice, however, has a negative influence on the profit margin of producers. In Denmark boars are not castrated but all carcases are chemically tested for boar taint. This is an extremely costly operation. In the UK and the Netherlands a great deal of research effort is applied to the development of a vaccine for the immunization of boars against boar taint.

Carcass classification

In the beef industry in South Africa leanness of carcases is one of the main production aims. In many countries of the world beef carcases are trimmed of their subcutaneous and outer fat cover to a level acceptable to the consumer, hence a major wastage of expensive fat occurs in such industries. In South Africa carcases are produced to suit consumer’s requirements and very little fat is trimmed. The result of this production system is that relatively small carcases (average 215 kg) are marketed. Small carcases chill rapidly and the meat tends to be tough due to cold shortening. This is, however, prevented to a large extent by electrical stimulation of carcases within a few minutes after stunning. The two major traits accommodated in the classification system are lean yield and tenderness. The younger the animal at slaughter the more soluble the connective tissue and the more tender the meat. Leanness and tenderness are both inheritable traits and receive attention in progeny testing schemes. Tenderness of beef is the most important quality characteristic in many countries of the world, and especially in South Africa. The development of a genetic probe for tenderness would be a major break through similar to the potential which a genetic probe for optimal marbling in lean cattle would have in the United States of America where overall palatability is the most sought after beef quality parameter.

Beef cattle genotypes

During the past 15 years a major project was undertaken, in which growth, carcase and meat quality traits of 34 pure and crossbred beef cattle genotype were studied intensively. This project has stimulated the interest of several beef cattle breed societies to investigate more thoroughly production and product characteristics of their breeds. The view of certain breed organizations was that substantial changes have been effected through selection to render such breeds more market related, for example in terms of leanness. In the case of one particular breed, preliminary results indicate that, at the same carcase fatness, carcases of a “modern” type are 50 kg heavier than those of the traditional early maturing type of 15 years ago. The shoulder height of performance tested bulls of this breed increased by 14 cm from 114 to 128 cm over the period 1980 to 1990. One negative finding of this research was however, that a decrease in the meat to bone ratio at the same carcass fat level was observed in these larger carcases from the taller animals. A possible explanation may be that too much emphasis was placed on bone growth relative to muscling or true frame size. Research on this breed, to further elucidate this finding, is presently planned.

Tenderness selection

Through the progeny testing scheme it was also established that the progeny of certain sires of a particular breed had significantly different meat quality attributes. These genetic differences, if substantiated by more fundamental investigations, could then be beneficially applied for the improvement of the most important beef quality trait in South Africa, which is tenderness. Fortunately tenderness can be positively manipulated biologically, biochemically as well as technologically. Hence the breeder and producer, the abattoir industry as well as the trade are all in a position to contribute to the production of meat of maximum tenderness.

CONCLUSION

Presently the competition in the protein food industry is such that it is of the utmost importance that all factors in the formula influencing the cost and quality of the product be optimized in order for an organization to remain viable, healthy, hence competitive and profitable.

In partnership with industry the Irene Animal Production Institute is bound to its mission to develop environmentally friendly technology for the promotion of the production and quality of animals and animal products enabling the producer to profitably supply meat of optimal quality at affordable prices to the trade, hence to the consumer. When these goals are met, agriculture as a national asset, as well as the industrial sector and the general consumer, will benefit from the efforts of a statutory body such as the Agricultural Research Council operating in partnership with the primary and secondary sectors of industry.
Pseudo-scientific barriers to international meat trade

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INTRODUCTION

Within the last few years, the world has witnessed, the imposition of some blatant barriers to the meat trade. We have also witnessed some very clever attempts by certain governments to justify those barriers in the interest of public health. It can be postulated that, as certain scientific disciplines such as biotechnology struggle for public acceptance, such trade disputes are likely to become more common.

To those of us in the meat business, these barriers alone are troublesome. But beyond the most obvious examples looms an even bigger issue that affects the advancement of science internationally, and hence the application of technology by people in all walks of life and all forms of business. It could be called many things, but the most fitting term is technological regression.

TECHNOLOGICAL REGRESSION

In most developed countries in the world, there exists an activist movement that is generally opposed to the modernization of industry and the aggressive pursuit of scientific innovation. These same people are generally opposed to liberalized trade. Regrettably, they have sufficient political influence and sufficient skills at propaganda--peddling to convince politicians and citizens alike that they are correct in their point of view. They are literally destroying the role of science in public policy debates and decisions.

The anti--technology movement in the U.S. and Europe had been classified as an elitist, upper class phenomenon. It has been argued persuasively that the peddlers of this propaganda, comfortable with their own well--being, are content to dismiss technological and economic growth as exploitative processes. They would feel differently if they lacked food security.

Example: EC Hormone Directive

On January 1, 1989, the European Community imposed a ban on the importation of beef from animals which had been treated with anabolic growth promotants. Why? Was it because the scientific community had concluded that these compounds are unsafe? No. The EC's own scientific commission headed by Dr. Eric Lamming concluded that the anabolic agents in use in Europe, the U.S., and the rest of the world were, to use their term, "harmless". Before the Lamming report, and since, numerous other scientific committees have reached an identical conclusion. Not a single scientific body has found any reason to suspect harmful effects on human health from the proper use of the anabolic compounds currently approved for use in the U.S. and other modernized countries.

Spokespersons for the EC have explained their reasons for the decision to ban anabolic agents and the importation of beef from cattle in which anabolic agents were used. The elitist arrogance referred to earlier is obvious in their explanation. Quoting Lars Hoelgaard, a representative of the EC Commission, from a speech he delivered to the International Livestock Congress in 1992:

"The EC--ban on the use of hormones should be seen for what it is: a change of values in highly industrialized countries where food production is no longer is a question as much of quantity as a question of quality. Quality in this respect should be broadly understood involving not only chemical composition, appearance and sensory features, but the whole process from the farm in terms of methods of production, processing and final distribution to the consumer. The ban is the reflection of a political decision--making process where politicians as elected representatives of their people make valid choices for their country.
plied to the consumer. As such, the ban is not a unique thing, but reflects a trend which has been in the process for many years, not only in Europe, but also in U.S. and in other industrialized societies. This is reflected in a more critical attitude towards the use of chemicals, pesticides, fertilizers, feed and food additives, etc. — a trend towards more “natural” products. The increased interest in laying down rules for production and labelling of organic farming as well as the growing concern for the environment again, broadly defined, is a reflection of this trend. In animal production the use of growth promotors as such is, therefore, under question. The controversy over the use of BST is a very good example — a discussion which is just as intense in the U.S. as it is in the European Community.

This statement literally proves the point that well--fed people, with elitist and arrogant attitudes, feel they can afford the “luxury” of putting useful and productive technology “on the shelf”. EC politicians were motivated by the so--called green movement to take this position. They then proceeded to convince the rest of the European population that anabolic growth promotants were dangerous to human health. This was a thinly disguised attempt to justify actions which were unjustifiable scientifically.

Ironically, the EC hormone directive backfired. A black market of hormone cocktails developed rapidly in the EC after the ban went into effect. Where a residue problem didn't exist before, it was created by the illegal use of unapproved and untested “cocktails”. Recently in Ireland, public health problems — traced to the illegal use of clenbuterol — have been documented. This made headlines in the national newspapers, and the anti--technology “greens” cite it as evidence that growth promotants are not safe. They fail to point out that such illicit use did not knowingly occur when safe and approved compounds were available through legal market channels. The actions of producers who use illegal compounds can not be condoned, but it can be explained.

THE COST OF TRADE BARRIERS IS GREATER THAN WHAT MEETS THE EYE.

It is not productive to review the long list of trade barriers that have been disguised as measures to protect public health when in fact the intention was either:

1. to protect domestic producers or
2. the result of an anti--technology movement.

Instead, it is more productive to discuss the impact of these on the outlook for worldwide food production and trade.

The common denominator in most of the meat trade disputes is the involvement of highly industrialized countries which possess a highly developed scientific infrastructure. Most scientific discoveries that can lead to more efficient agricultural production are made in these countries. At a minimum, the most significant basic scientific discoveries are made in rich countries, even though the application of the technologies borne from those discoveries may take place in less developed and less affluent countries where the need to produce more food is urgent.

Furthermore, most scientific breakthroughs are made either directly by scientific corporations or by universities utilizing funds form science--dependent corporations. If good science was also not good business, this would not be happening. But science HAS been good business for the past century. Corporations, able to protect these scientific breakthroughs by patents, have made good profits and have re--invested in more research; hence, more breakthroughs. There has been, until recently, a fertile and, indeed, anxious market for the useful technologies in virtually all developed countries. This has been a strong motive for companies to re--invest heavily in research that might lead to more new products. What has been created, in effect, is a “technology snowball”. Much like a conventional snowball, it picks up speed and size as it rolls downhill. People throughout the world have benefitted from this as food security has steadily improved in all regions of the world despite the obstacles of shooting wars and corrupt governments.

The construction of trade barriers against food products produced with the use of new technology can have but one effect: it will reduce the incentive for science--based corporations to invest in research because the size of the market is smaller than it otherwise would be. This will lead to slower gains in agricultural productivity throughout the world, even in those countries where the resistance to new technology is non--existent (the African Continent, for example), because there will simply be fewer breakthroughs.

SUMMARY:

- Anti--technology factions exist in most developed countries.
- These factions have been effective in influencing public decisions and consumer attitudes (the EC hormone directive is an example).
- Activities of these factions reduce the market potential for new food production technologies.
- A shrinking market for new technologies discourages private investment in research that could lead to new breakthroughs.
- Activists have also attempted, with some success, to reduce public investment in research.
- The costs of pseudo--scientific barriers to trade go far beyond the obvious short--term reduction in trade. Such bar-
riers could cause permanent retardation of scientific prog-
ress.
The application of genotype evaluation in beef cattle

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INTRODUCTION

A fast developing meat industry, an ever changing economic climate and a more informed meat consumer are increasingly exerting pressure on the meat producer to develop his production operation into a highly specialised business, accommodating inter alia the following demands and conditions.

a. Unfavourable meat to feed price ratios, especially in the feedlot industry.

b. The weakening economy, resulting in relatively high costs of overheads (labour, medicine, transport, etc.).

c. Prevailing drought, contributing directly to the above-mentioned two aspects.

d. A modern consumer, demanding a product more acceptable in eating quality, composition (minimum plate waste: bone and excessive fat), nutritive value and wholesomeness.

e. Introduction of the beef carcass classification system from 1 July 1992. This system operates closer to free-market principles, placing a higher responsibility on the trade (wholesale and retail) to ensure that the carcass with the higher auction price also achieves the higher retail value (cutability) and consumer preference.

For the producer to effectively accommodate the above-mentioned aspects he should optimally utilize production and product associated factors such as genotype, sex and feeding systems (besides normal management practices) to ensure a highly efficient business. In order to introduce the necessary changes, a constant flow of relevant and useful information regarding genotype, sex and feeding systems should be at the producer’s disposal. With this in mind and in the light of the considerable genotypic variation in South Africa (SA) and the consequent opportunity for between and within breed selection, and the lack of suitable information regarding production and especially product (carcass and meat) characteristics of the different genotypes (pure breeds and crosses) in S.A., the Irene Animal Production Institute (IAPI) identified the need to initiate a Genotype Evaluation Programme (GEP) to develop practical technology for the meat industry. With this programme it is believed that a considerable contribution could be made in assisting the producer (stud and commercial) to optimize his production system and comply more closely with the above-mentioned demands. More specifically, this programme serves a useful purpose in:

a. Establishing the comparative position of a specific breed, regarding production and product characteristics, thereby also indicating its possible role within the broad production spectrum in SA.

b. Providing guidelines, not easily and readily available in practice, for the selection of particular, economically important traits, including production efficiency and meat quality characteristics.

c. Identifying specific genetically determined carcass and meat quality traits, enabling industry to introduce a branded-beef programme.

This GEP programme was initiated in 1975 with the extensive Vaalharts crossbreeding trial, evaluating inter alia, six pure-breds and two-way crossbred types and 20 three-way crosses (De Bruyn, 1991). This complete production and product description of 34 genotypes proved to be of such benefit to the beef industry that various breed societies expressed the need for the continuation of this genotype evaluation programme. The extended programme has accommodated breed societies almost annually since the Drakensberger breed was evaluated in 1988.
In this presentation the different parameters investigated by this programme will be briefly discussed. The importance of these parameters to the beef industry will also be highlighted.

**GROWTH EVALUATION (ADG AND FCR)**

High feed costs, resulting in an unfavourable feed:meat price ratio, as well as a very narrow gap between positive and negative profit margins, constantly compels the feedlot owner to specifically select genotypes with favourable growth performances. Although research projects of the past decade or two highlight the favourable growth performances mostly of the late maturing continental breeds (Cundiff, Koch, Gregory & Smith, 1981; Baker Bryson & Knutson, 1987), Phase C results (1990) indicate that a selection range beyond these breeds exists within the much wider genetic population of S.A. (Table 1).

Opportunity for selection therefore extends to various synthetic and *Bos taurus* breeds of both high average growth rate (1500 to 1800 g/day) and feed conversion ratios of between 7,20 and 6,50 (Table 1). Within breed variation for these traits would definitely allow for further selection. Distribution of Phase C growth results would thus be of considerable value for the producer in his breed selection. The Genotype Evaluation Programme thus serves as a useful barometer of a specific breed’s growth performance at commercial level, due to the fact that the feeding conditions (facilities and feed) of this programme are identical to those of Phase C. The growth evaluation of this programme is further integrated with the commercial industry by evaluating intact bulls, steers and implanted steers. The specific implant is that which is most commonly used in all major feedlots.

In order to demonstrate the commercial application of a specific breed’s growth performance, the evaluation programme’s findings for the Pinzgauer are presented in Table 2.

Growth results for bulls in the GEP (Table 2) clearly demonstrate the value for commercial application, when compared with the performance data of Phase C tested Pinzgauer bulls (Table 1). Similarly, the comparative growth results of implanted steers, as used in the feedlot industry, are also of significance. When compared to the ADG’s observed in feedlots (Table 2), it is evident that the GEP’s growth results for the Pinzgauer indicate that:

a. this breed would contribute positively, either as an intact male or implanted steer, to the enhancement of the growth performance of feedlot cattle in general and

b. the genetic growth potential of this breed, as determined by the Phase C test, can be successfully applied in the commercial feedlot industry.

The production and product traits of various other breeds could be similarly determined, facilitating decisions regarding application in industry or adaptation in selection policy. The latter should, however, always be based on information forthcoming from performance and progeny testing of the breeding stock of a particular breed.

**SLAUGHTER ANIMAL EVALUATION**

The dressing percentage (ratio of the different body parts, whole carcass and organs relative to total live body weight), together with the final carcass classification, are the two major determinants of the final price realized per slaughter animal. Consequently, an important aim in any beef production system is to maximize dressing percentage.
Various researchers indicate that dressing percentage is influenced by:

a. Differences in carcass fatness (Morgan, Clark, McKuan & Saul, 1978; Preston & Willis, 1974)
b. Specific genotypic effects on certain body parts and/or organs e.g. the Brahman with a lighter alimentary canal (Moran, 1970).

However, for research results to be directly applicable to industry, it is important that results are compared on the evaluation basis used in industry viz. uniform carcass fatness (Carcass classification: fat code). Much of the research in this regard was, however, performed on either a constant mass or time basis. It was therefore decided that the GEP would be designed in such a way that genotypes could be compared at a common carcass fatness. By performing a complete slaughter animal evaluation (weighing all body parts and organs), the dressing percentage and relative contribution of each body part and organ could be determined on the directly market orientated basis of common fatness. The dressing percentages and carcass masses, determined at a subcutaneous fat level of 6 %, are presented in Table 3 (De Bruyn, 1991) for a number of purebred genotypes.

Table 3: Dressing percentage and carcass mass (cold) of six purebred genotypes, as determined at a subcutaneous fat level of 6.0 % (fatcode)

<table>
<thead>
<tr>
<th>Breed</th>
<th>Dressing percentage* (%)</th>
<th>Carcass mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hereford</td>
<td>55.2*</td>
<td>138</td>
</tr>
<tr>
<td>Afrikaner</td>
<td>56.2*</td>
<td>163</td>
</tr>
<tr>
<td>Brahman</td>
<td>59.4*</td>
<td>164</td>
</tr>
<tr>
<td>Bonsmara</td>
<td>58.4*</td>
<td>194</td>
</tr>
<tr>
<td>Simmental</td>
<td>58.2*</td>
<td>219</td>
</tr>
<tr>
<td>Charolais</td>
<td>61.2*</td>
<td>248</td>
</tr>
</tbody>
</table>

* - Water withheld from animal for about 16 h

Except for the Brahman, the dressing percentage results in Table 3 seem to be positively influenced by carcass mass. De Bruyn (1991) confirmed this deduction by showing that, should the different genotypes be grouped in maturity types, a direct positive relationship exists between final carcass mass and dressing percentage, compared at constant carcass fatness. These results, emphasizing a more favourable dressing percentage in the later maturing animal (higher carcass mass at constant fatness), are thus directly applicable to industry. Apart from the above-mentioned carcass mass effect, the favourable dressing percentage of the earlier maturing Brahman could be ascribed to a direct effect of genotype. Body composition results explain this observation, solely due to a significantly (P<0.05) smaller alimentary canal relative to other breeds (De Bruyn, 1991). Similarly, the very high dressing percentage of the Charolais is directly related to a lower percentage hide. It is thus evident that complete slaughter animal evaluation, as carried out in the GEP, could provide useful guidelines for selecting genotypes with favourable dressing percentages, as well as explaining these differences.

This programme further proved its worth to the beef industry by identifying a detrimental selection pressure against dressing percentage in the modern Hereford, during evaluation of the latter breed in 1990/91. Dressing percentages of the modern (90/91) and traditional (1976-79) Hereford are compared in Table 4 (De Bruyn, Naudé, Hofmeyr & Strydom, 1992).

In contrast to the positive relationship between final carcass mass and dressing percentage, observed in the initial phase of the GEP (De Bruyn, 1991), results in Table 4 show that, in spite of the significantly later maturity of the “modern” Hereford (heavier carcass mass: constant fatness), these animals did not show a higher dressing percentage than the traditional Hereford. Smith, Crouse, Mandingo & Neer (1977) also indicated that the heavier carcass masses of later maturing animals of similar fatness, were associated with higher dressing percentages. It could thus be concluded that while selecting for later maturity in the Hereford, the expected concomitant increase in dressing percentage did not occur.

**CARCASS EVALUATION**

The production of a carcass with the most optimal composition of maximum percentage muscle with minimum percentage bone (i.e. maximizing the muscle: bone ratio) and the optimum percentage total fat, is very important for both producer and middleman, as well as for the consumer. The importance of carcass composition is further highlighted by the introduction of the Beef Carcass Classification System in July 1992, whereby carcasses are classified in seven fatness (hence lean yield) classes. Due to the price differential between these carcass classes, a much closer balance between eventual retail value and auction price is essential to the trade. Carcass com-

---

**Table 4:** Means for the dressing percentage and carcass mass (cold) of the modern and traditional Hereford, as determined at a subcutaneous fat level of 6.0 %

<table>
<thead>
<tr>
<th>Breed</th>
<th>Dressing percentage (%)</th>
<th>Carcass mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern Hereford</td>
<td>55.3</td>
<td>187</td>
</tr>
<tr>
<td>Implanted steer</td>
<td>53.8</td>
<td>198</td>
</tr>
<tr>
<td>Bull</td>
<td>55.0</td>
<td>203</td>
</tr>
<tr>
<td>Traditional Hereford</td>
<td>55.5</td>
<td>197</td>
</tr>
<tr>
<td>Steer</td>
<td>187*</td>
<td>217</td>
</tr>
<tr>
<td>Bull</td>
<td>199*</td>
<td>217</td>
</tr>
<tr>
<td>steer</td>
<td>136*</td>
<td></td>
</tr>
</tbody>
</table>

* - Means in the same row with different superscripts differ significantly (P<0.05)
position is thus increasing in importance. It was therefore inevitable that complete carcass evaluation be included in the GEP, to enable appropriate advice to be passed on to the industry (producer and middleman).

The following parameters are investigated to obtain comprehensive carcass composition data for each genotype: Carcass mass; carcass fat cover score; carcass dissection into subcutaneous fat, meat and bone of each of 15 primal cuts; estimate of total muscle and fat percentages of the carcass, estimate of meat:bone and muscle:bone ratios. These parameters are all direct indicators of the relative yields of total carcass fat, bone and muscle/lean.

Furthermore, it is important to mention that these parameters are recorded at four different developmental stages. Sample animals of each genotype are slaughtered at the commencement of the trial (weaning) and again at three predetermined slaughter masses, e.g. Santa Gertrudis bull: (commencement of the trial (weaning) and again at three predetermined developmental stages. Sample animals of each genotype are slaughtered at the commencement of the trial (weaning) and again at three predetermined slaughter masses, e.g. Santa Gertrudis bull: (commencement (producer and middleman).

Regression equations (x subcutaneous fat %) (Table 5)

Carcass evaluation is thus directly applicable to industry situations in which it is desirable to present carcass composition data of a specific genotype at various points (fat code), rather than at one single point only. Should there be a fat preference change by the consumer from, for instance, fat code 3/4 to 2, results of the GEP could be very easily adapted to accommodate this change in the production system.

Besides this built-in procedure to allow flexible application in industry, the major aim of carcass evaluation remains the:
- description of carcass composition characteristics for each genotype/
- identification of genotypes with favourable carcass composition characteristics and
- identification of possible negative aspects of carcass composition, together with appropriate recommendations.

Table 6: Means for carcass composition of the different Hereford treatments, as calculated at a subcutaneous fat of 6,0 % (De Bruyn et al., 1992).

Table 7: Carcass composition of 6 purebred beef genotypes (constant subcutaneous fat)
The GEP carcass composition results are presented in tables 6 and 7, as illustration of the above-mentioned points.

If carcass composition characteristics such as percentage bone and meat, and muscle:bone ratio are considered as in Table 7, far more favourable compositions are evident for both the later maturing Simmentaler and Charolais, especially for the latter. As is the case with dressing percentage (Table 3), final carcass mass at constant fatness seems to have a major influence on carcass composition: percentage bone decreases with percentage meat, and muscle: bone ratio widens as carcass mass, at constant fatness, increases (Tables 3 and 7). A higher relative retail value can thus be obtained from later maturing breeds. The opportunity to select these high yielding type of carcasses, identified by the GEP, now exists for industry. In countries such as the U.K. and New Zealand a premium is paid for carcasses known to yield high lean percentages.

UK (personal observation)


A higher price is payed for later maturing beef crosses with favourable conformation and muscle: bone ratios.

<table>
<thead>
<tr>
<th>Breed</th>
<th>Pennies per kg live mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friesian/Holstein</td>
<td>104,11</td>
</tr>
<tr>
<td>Hereford cross</td>
<td>107,68</td>
</tr>
<tr>
<td>Simmentaler cross</td>
<td>112,35</td>
</tr>
<tr>
<td>Limousin cross</td>
<td>113,63</td>
</tr>
<tr>
<td>Charolais cross</td>
<td>113,91</td>
</tr>
<tr>
<td>Other</td>
<td>107,32</td>
</tr>
</tbody>
</table>

New Zealand

The importance of quality was highlighted in the 'New Zealand Meat Producer 20 : 18' (1992), mentioning a possible premium for meat tenderness, as reflected by all five meat tenderness determinations (Table 8). The Hereford, on the other hand, was found to have the most favourable tenderness results, although not significantly different (P<0,05) from those of the Afrikaner, Bonsmara or Charolais, with the exception of the sensory score for the Charolais. Information could thus be made available to industry regarding the influence of genotype on eating quality. Possible future developments in both these two categories, either dependent on, or independently of the GEP, include:

a. Genotypes with favourable meat quality characteristics may be introduced to a greater extent in industry, in order to comply with the increased consumer demand for optimal eating quality. More specifically, should certain sire-lines of very favourable meat quality characteristics (especially tenderness) be identified by the GEP or phase E, then the possibility of promoting the meat of the progeny of this specific sire-line in a "branded beef" programme could be considered. The GEP could therefore make the identification of genetic variation within a specific breed possible, enabling selection for a particular, heritable quality trait. It is thus evident that the GEP could possibly as-

Table 8: Means for meat tenderness determinations for the different purebreds

<table>
<thead>
<tr>
<th>Breed</th>
<th>Shear force (N/25.4mm)</th>
<th>Sensory score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60 °C</td>
<td>70 °C</td>
</tr>
<tr>
<td>Hereford</td>
<td>45,9°</td>
<td>71,6°</td>
</tr>
<tr>
<td>Afrikaner</td>
<td>51,7°</td>
<td>82,5°</td>
</tr>
<tr>
<td>Brahman</td>
<td>72,6°</td>
<td>113°</td>
</tr>
<tr>
<td>Bonsmara</td>
<td>54,4°</td>
<td>83,2°</td>
</tr>
<tr>
<td>Simmentaler</td>
<td>68,4°</td>
<td>111°</td>
</tr>
<tr>
<td>Charolais</td>
<td>48,5°</td>
<td>78,7°</td>
</tr>
</tbody>
</table>

- * = Meat sample cooked in waterbath for 1 hour
- ° = Shear force on sensory sample (dry cooking method)
- t = least favourable and 5 = most favourable attribute
- * = Means of different superscript in the same column differ significantly (P<0,05).
sist in the promotion of meat quality (tenderness) in
general.
It is important to stress that the beef producer can incor-
porate Phase E of the National Beef Cattle Performance
and Progeny Testing Scheme with results of the GEP, to
positively influence product quality (carcass and meat) and
growth performance of his herd. The following Phase E re-
sults (Table 9) demonstrate the positive selection possibili-
ties that could be utilized:
b. In every biological population all traits are characterized by
a normal distribution, varying from less favourable to more
favourable. Therefore, although certain genotypes gener-
ally produce less tender meat, it can nevertheless be ex-
pected that genetic differences will exist within these same
genotypes.

Although meat tenderness per se is important, selection can
only progress if the biological reasons behind differences in
meat tenderness, and their heritabilities, are known and under-
stood more completely. These heritable traits can thus be util-
ized for improvement of meat tenderness. Therefore, meat
quality characteristics such as pH, collagen content and solu-
bility, myofibrillar fragmentation, sarcomere length and muscle
fibre size and type are investigated in detail in the GEP. All
these characteristics are either associated with or influence
meat tenderness in one way or another.

CONCLUSION
An internationally competitive and economically viable beef in-
dustry demands that real action be taken to improve production
efficiency and product quality in South Africa. The GEP can
conceivably contribute very positively towards attaining this
goal by providing firsthand information to producer, middleman
and consumer regarding:
- growth performance under intensive conditions (ADG &
  FCR)
- quantitative carcass characteristics (final mass and dress-
ing percentage).
- qualitative carcass characteristics (carcass composition)
  and
- meat quality characteristics (especially tenderness).

All breed societies, private breeders and commercial produc-
ers could therefore participate in the GEP, which may enable
them to obtain objective qualitative and quantitative information
regarding production and product traits of their breeds, which
in turn may assist them in attaining breeding goals.

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Table 9: Phase E results for various tested bulls

<table>
<thead>
<tr>
<th></th>
<th>Bulls*</th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K54</td>
<td>H73</td>
<td>D17</td>
<td></td>
</tr>
<tr>
<td>ADG [g/day]</td>
<td>1870</td>
<td>1877</td>
<td>1716</td>
<td></td>
</tr>
<tr>
<td>FCR [kg/kg]</td>
<td>5,81</td>
<td>5,57</td>
<td>5,82</td>
<td></td>
</tr>
<tr>
<td>Dressing percentage (%)</td>
<td>58,3</td>
<td>58,1</td>
<td>58,2</td>
<td></td>
</tr>
<tr>
<td>Total fat (%)</td>
<td>27,3</td>
<td>24,7</td>
<td>25,9</td>
<td></td>
</tr>
<tr>
<td>Muscle (%)</td>
<td>58,3</td>
<td>59,6</td>
<td>60,0</td>
<td></td>
</tr>
<tr>
<td>Bone (%)</td>
<td>13,9</td>
<td>15,2</td>
<td>13,8</td>
<td></td>
</tr>
<tr>
<td>Muscle:bone ratio</td>
<td>4,19</td>
<td>3,92</td>
<td>4,35</td>
<td></td>
</tr>
<tr>
<td>Carcass mass [kg]</td>
<td>229,0</td>
<td>224,7</td>
<td>224,9</td>
<td></td>
</tr>
<tr>
<td>Shear force [N/25,4mm]</td>
<td>107</td>
<td>110</td>
<td>92</td>
<td></td>
</tr>
</tbody>
</table>

* 9 to 10 progeny tested per bull
Breeder-feeder dimorphism

M.M. Scholtz

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INTRODUCTION

Animals can be tested over a constant time or to similar physiological ages or levels of carcass finish. Constant time tests favour large types, lines or breeds, while with tests of feed efficiency over corresponding physiological intervals or to a similar level of carcass finish there is little, if any association with mature body mass (Lowman, 1987; Southgate, 1988).

At similar sizes, animals with large mature body masses generally eat more and grow faster per day than smaller animals. However, in relative terms (per kg body mass) large animals eat and grow less than small animals. The smaller amount of feed per day per kg body mass is reflected as a better constant time feed efficiency of larger animals. Large animals, however, take longer to grow to a given percentage of mature mass. The better efficiency per day is thus lost over the total period because it takes longer for larger animals to reach market finish.

Probably as a consequence of the longer developmental period of large animals, their inter-birth periods tends to be longer, resulting in a lower reproduction rate. This effect is cancelled in reproductive efficiency because larger dams eat less per unit body mass per day than smaller dams. Thus, when the growth and reproductive efficiencies of the whole production system are taken into account, the total life cycle or herd feed efficiencies shows no association with mature body size (Roux, 1992c), on condition that they are equally adapted to the environment.

It therefore seems that at the present time there are only two ways of appreciably improving total herd efficiency, viz.:
- hormonal treatment
- biotechnological animal size manipulation
- dietary induction
- sexual dimorphism
- terminal crossbreeding

The advantage of feeder-breeder dimorphism follows since any system with large feeders (slaughter animals) from small breeders (breeding females) must be more efficient than one with feeders and breeders of equivalent size, simply because small dams eat less than large ones (Roux, 1992c).

Hormonal treatment

The advantages of this type of treatment is well-known and will not be discussed here. It is however, fascinating that males are castrated and afterwards implanted with hormones. Producers seem to be moving hormone-releasing objects from their normal position to behind the ears. The viability of achieving feeder-breeder dimorphism in this way in the long run is doubtful due to public pressure against the use of hormones.

Biotechnological animal size manipulation (Transgenic animals)

An example of animal size manipulation by producing transgenic animals is the micro-injection of the structural gene for rat growth hormone into the pronuclei of fertilized mouse eggs (Palmiter et al., 1982). An important feature of the experiment was the use of a DNA fragment containing a special promotor gene which was switched on by the feeding of zinc in the diet. These mice showed a mass gain of up to 1.8-fold higher than the controls.

It should be realized that this technology is still in its infancy and as such, many problems remain to be investigated. The
most important of these problems remains that of the control of the gene expression. Laboratories around the world are searching for suitable promotor sequences; these promotor genes must be tissue specific, must be controllable and should not exert a negative influence on the control of other genes or metabolic pathways. Other problems which require investigation are the mechanism and position of gene integration, the identification of an integration event and the question of vectors to facilitate transgenic production. To date, laboratories have concentrated on the technical problems involved in transgenic production; in the near future, research organizations and organized industry will face the ethical and legal problems associated with this technology.

**Dietary induction**

In chickens and pigs it is general practice to restrict the size of breeders through restricted feeding. Evidence favourable to the dietary induction of feeder-breeder dimorphism follows from the observation by Scholtz & Roux (1991) that continued gains in average daily gain and body mass at central testing stations for animals fed concentrated diets, did not materialize in on-farm testing under extensive conditions for the major breeds. Theron et al., (1992) also found a low genetic correlation \( r_g = 0.03 \) between the growth of bulls in the feedlot and heifers under extensive conditions.

In cattle it is common practice to keep cows on natural pasture and to feed weaners in feedlots on concentrated diets to market finish. In this way feeder-breeder dimorphism can be obtained merely by the exposure of animals to a suitable diet.

The gain in herd efficiency from feeder-breeder dimorphism achievable by hormonal treatment, biotechnological size manipulation or dietary induction is given in Table 1.

Table 1: The percentage gain in herd efficiency from feeder-breeder dimorphism achievable by hormonal treatment, biotechnological size manipulation or dietary induction when all market animals are manipulated (Roux, 1992c)

<table>
<thead>
<tr>
<th>Feeder-breeder mass</th>
<th>1.2</th>
<th>1.6</th>
<th>2.0</th>
<th>3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>% gain in cattle</td>
<td>9</td>
<td>24</td>
<td>37</td>
<td>64</td>
</tr>
<tr>
<td>% gain in sheep</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% gain in pigs</td>
<td>5</td>
<td>14</td>
<td>21</td>
<td>36</td>
</tr>
</tbody>
</table>

**Sexual dimorphism**

The feed efficiency of steers and heifers are approximately equal when fed to similar levels of carcass finish (Lowman, 1987). This suggests an advantage of sexual dimorphism against monomorphism. In cattle the average sexual dimorphism (sire/dam mass) is given as 1.4 (Marlowe, 1962 as quoted by Taylor et al., 1985). Roux (1992c) found that the sexual dimorphism of South African beef breeds varies between 1.2 and 1.6. The advantage in herd efficiency due to sexual dimorphism, in comparison to monomorphism, is given in Table 2.

Table 2: Percentage gain in herd efficiency through sexual dimorphism in comparison to monomorphism (Roux, 1992c)

<table>
<thead>
<tr>
<th>% Young females marketed</th>
<th>Male/female body mass ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.2</td>
</tr>
<tr>
<td>50 (cattle)</td>
<td>6</td>
</tr>
<tr>
<td>67 (cattle or sheep)</td>
<td>5</td>
</tr>
<tr>
<td>75 (sheep)</td>
<td>5</td>
</tr>
<tr>
<td>95 (pigs)</td>
<td>3</td>
</tr>
</tbody>
</table>

Thus, by choosing the correct breed, sexual dimorphism can be increased from 1.2 to 1.6, which will result in an increase of 10% in herd efficiency (Table 2).

**Terminal crossbreeding**

An easy way of obtaining feeder-breeder dimorphism is through terminal crossbreeding, when a large sire breed or line is used on a small dam breed or line and all terminally crossbred offspring are sold for slaughter. Smith (1979) pointed out that size should be exploited in terminal crossbreeding by selecting sire and dam lines with the greatest tolerable divergence in size, to produce cattle of the heaviest acceptable market mass.

The use of sire and dam lines in terminal crossbreeding may also be the ideal solution in beef cattle to overcome the problems of the antagonism between growth and reproductive performance (Scholtz & Roux, 1984; Roux & Scholtz, 1984). In a system of terminal crossbreeding it would be possible to combine growth and fertility, which are likely to be two antagonistic traits.

For terminal crossbreeding to be successful it is necessary for a large proportion of the breeding herd to be available for crossbreeding. Thus, fertility is very important. An alternative would be to buy cows if a reliable source is available. In the South African situation small framed indigenous cows may be ideal for terminal crossbreeding. There may, however, also be circumstances (area, environment, nutrition) where specific crossbred genotypes may perform better as dam lines than other purebred or indigenous cows.
In discussions with producers, the most important practical objection against terminal crossbreeding is always felt to be the possibility of serious fetal dystocia. There is a considerable amount of evidence that an increase in body mass by selection may often lead to fetal dystocia in primiparous animals (Baker & Morris, 1984; Roux & Scholtz, 1984). It is, therefore, a question of considerable importance whether fetal dystocia can be avoided in terminal crossbreeding by a strong maternal limitation on fetal size, which curtails the genetic effect of the sire breed at birth, while allowing adequate expression of the genetic growth potential later in life.

No calving difficulties or perinatal deaths occurred in 29 Charolais x Nguni, 17 Simmental x Nguni and 17 Chianina x Nguni crossbred calves. If a 10 % chance of dystocia or death exists, the probability of observing one or more cases from a sample of 63 would be 100 (1-0.9^{63}) = 99.9 %. If a 5 % chance exists the probability would be 96.1 %. Therefore, it seems that dystocia will be negligible if a breed such as the Nguni is used as a damline. There was no difference in the percentage of calves surviving from birth to weaning between the Nguni and its crosses, or in the re-conception rates between Nguni cows that suckled pure Nguni or crossbred calves. Thus, there appears to be no additional drain on cows when producing crossbred offspring.

The performance of the different breeds and crosses is given in Table 3. While the average birth mass was 10 % below the midparent value, the average weaning mass was 6 % above the midparent value. The postweaning growth rate of the crosses was 43 % higher than that of Nguni, while the feed conversion ratio (FCR) was 10 % better than that of the best purebred. Despite the suppression on birth mass below that of the mid-parent value, the weaning mass and growth rate of the different crosses are close to those of the larger parent. The negative maternal effect on calf birth mass due to the smaller cow, therefore, does not seem to persist up to adult life as in the horse (Hammond et al., 1971).

Direct experimental evidence on the advantage of feeder-breeder dimorphism is available for sheep (Large, 1970), was summarized by Roux (1992c) and is given in Table 4.

Table 3: The performance of different breeds and their crosses

<table>
<thead>
<tr>
<th>Trait</th>
<th>Breed type</th>
<th>% deviation from midparent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nguni</td>
<td>Charolais</td>
</tr>
<tr>
<td>n</td>
<td>301</td>
<td>40</td>
</tr>
<tr>
<td>Birth mass (kg)</td>
<td>27</td>
<td>47</td>
</tr>
<tr>
<td>Weaning mass (kg)</td>
<td>183</td>
<td>222</td>
</tr>
<tr>
<td>ADG</td>
<td>1.12</td>
<td>1.77</td>
</tr>
<tr>
<td>FCR</td>
<td>7.5</td>
<td>6.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trait</th>
<th>Breed type</th>
<th>% deviation from midparent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Simmental</td>
<td>Cross</td>
</tr>
<tr>
<td>n</td>
<td>*</td>
<td>17</td>
</tr>
<tr>
<td>Birth mass (kg)</td>
<td>46</td>
<td>31</td>
</tr>
<tr>
<td>Weaning mass (kg)</td>
<td>227</td>
<td>215</td>
</tr>
<tr>
<td>ADG</td>
<td>1.71</td>
<td>1.55</td>
</tr>
<tr>
<td>FCR</td>
<td>7.8</td>
<td>6.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trait</th>
<th>Breed type</th>
<th>% deviation from midparent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chianina</td>
<td>Cross</td>
</tr>
<tr>
<td>n</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Birth mass (kg)</td>
<td>34</td>
<td>30</td>
</tr>
<tr>
<td>Weaning mass (kg)</td>
<td>199</td>
<td>214</td>
</tr>
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<table>
<thead>
<tr>
<th>Overall mean</th>
<th>Nguni</th>
<th>Large European</th>
<th>Cross</th>
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</thead>
<tbody>
<tr>
<td>Birth mass (kg)</td>
<td>27</td>
<td>42</td>
<td>31</td>
</tr>
<tr>
<td>Weaning mass (kg)</td>
<td>183</td>
<td>216</td>
<td>215</td>
</tr>
<tr>
<td>ADG</td>
<td>1.12</td>
<td>1.74</td>
<td>1.60</td>
</tr>
<tr>
<td>FCR</td>
<td>7.5</td>
<td>7.2</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Table 4: The percentage relative gains in herd efficiency with terminal crossbreeding of large (Suffolk) rams to small ewes (Roux, 1992c)

<table>
<thead>
<tr>
<th>Breed of ewe</th>
<th>n Ewe body mass (kg)</th>
<th>Lamb carcass mass (kg)</th>
<th>Efficiency gains (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>46 78.6</td>
<td>20.1</td>
<td>6.29 ±0.09</td>
</tr>
<tr>
<td>Kerry</td>
<td>21 57.6</td>
<td>20.7</td>
<td>7.24 ±0.19</td>
</tr>
<tr>
<td>Welsh</td>
<td>20 33.4</td>
<td>14.9</td>
<td>8.03 ±0.19</td>
</tr>
</tbody>
</table>

A generalization of the percentage gain in herd efficiency from terminal crossbreeding with favourable complete dominance or complete additive gene action is given in Tables 5 and 6 respectively.

REMARK

For further information and assumptions on the estimation of herd efficiency in meat production the papers of Roux (1992a; 1992b; 1992c) and Roux and Scholtz (1992) should be consulted.

Table 5: The percentage gain in herd efficiency from terminal crossbreeding with favourable complete dominance

<table>
<thead>
<tr>
<th>% of herd crossbred</th>
<th>Sire/dam line body mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 (Cattle)</td>
<td>6 16 25 43</td>
</tr>
<tr>
<td>67 (Cattle or sheep)</td>
<td>7 19 29 51</td>
</tr>
<tr>
<td>75 (Sheep)</td>
<td>7 20 31 55</td>
</tr>
<tr>
<td>95 (pigs)</td>
<td>5 14 21 35</td>
</tr>
</tbody>
</table>

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Table 6: The percentage gain in herd efficiency from terminal crossbreeding with complete additive gene action

<table>
<thead>
<tr>
<th>% of herd crossbred</th>
<th>Sire/dam line mass</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1.2</td>
</tr>
<tr>
<td>50 (Cattle)</td>
<td>3</td>
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<tr>
<td>67 (Cattle or sheep)</td>
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</tr>
<tr>
<td>75 (Sheep)</td>
<td>4</td>
</tr>
<tr>
<td>95 (Pigs)</td>
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</table>

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INTRODUCTION

Providing the consumer with what he requires, at an affordable price, is the most important task of the meat industry. The consumer's perception of quality (his/her needs) is, however, often dictated by the balance of information supplied to him/her - primarily via the media. It should thus also be a major concern of the industry to ensure that the correct and complete facts are provided to the consumer so that we may constantly supply the consumer with the best there is to be had. We are all conditioned to accept the concept that fat, particularly cholesterol and the saturated fatty acids associated with animal products, is bad (Morris, 1991; Allen, 1987). Just consider the publicity bandwagon resultant from the positive correlation between coronary heart disease and mean serum levels of cholesterol and fat. A considerable information base, pertaining to the fat content and nutritional aspects of food, is freely available to the general public (consumer) via information brochures, booklets etc. Unfortunately the information on meat is frequently incorrect or misleading as it is based on old or irrelevant sources of primary information (Goutefongea & Dumont, 1990). Furthermore, since fat is a highly concentrated energy source, the production of meat with any amount of unwanted fat is expensively wasteful in terms of growth efficiency and feed utilisation - especially in the light of the global protein shortage. This is justification of the international trend that lean meat is a quality perception.

Let's give the picture some perspective. As stated by Hoffman (1990), the percentage of meat yield is not a measure of quality. Rather, meat of the optimal quality may be defined as being...

- appealing to the customer;
  typical, fresh odour & colour, neither dry nor exudative and presentable - tissues are firm & with cohesiveness between them (Wood, 1990);
- appealing to the consumer - as consumed;
  tender, succulent and with intense yet typical flavour & aroma profiles. Tenderness being, singly, the most important criterion in consumer acceptance (Asghar & Pearson, 1980);
- wholesome & nutritious;
  high in protein, vitamins and essential minerals while relatively low in fat content (particularly saturated fatty acids & cholesterol) and caloric density, free of chemical residues and microbial/foreign contaminants
- uniform - predictably of constant character.
  Once bitten twice shy - a couple of bad items or batches may destroy the perception of quality for that product.

Despite international pressures, the South African meat market services a complex mixture of third and first world peoples separated by both economics and culture. Although neither effect should not be underestimated, all groups expect to receive a product of consistent quality that each may forfeit certain other quality attributes according to pocket. In the light of this and available meat processing technologies, it may be concluded that a quality characteristic of primary importance to the processed meats manufacturer is uniformity.

Increasingly noticeable is the gradual realisation that there is more to “dietary fat watching” and lean production than mere calorie counting, reducing the risks of the related “diseases of affluence” and protein supply. Besides being a concentrated energy source, dietary fat facilitates the absorption of the fat-soluble vitamins, certain fats are essential to growth & performance while others are reported to afford protection against diseases such as cancer and even coronary heart disease. Furthermore, while overleaness has manifest in dry, tasteless and tough meat, the tendency for the fat of lean animals to be more unsaturated and soft has resulted in some negative technological, stability and eating quality attributes of that fat hence the product.

The balance between excessive and insufficient fat levels in the definition of the optimum quality lean meat, as well as the
type of fat required, may only be determined with a thorough knowledge of the biochemical and physiological role of fat. Particular attention should be given to postmortem metabolism and the contribution of the respective fat components to the desirable characteristics of lean meat and meat products. Judging from current consumer perceptions, the demand for leaner meat products is set to increase.

The reduction of fat with increased lean production has led to changes in meat quality as a direct consequence of changes to both the muscle character and the fat tissues. Pre- & Post-slaughter handling also exert significant effects on meat quality. The recent impressive reduction in the fatness of pigs (dissectable fat down 15 %, carcass lipid down 18 % and muscle lipid down 9 %) has been accomplished through genetic selection, sophisticated nutrition & management - including changes in slaughter mass, maturity or age and also by non-castration practices. As a consequence, swine sex odour (boar taint) and the fatty acid profile of the pork fat have become major factors determining the quality of the meat and associated fatty tissues.

**SWINE SEX ODOUR HAMPER BOAR PRODUCTION**

Despite the higher efficiencies of boar production as opposed to that of barrows, there is considerable resistance to the general production of intact boars since ca. 5 - 10 % of intact males express an intense objectionable boar odour/taint (Garcia-Regueiro & Diaz, 1989) - particularly evident when the meat or fat is heated. This sweaty, urinelike odour, sometimes likened to the smell of faeces, is not unique to boars as it is also detected at low levels in gilts and castrates (Pearson, Thompson & Price, 1969). Cold meat products are less affected as the odouriferous compounds are only volatilised at a relatively high temperature - 112 °C. The severity of boar odour is unaltered by freezing, even after several years of frozen storage (Pearson et al., 1969). The basis of this taint is not fully understood, but two compounds have been identified as major contributors to boar taint - 5α-Androst-16-en-3-one (5αAn) and skatole.

**Androstenone is the primary contributor to boar taint**

In 1936 Lerche described the unpleasant smell as "boar odour" following the observation that it disappeared following castration - the odour level declined considerably by 33 days (Brooks and Pearson, 1986). Initially the agent was demonstrated in testicular tissue and later shown to be concentrated in adipose tissue (Schanbacher, Yen & Pond, 1985).

Patterson (1968) identified the hormone (pheromone) 5αAn as responsible for boar taint of the fat from non-castrated pigs and subsequently the 3-α & 3-β alcohol forms (androstenols) of this androstene were implicated as lesser contributors to this unpleasant characteristic. Desmoulin, Bonneau, Frouin & Bidard (1982) noted that the incidence of the latter compounds in pork fat had not been widely investigated. The androstenes are unsaturated steroids, synthesised from the nexus metabolite pregnenolone, on an exclusive pathway to that of the adrenal corticoids and sex hormones (Brooks & Pearson, 1986; Schanbacher et al., 1985). 5αAn is synthesised within the testes (Gower & Ahmad, 1967) and secreted into systemic circulation via the spermatic vein.

Despite that gonadotropic stimulation influences secretion of 5αAn (Booth, 1982), the appreciably lower odour levels in barrows were not raised significantly by testosterone or testosterone propionate implantation (Schanbacher et al., 1985) thus indicating that the pheremone most closely associated with boar taint is not produced by the peripheral metabolism of testosterone. Patterson (1982), finding that first year season effects were contrary to the fourfold elevation of androstenone levels in synchrony with the natural mating season of the second year as recorded by Claus (1977, reported by Patterson), noted that the significant effects of breed, season and rearing conditions (e.g. boars raised to 90 kg slaughter-mass, mixed with gilts tend to have lower androstenone levels than when raised with other boars) on the expression of boar taint are too small to be of commercial importance. A small group with higher androstenone levels was identified possibly indicating a sub-population of animals that could respond to external stimuli in a different manner from the normally distributed population.

Immunisation attempts, using either conjugates of androstenone or gonadotrophin releasing hormone as immunogens, to combat the formation of the odouriferous androstenes have been partially successful despite that expression of the male character was not reduced in all cases (Brooks, Pearson, Hoberg, Pestka & Gray, 1986; Patterson, Buxton & Partridge, 1987). Boar odour intensity scores for pGH-treated boars, despite being dose dependent, were found to be intermediate between those of boars and barrows - an indication that this treatment is also partially successful (Hagen, Mills, Bryan & Clark, 1991).

The odorous Δ16-androstanes accumulate in the submaxillary- and parotid- salivary glands (pheromaxein, the specific binding protein) prior to secretion into the saliva. Also, due to their lipophilic character they accumulate in the body fat, particularly of mature boars (Patterson, 1968; Booth, Williamson & Patterson, 1986; Brooks & Pearson, 1986).
The smell threshold levels for the detection of the androstenols in back fat is reported to be similar to that of androstenone (range 1.5 - 1.0 μg/g), with the alpha isomer producing a more intense odour (Garcia-Rigueiro & Diaz, 1989). Notably, androstenone levels in pork range between 0.08 μg/g & 7 μg/g of fat tissue (Thompson & Pearson, 1977). However only a fraction of the population can detect these compounds, women more frequently than men. A survey by the MLC revealed that only 2.8 % of the UK consumers are able to detect boar taint during cooking (Anonymous, 1992).

The critical mass associated with high (&<1 μg/g fat) androstenone levels is 100 kg but lighter animals may also show excessive androstenone content (Booth et al., 1986; Brennan, Shand, Fenton, Nicholls & Ahern, 1986). Malmfors, Lundström & Hansson (1978b) observed higher levels of 5α-An and more frequent identification of boar taint for 130kg boars than for those at lower live mass. They reported that the positive correlation between the 5α-An content of the lumbar backfat and the incidence of boar taint observed by a trained panel only accounted for only 55% - 80% of the observed variations in boar taint scored on a six point scale. The results of trained panel and consumer panel tests frequently agree broadly but the former are considered to be more accurate (Wood, Jones, Francombe & Whebehan, 1986). The low correlation between odour scores and levels of androstenone (r=0.4 - 0.76), also found by other researchers (Fuchs, 1971; Thompson & Pearson, 1977; Mortensen, Bejerholm & Pedersen, 1986), suggests that other compounds may contribute to sex odour in pork. Consumer responses to meat from entire boars has been varied, primarily due to variations in experimental design and consumer preferences. Walstra, Engel and Mateman (1986), measuring both androstenone and skatole, found that variations in consumer identification of boar taint were not explained by the presence of these compounds alone and concluded there must be other factors at play.

Skatole, another major contributor to boar taint

Skatole (3-methylindole), a product of tryptophan degradation possibly resulting from bacterial activity in the large intestine (Yokoyama et al., 1977, as reported by Porter et al., 1989), is also associated with boar taint - less attention is given to the role of indole. Although skatole cannot be directly associated with the sex character, entire male pigs have higher skatole levels than castrates or gilts. On the other hand indole levels are higher for castrates. The mean skatole levels in the backfat of boars and gilts were measured to be 0.047 μg/g (range 0.019 to 0.178) and 0.026 μg/g (range 0.021 to 0.033) as determined by WCOT GLC (Porter, Hawe & Walker, 1989). The smell threshold level for the detection of skatole in back fat is 0.100 μg/g (Garcia-Rigueiro & Diaz, 1989). Mortensen, Bejerholm & Pedersen (1986) reported that meat with skatole levels above 0.25 ppm (ca. 0.32 μg/g) is unacceptable and that below this level the meat of boars was judged to have “other smells” six times as often as that of castrates. The response varied with different cuts of meat and those assessed while heated had greater negative response. Skatole showed a decrease in several samples of cured ham while the levels of all agents associated with boar odour were similar for both fresh meat and meat products.

Various methods have been described for the determination of skatole (& indole) in pork. Because they are intricate and time consuming, WCOT capillary GC and HPLC (detection limit 0.002 μg/g) techniques are more suited to research but spectrophotometric techniques are rapid and suited to production line application (detection limit 0.01 μg/g), despite that they over-estimate skatole through interference (Porter et al., 1989). Recent work using HPLC techniques has shown that the automated spectrophotometric method used for production line monitoring is a good estimate of skatole levels (Hansen-Moller & Andersen, 1992). Skatole concentrations however account for only 33% of the boar taint detected and the combination of these values with Androstenone levels accounts for only 50% of the boar odour detected (Lundström, Hansson, Fjelkner-Mødg & Persson, 1980).

Other possible contributors to boar taint

Fatty acid composition has also been noted to contribute to boar odour (Malmfors, Lundström & Hansson, 1978) but Pearson, Thompson and Price (1969) postulated that the androstenols may have some regulatory effects on fat tissue. Reports have also been made of the contribution of volatile aldehydes to boar taint (De Brabander, Verbeke, de Wilde, Storm & van der Linden, 1986). Viallon, Berdague, Denoyer, Tran, Bonneau & Le Denmat (1992) found highly significant correlations between androstenone content and ortho-xylene, decanal and an unknown compound.

FAT DEPOT DISTRIBUTION & SATURATION CONTRIBUTE TO MEAT QUALITY

Fat deposition in the body may be subcutaneous (the major fraction in pigs), intermuscular, intramuscular (IMF), in the body cavity or as intra-cellular fat droplets. These depots, localised clusters of identifiable adipose cells chiefly filled with triacylglycerides, serve primarily as energy reserves as opposed to the structural role of the more polar lipids present in all cell membranes. The relative distribution, physical and chemical properties and extent of these depots are dependent on species, diet, age, sex, breed and fatness.
Not only are the proportions of the relative fat deposits determinative of meat quality, but the degree of fatty unsaturation in the fat is of major importance. However, the importance ascribed to fat deposits in the quality of meat is disputed. The dispute, or miscalculation, over the contribution of body fat to meat quality is due to the fact that the effectors of meat quality are interactive and contributions to quality may be indirect. The relative contributions of dissectable and marbling fat to meat quality will be discussed shortly. Looking at the interaction of fat tissue composition and established effectors of meat quality is of major importance. However, the importance ascribed to fat depots in the quality of meat is disputed. The extent and mechanisms of the direct contribution from changes in fat composition to these factors known to adversely affect meat quality are unknown.

Firm fat improves point of sale meat quality & meat handling

Visual appearance is an important aspect of meat quality at the point of sale. The ratio of fat to lean influences consumer choice - fresh pork on the South African meat market is not trimmed of excess subcutaneous fat. Consumers prefer the fat to be white and firm, however, immature fat tissues have a pink hue due to an extensive capillary network and the lack of opacity, characteristic of harder, higher melting fat that masks the underlying heme pigments (Enser, 1983). In confirmation, Ilian, Razzague, Al-Awadi & Salman (1988) reported that fat tissue appears relatively grey or yellowish if the lipid is not fully solidified. Furthermore, the softer more unsaturated fats may develop an orange colour resulting from early rancidity (San
toro, 1983; Barton-Gade, 1983). However, Barton-Gade (1983) also reported that undesirable fat colour more often results from dietary pigment accumulating in the fat depots. Also of importance, the presentation of fresh pork is adversely affected by soft unsaturated fat as this tends to separate from the lean, has a wetter appearance and does not maintain the conformation of the cut (Wood 1990). The problem that carcasses do not set after chilling, resulting that pork meat cuts do not hold their form and are difficult to handle and also that the fat is soft, oily and floppy was reported to be more of a problem to butchers and retailers that to consumers (Wood, 1983). Reid (1983) indicated that boar sides tend to have lower firmness and colour scores than gilts. Intramuscular lipid content affects the firmness of muscle. Fat separation appears to be aggravated by the curing process of bacon manufacture (Reid, 1983) resulting in handling difficulties and higher rejection rates during bacon slicing. A large proportion of pork is used for the production of bacon in South Africa.

Individual point of sale aspects of quality (firmness, tissue separation and wetness) that are negatively associated with overleanness were found to be particularly unattractive at light carcase masses, highlighting an important interaction between carcass mass and leanness in determining pork quality (Wood, 1990). South African pork carcases are light weight. Forty percent of the pig carcases marketed in the RSA during 1991 fall in the mass range 41 kg to 55 kg (mean 47.5 kg) from Table 10d of the statistics of the Meat Board 1991.

Houben & Krol (1983) illustrated that fermented sausages should not be manufactured from raw materials where the poly-unsaturated fatty acid (PUFA) content of the backfat is as high as 30 % since this results in obstructed flow of the batter and fat exudation during manufacture, fat sweating during smoking & ripening and a final product with a poor texture and tendency towards premature rancidity. Interestingly, the softer texture of meat-loaf produced was judged as an improvement. These researchers considered the 12 % PUFA limit of Pra-
bucki (1978) as too rigid. To limit the backfat PUFA levels to 12-15 %, the addition of oils (soya or maize) to pig diets must be limited to 1,5 % (Berschauer 1986).

Solid and semi solid food products are multiphase systems where the stability of any phase may be crucial to the stability of the whole product. Thus, fat holding properties do not only depend on the interfacial film which is stabilised by protein binding properties but rather the whole structure should be considered as playing a role. Shut (1968, as cited by Wood, 1990) found that although melted fat resulted in finer emulsions, the most stable emulsion was produced when the whole fat tissue was used. Furthermore, Evans & Ranken (1975) determined that softer adipose tissue generally has a higher connective tissue content and thicker cell membranes which appear to reduce lipid losses during cooking. These results suggest that the technological character of pork fat is not solely dependent on the degree of fat saturation but it also depends on the maturity of the adipose tissue used.

The marked effect of the amount of carcase fat on the appearance and handling characteristics of pork may be explained by changes in the chemical composition of the fat. Various workers (Kühne, 1983; Wood, Enser & Fisher, 1983) have shown that as fatness increases (P2 fat thickness) so does the lipid content of the fat tissues while the water, collagen and linoleic (C18:2) acid contents of the corresponding fat tissues de-
Intramuscular fat contributes to eating quality

Intramuscular fat (marbling) and, to a lesser degree, intermuscular fat (ca. 2% and 20% of the total fat respectively), are important contributors to the eating quality of pork should they remain after cooking. Based on palatability research, it is recommended that the minimum level of intramuscular fat in pork should be between 1% (Wood, 1990 - UK context) and 3% (Savell & Cross, 1986 - USA context).

Tenderness

Four theories regarding the mechanisms whereby marbling influences tenderness have been proposed (Savell & Cross 1986)...

- BITE THEORY
  Marbling replaces protein with lipid thereby reducing the bulk density. Thus, the fat of comparatively low shear resistance will dilute the effects of the muscle fibres. This mechanism is analogous to that seen in high-fat cheeses and biscuit textures.

- STRAIN THEORY
  Deposits of fat in the peri- or endomysium thin and weaken the connective tissue membranes decreasing their resistance to fragmentation. Purslow (1985) concluded that the physical disruption of the muscle structure when meat is chewed is always initiated between fibre bundles in the perimysial tissue. As this is where intramuscular fat depots are located, it is possible that marbling interrupts the bonding between fibres facilitating fracture. Presumably fat inclusion in the perimysium would also reduce the forces required to break the connective tissue.

- LUBRICATION THEORY
  Marbling lubricates muscle fibres and fibrils increasing juiciness and the sensation of tenderness. This mechanism relies on rapid and significant fat release from the fat cells of the depot and would be subject to temperature effects and the degree of fat saturation. Speculation that melted fat rendered from subcutaneous or intermuscular fat may migrate into the lean or that pork cuts trimmed of all visible fat may show differences in the cooking rate and marbling fat rendering has been challenged by the finding that the fat composition of the lean and lipid retention were unaffected by complete fat trimming (Novakofski, Park, Bechtel & McKeith, 1989).

- INSURANCE THEORY
  High marbling prevents dryness and toughness resulting from high heat and incorrect cooking. Fat losses during cooking, irrespective of method, are linearly correlated (r= 0.986) with the fatness of the cut but are a function of the surface area to volume ratio. Furthermore, more than 85% of the fat is retained during cooking (Johansson & Reutersward, 1987).

When it is considered that the effects of changes in the degree of marbling are only significant at lower fat levels then it appears that the strain theory is most feasible. It is possible, however, that a combination of the mechanisms described by the first three theories underlies the true means whereby intramuscular fat contributes to the tenderness of pork.

Juiciness

The sensation of juiciness depends on the release of ample liquid both from the food and saliva (Asghar & Pearson, 1980). Initial juiciness is a function of the degree of cooking and the water holding capacity of the meat. Mittal and Barbut (1992) reported that the waterholding capacity of pork breakfast sausages decreased in low fat products resulting in a springy, cohesive and chewy product that received lower sensory scores. On the other hand, sustained juiciness is a function of the fat (unsaturated) which coats the mouth and stimulates salivary action. The absence of fat in well cooked meat results in accentuation of the dryness of the meat. This may result, in part, from a possible barrier effect whereby the fat might inhibit water loss from the product.

Flavour

Although the basic flavour of meat is non-lipid in origin (Smith & Carpenter, 1974 reported by Wood, 1990), volatiles produced from the hydrolysis of lipids - particularly phospholipids, in the muscle tissues account for the species specific cooked flavour of pork (Mottram & Edwards, 1983). Fogerty, Whitfield,
Supplementation of Aaron, 1991) plasma (spray dried) in food products (pH= 5,5 - 7) may be ide dismutase and albumin, thus the inclusion of porcine Blood plasma contains several antioxidants, including superox- Improving fat stability

Fat unsaturation effects product stability

Lipid peroxidation (rancidity) is one of the primary mechanisms of quality deterioration in foods, particularly meat, affecting aroma, flavour, colour, texture, nutritive value and toxicity (Kanner et al., 1992). When cells are injured (as results following slaughter), lipid peroxidation is favoured. Initiation of per- oxidation, requires the formation of catalysts with a redox potential over +1V that will then react with the ground state singlet molecules of the PUFA’s. It appears that iron ions and the OH radicals, formed from biological H2O2, are the most im- portant catalysts in the initiation of rancidity. Phospholipids, particularly phosphatidyl ethanolamine, are the major contribu- tors to oxidative off-flavours in several animal muscles. Sus- ceptibility and severity of oxidation depend on the degree and amounts of unsaturated fatty acids (Kanner et al., 1992). Just consider the relative auto-oxidation rates of methyl oleate, lino- leate and linolenate at 20 °C = 1 : 12 : 25 respectively (Hou- ben & Krol, 1983).

Trimming away of external fat prior to the production of cooked, cured ham leads to a marked reduction in the typical cured flavour associated with the interaction between nitrite and INTRA-muscular fat. As the external fat of normal (not trimmed) products is neither oxidised nor nitrosated the de- crease in flavour intensity is unexplained (Mouloud, Dumont & Goutefongea, 1992). Interestingly, lowering the fat content of processed products emphasises the flavour of seasoning agents such as salt. However reduction of the latter reduces the ionic strength and consequently the water holding capacity and stability of the product (Goutefongea & Dumont, 1990).

THE FATTY ACID CONTENT IS REFLECTED IN THE FAT SOFTNESS

The ratio of stearic acid to linoleic acid is the best measure of fat softness. Enser et al. (1984) showed a good correlation be- tween melting point and stearic acid (+0,85) or linoleic acid (-0,73) contents of dorsal fat. A step further, Wood (1983), noting that the relative percentage of linoleic acid decreases with fatness and that high levels of this fatty acid (≥150 mg/g lipid) depress the fat melting point, reported that fat firmness is best described by the relative proportions of saturated and monoun- saturated fatty acids of chain length 16 and 18. Confirming these findings, Flores et al., (1988) recorded that the fat melting point is best explained by the stearic acid content alone (simple regression correlation coeff = +0,942). They also re- ported a high negative correlation (-0,846) between oleic acid and the fat melting point and noted a high positive correlation between slip point and the palmitic or stearic acid contents (0,867 & 0,792 resp.) and accordingly negative correlation with oleic and stearic acid contents (-0,856 & -0,748). The Iodine value could be explained by stearic or oleic acid content (corr = -0,902 & +0,897 resp.) They showed that the multiple corre- lation between palmitic, palmitoleic, stearic & oleic content with iodine value was 0,977.

Gispert, Diaz, Oliver, Tibau & Diestre (1990) accounted for the breed effect, at equal fatness, on backfat softness by the ratio (C16:1+C18:1+C18:2):(C14:0+C16:0+C18:0). The fatter type pigs showed a more saturated fat- The C16:0 concentration was raised and the C18:2 lower in Duroc vs Landrace pigs. Similar results were reported by Nunez et al. (1990). Various researchers have reported that the fat deposition of restricted-
fed hogs was not only slower but the deposited fat was also softer than that of full-fed hogs. This effect was shown to be due to the preferential deposition of polyunsaturated fatty acids especially linoleic acid. This is due to the fact that palmitic acid deposition is concentration dependent while that for linoleic acid is fairly constant.

NON-CASTRATION POLICY

Since dietary fat is preferentially used for body fat synthesis and dietary long chain fatty acids are predominantly incorporated into the body fat, the effects of variations in the fatty acid profile of dietary fat are significant, particularly under conditions of reduced de novo fat synthesis. This implies that the fat of leaner type pigs will reflect the fatty acid composition of the diet more closely than the obese type animals thus restricting lean production efficiency by the possible negative attributes of the end product. The problems such as lower curing yield and floppy fat (higher water content and unsaturated fat) expressed by carcases of boars is indicative of immature tissue development (Wood & Mottram, 1981). Furthermore, as boars are leaner at the same mass as compared to barrows (Cruz-Bustillo et al., 1987) but at the same fatness their fat characteristics (water content and degree of unsaturation) are similar to those of castrates (Wood, 1985) it appears that the fat softness effects of boar production are merely result from a leaner type.

CONCLUSION

This focuses the spotlight on the trend toward lean pork production as this practice results in greater unsaturation of the fatty acids in all lipid reserves. We may look to producing larger carcases with a moderate to low fat cover. A pig slaughtered at a mass of 85 kg to 100 kg should grade with a backfat thickness, P2, between 12 mm and 18 mm to be of optimal fat and meat quality (Foster, 1981). Furthermore as the fat content of the pig adipose deposits is easily manipulated via the diet, a specialist foods (e.g. Evening Primrose oil) market may be developed for the treatment of some “diseases of affluence.” There is thus great potential for the production of lean pork!

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Effect of protein source on growth and carcass quality characteristics in feedlot lambs

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INTRODUCTION

Due to the population growth in South Africa and environmental factors, such as droughts, the demand for mutton often exceeds the production capacity of this farming enterprise. This under-supply has lead to price increases for mutton. This, in turn, is partially responsible for farmers retaining their present flock sizes, or even increasing them, despite the natural resource (veld) being in a poor condition or even over-utilized.

It is thus not surprising that intensification of this traditionally extensive, farming enterprise is being considered, or applied, by many producers, as this is one of the few viable options left to the farmer. Intensification can vary from dry land cultivated pastures to finishing in the feedlot.

This study was restricted to the feedlot situation and the finishing of weaner lambs. Many studies have been reported on the finishing of lambs in the feedlot (Kernick, 1985; Brand & Cloete, 1990). However, this study was not restricted to animal performance alone, but the effect of diet on carcass characteristics was also studied. The diets were formulated in such a manner that the effect of protein source (quality) on above-mentioned characteristics could be evaluated.

MATERIALS AND METHODS

Lambs

A group of SA Mutton Merino cross Merino lambs (30 ewes and 30 rams), weighing from 18 to 25 kg, were bought from a farmer. The lambs were drenched (Multi spec), inoculated (pulpy kidney and pasturella) and randomly divided into 7 dietary groups - 4 ewes and 4 rams per group. The lambs were placed in single pens and had free access to water. The lambs were weighed once a week and slaughtered when they had reached a weight of ca 42 kg.

Diets

The diets fed to the lambs were formulated to have a crude protein content of ca 15%, a ME value of ca 11 MJ/kg and a crude fibre content of ca 10% (Table 1). Grain sorghum was used as the main energy source in 5 of the 7 diets and for the remaining two, maize grain was used. The grain component was not milled and the minerals coated onto the whole grain seeds before the other ingredients were added to the diet. The protein sources used with the sorghum diets were fishmeal, cottonseed oilcake, sunflower oilcake, whole soybeans and urea. Fishmeal and urea was used as protein source with the maize diets.

Table 1: Composition of the different diets fed to the lambs

<table>
<thead>
<tr>
<th>Diet</th>
<th>Hay</th>
<th>Molasse</th>
<th>Minerals</th>
<th>Grain</th>
<th>Protein</th>
<th>Cost/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>S + FISH</td>
<td>15.0</td>
<td>2.5</td>
<td>3.8</td>
<td>74.2</td>
<td>5.1</td>
<td>299.85</td>
</tr>
<tr>
<td>S + COC</td>
<td>15.0</td>
<td>3.0</td>
<td>3.8</td>
<td>68.3</td>
<td>1.0</td>
<td>273.06</td>
</tr>
<tr>
<td>S + SOC</td>
<td>15.0</td>
<td>3.0</td>
<td>4.0</td>
<td>68.0</td>
<td>1.0</td>
<td>277.12</td>
</tr>
<tr>
<td>S + SOYA</td>
<td>15.0</td>
<td>3.0</td>
<td>4.0</td>
<td>67.5</td>
<td>10.0</td>
<td>270.45</td>
</tr>
<tr>
<td>S + UREA</td>
<td>15.0</td>
<td>2.5</td>
<td>4.2</td>
<td>77.9</td>
<td>5.0</td>
<td>230.22</td>
</tr>
<tr>
<td>M + UREA</td>
<td>15.0</td>
<td>3.0</td>
<td>4.4</td>
<td>77.1</td>
<td>5.0</td>
<td>310.85</td>
</tr>
<tr>
<td>M + FISH</td>
<td>15.0</td>
<td>3.0</td>
<td>3.5</td>
<td>74.3</td>
<td>4.4</td>
<td>363.35</td>
</tr>
</tbody>
</table>

Mineral mix contained 1 % urea plus 0.5 % salt, 0.5 % lime, 1.0 % Ca-hydroxide, 1.0 % NH₄Cl, a vitamin premix (plus ionophore and antibiotic) and phosphate where needed.

S = Grain Sorghum, COC = Cottonseed Oilcake, SOC = Sunflower Oilcake, M = Maize Grain.

Feedbins were filled daily to ensure ad lib intake. Feed residues were removed 3x a week, pooled and weighed per week. Live mass and warm carcass mass was taken on the day of the lamb being slaughtered. Cold carcass mass was determined the following day. The carcasses were also graded on
the day following slaughter, and thereafter fat thickness was measured on 3/4 lumbar vertebrae - 2.5 cm from the mid-vertebrae position. Each carcass was split into two sides.

**Sensory analysis**

The one side was then subdivided into 7 commercial cuts. Each cut was dissected into meat, fat and bone. The whole *M. longissimus thoracis et lumborum* portion of the other side was removed for later sensory analysis (Fourie, 1992).

**Statistics**

One-way analysis of variance was done, using diet as the independent variable, with STATGRAPHICS™ Version 2.1.

**RESULTS AND DISCUSSION**

**Growth characteristics**

The daily DM intake of each lamb for the total feeding period is presented as an average per diet in Table 2. No statistical differences in intake were found between the fishmeal diets and urea diets, for both of these grain sources (maize versus sorghum). Intake on the maize-urea diet was the lowest, although not significantly different from the maize-fishmeal and sorghum-fishmeal diets. The two sorghum diets combined with either cottonseed oilcake meal (COC) or sunflower oilcake meal (SOC) had statistically higher intakes than the above-mentioned. Intakes on the sorghum-soyabean and sorghum-urea diets were intermediate. The daily DM intakes on the above-mentioned diets were lower than those obtained in previous trials conducted at this Institute.

<table>
<thead>
<tr>
<th>Diet</th>
<th>Feed/day (g)</th>
<th>ADG (g/d)</th>
<th>FCR (kg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S + FISH</td>
<td>810.31†</td>
<td>267.28‡</td>
<td>3.11†</td>
</tr>
<tr>
<td>S + COC</td>
<td>996.90†</td>
<td>256.12‡</td>
<td>4.15‡</td>
</tr>
<tr>
<td>S + SOC</td>
<td>966.16†</td>
<td>240.11*</td>
<td>4.50*</td>
</tr>
<tr>
<td>S + SOYA</td>
<td>873.21*</td>
<td>293.24*</td>
<td>3.01*</td>
</tr>
<tr>
<td>S + UREA</td>
<td>843.13*</td>
<td>238.17*</td>
<td>3.61*</td>
</tr>
<tr>
<td>M + UREA</td>
<td>794.75*</td>
<td>240.30*</td>
<td>3.31*</td>
</tr>
<tr>
<td>M + FISH</td>
<td>799.90*</td>
<td>249.66*</td>
<td>3.32*</td>
</tr>
<tr>
<td>SE</td>
<td>10.82</td>
<td>5.74</td>
<td>0.09</td>
</tr>
</tbody>
</table>

†‡§ Means with different superscripts in each column differ significantly (P<0.05)

The calculated average daily gains (ADG) obtained for the various diets are presented in Table 2. Lambs fed the sorghum-soyabean diet had the highest ADG. The sorghum-fishmeal, sorghum-COC and maize-urea diets were lower, however not significantly so. Although the maize-fishmeal and sorghum-SOC and sorghum-urea diets resulted in the lowest ADG, they were only significantly lower than the sorghum-soyabean diet. ADG's for the fishmeal and urea diets were not affected by the grain component in the diets (maize versus sorghum). The relatively lower ADG obtained from lambs fed the maize-fishmeal diet is unexpected. Previous trials conducted at this Institute (Meyer & Osler, 1992) indicated that although there was no statistical difference between diets containing fishmeal in combination with either maize or sorghum, the maize-fishmeal diet tended to exhibit the highest ADG. Possibly the small number of animals per diet (8) and the fact that a high incidence (2) of prolapse of the uterus or rectum occurred in lambs fed this diet, during the present trial, (animals completed the trial, however) may offer an explanation.

Feed conversion ration (FCR) is probably a better index for performance than ADG, since feed intake and the resultant growth is considered. Thus, FCR is a more valuable indicator of economical performance than ADG. Lambs fed the sorghum-soyabean diet had the lowest FCR (3.01), followed by the sorghum-fishmeal diet and the two maize diets. The FCR's for the sorghum-COC (4.15) and sorghum-SOC diets (4.50) were significantly higher than those of the sorghum-soyabean diet (Table 2). The high FCR obtained for the sorghum-COC diet is in agreement with previous studies (Meyer & Osler, 1992). However, the high FCR, for the the SOC diet, was not found in previous studies. Slight changes in the diets fed during these studies (hay component was changed for this trial) may be responsible for above-mentioned changes in FCR and thus the hay component used in feedlot diet will be studied in future. If FCR's were to be used to rank the diets in terms of animal performance, the sorghum-soyabean and sorghum-fishmeal diets would be high, maize-urea and sorghum-urea as intermediate and sorghum-COC and sorghum-SOC as low.

During 1990/91, when this study was conducted, ration costs (Table 1) per ton varied from R363,35 (maize-fishmeal) to R230,22 (sorghum-urea). By multiplying FCR with ration/feed cost, costs per kg live mass gain can be calculated. The sorghum-soyabean (R0,81/kg gain) and sorghum-urea diets were ranked most cost effective (low), followed by sorghum-fishmeal and maize-urea as intermediate and the most expensive diets (high) were sorghum-COC, maize-fishmeal and sorghum-SOC (R1,25/kg gain). However, during 1992 sharp increases occurred in maize, soyabean and especially sorghum prices (due to drought/importation). Currently, the maize-
urea diet would be the most cost effective diet, at R1,45/kg gain, followed by the sorghum-urea, sorghum-fishmeal, sorghum-soyabean and maize-fishmeal diets. The SOC and COC would be the most expensive, with the sorghum-SOC costing R2,12/kg live mass gain. Feed costs are not the only financial aspects to be considered when deciding on which diet to feed to lambs in the feedlot, as the quality of the product (mutton) would also influence the actual income realized.

### Carcass characteristics

To eliminate any possible effects of mass on carcass composition, the lambs were slaughtered in 4 groups (42 kg) and not all on one day. It is clear from Table 3 that this procedure was successful, as no statistical differences were found in live mass of the lambs at slaughter, for the different diets. As diet had no significant effect on carcass mass, differences in carcass composition would be due to the diet fed to the lambs.

### Table 3: Carcass composition of the lambs fed the various diets

<table>
<thead>
<tr>
<th>Diet</th>
<th>Live mass (kg)</th>
<th>Carcass mass (kg)</th>
<th>% Fat</th>
<th>% Meat</th>
<th>% Bone</th>
</tr>
</thead>
<tbody>
<tr>
<td>S + FISH</td>
<td>44.61</td>
<td>21.77</td>
<td>73.64</td>
<td>14.32</td>
<td></td>
</tr>
<tr>
<td>S + COC</td>
<td>43.97</td>
<td>20.99</td>
<td>73.16</td>
<td>14.15</td>
<td></td>
</tr>
<tr>
<td>S + SOC</td>
<td>43.46</td>
<td>21.75</td>
<td>75.51</td>
<td>13.75</td>
<td></td>
</tr>
<tr>
<td>S + SOYA</td>
<td>42.44</td>
<td>21.19</td>
<td>74.87</td>
<td>13.87</td>
<td></td>
</tr>
<tr>
<td>S + UREA</td>
<td>44.13</td>
<td>21.43</td>
<td>74.13</td>
<td>13.83</td>
<td></td>
</tr>
<tr>
<td>M + FISH</td>
<td>42.34</td>
<td>21.32</td>
<td>74.13</td>
<td>13.11</td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>2.33</td>
<td>1.38</td>
<td>0.27</td>
<td>0.31</td>
<td>0.29</td>
</tr>
</tbody>
</table>

** means with different superscripts in each column differ significantly (P<0.05)

S = Grain Sorghum, COC = Cottonseed Oiacle, SOC = Sunflower Oiacle, M = Maize Grain

### Table 4: Commercial cuts expressed as a percentage of carcass obtained from the lambs fed the various diets

<table>
<thead>
<tr>
<th>Diet</th>
<th>Leg</th>
<th>Loin</th>
<th>Thick rib</th>
<th>Rib</th>
<th>Flank</th>
<th>Shoulder</th>
<th>Neck</th>
</tr>
</thead>
<tbody>
<tr>
<td>S + FISH</td>
<td>32.36</td>
<td>13.52</td>
<td>10.47</td>
<td>10.89</td>
<td>5.56</td>
<td>17.81</td>
<td>9.38</td>
</tr>
<tr>
<td>S + COC</td>
<td>32.11</td>
<td>13.69</td>
<td>11.14</td>
<td>12.08</td>
<td>5.50</td>
<td>15.41</td>
<td>10.07</td>
</tr>
<tr>
<td>S + SOC</td>
<td>31.99</td>
<td>13.64</td>
<td>10.84</td>
<td>10.66</td>
<td>5.55</td>
<td>18.09</td>
<td>9.22</td>
</tr>
<tr>
<td>S + UREA</td>
<td>31.86</td>
<td>14.71</td>
<td>10.77</td>
<td>10.90</td>
<td>6.32</td>
<td>15.76</td>
<td>9.70</td>
</tr>
<tr>
<td>M + FISH</td>
<td>31.46</td>
<td>13.76</td>
<td>10.87</td>
<td>10.93</td>
<td>5.27</td>
<td>17.78</td>
<td>10.0</td>
</tr>
<tr>
<td>SE</td>
<td>1.00</td>
<td>0.45</td>
<td>0.35</td>
<td>0.36</td>
<td>0.21</td>
<td>0.56</td>
<td>0.36</td>
</tr>
</tbody>
</table>

S = Grain Sorghum, COC = Cottonseed Oiacle, SOC = Sunflower Oiacle, M = Maize Grain

The percentage meat and bone in the carcasses (Table 3) were not statistically affected by the diet fed to the lambs. However, the percentage subcutaneous fat dissected from the lambs for the sorghum-SOC diet, was statistically lower (10.7 %) than that for the sorghum-COC (12.7 %), maize-fishmeal (12.8 %) and the maize-urea diets (12.9 %), which had the highest fat content. Neither the quality of the protein source (expressed as rumen bypass protein) nor the protein quality of the total diet, had an effect on the subcutaneous fat content of the carcasses. However, using sorghum rather than maize, as the energy component in the diet, reduced the fat content of the carcasses by 0.8 % for the sorghum-fishmeal and by 0.9 % for the sorghum-urea diets, when compared to maize plus fishmeal or maize-urea diets respectively. Further-

### Table 5: The effect of diet on meat content in the various commercial cuts obtained from each carcass

<table>
<thead>
<tr>
<th>Diet</th>
<th>Leg</th>
<th>Loin</th>
<th>Thick rib</th>
<th>Rib</th>
<th>Flank</th>
<th>Shoulder</th>
<th>Neck</th>
</tr>
</thead>
<tbody>
<tr>
<td>S + FISH</td>
<td>8.73a</td>
<td>6.47a</td>
<td>20.61</td>
<td>12.08</td>
<td>9.42</td>
<td>14.50</td>
<td>13.93</td>
</tr>
<tr>
<td>S + COC</td>
<td>7.68a</td>
<td>6.74a</td>
<td>10.70</td>
<td>11.91</td>
<td>9.04</td>
<td>15.87</td>
<td>14.9</td>
</tr>
<tr>
<td>S + SOC</td>
<td>7.86a</td>
<td>6.48a</td>
<td>19.45</td>
<td>19.46</td>
<td>8.97</td>
<td>11.04</td>
<td>10.04</td>
</tr>
<tr>
<td>S + SOYA</td>
<td>7.47a</td>
<td>6.40a</td>
<td>16.87</td>
<td>16.87</td>
<td>9.45</td>
<td>14.52</td>
<td>8.87</td>
</tr>
<tr>
<td>S + UREA</td>
<td>9.42a</td>
<td>6.05a</td>
<td>12.24</td>
<td>12.24</td>
<td>16.01</td>
<td>10.42</td>
<td>10.42</td>
</tr>
<tr>
<td>M + UREA</td>
<td>9.08a</td>
<td>6.69a</td>
<td>10.04</td>
<td>10.04</td>
<td>10.04</td>
<td>11.68</td>
<td>11.68</td>
</tr>
<tr>
<td>M + FISH</td>
<td>8.57a</td>
<td>6.67a</td>
<td>11.95</td>
<td>11.95</td>
<td>9.04</td>
<td>11.47</td>
<td>11.47</td>
</tr>
<tr>
<td>SE</td>
<td>0.25</td>
<td>0.45</td>
<td>0.31</td>
<td>0.22</td>
<td>0.66</td>
<td>0.54</td>
<td>0.61</td>
</tr>
</tbody>
</table>

** means with different superscripts in each column differ significantly (P<0.05)

S = Grain Sorghum, COC = Cottonseed Oiacle, SOC = Sunflower Oiacle, M = Maize Grain

### Table 6: The effect of diet on the subcutaneous fat content in the various commercial cuts obtained from each carcass

<table>
<thead>
<tr>
<th>Diet</th>
<th>Leg</th>
<th>Loin</th>
<th>Thick rib</th>
<th>Rib</th>
<th>Flank</th>
<th>Shoulder</th>
<th>Neck</th>
</tr>
</thead>
<tbody>
<tr>
<td>S + FISH</td>
<td>8.73a</td>
<td>6.47a</td>
<td>20.61</td>
<td>12.08</td>
<td>9.42</td>
<td>14.50</td>
<td>13.93</td>
</tr>
<tr>
<td>S + COC</td>
<td>7.68a</td>
<td>6.74a</td>
<td>10.70</td>
<td>11.91</td>
<td>9.04</td>
<td>15.87</td>
<td>14.9</td>
</tr>
<tr>
<td>S + SOC</td>
<td>7.86a</td>
<td>6.48a</td>
<td>19.45</td>
<td>19.46</td>
<td>8.97</td>
<td>11.04</td>
<td>10.04</td>
</tr>
<tr>
<td>S + SOYA</td>
<td>7.47a</td>
<td>6.40a</td>
<td>16.87</td>
<td>16.87</td>
<td>9.45</td>
<td>14.52</td>
<td>8.87</td>
</tr>
<tr>
<td>S + UREA</td>
<td>9.42a</td>
<td>6.05a</td>
<td>12.24</td>
<td>12.24</td>
<td>16.01</td>
<td>10.42</td>
<td>10.42</td>
</tr>
<tr>
<td>M + UREA</td>
<td>9.08a</td>
<td>6.69a</td>
<td>10.04</td>
<td>10.04</td>
<td>10.04</td>
<td>11.68</td>
<td>11.68</td>
</tr>
<tr>
<td>M + FISH</td>
<td>8.57a</td>
<td>6.67a</td>
<td>11.95</td>
<td>11.95</td>
<td>9.04</td>
<td>11.47</td>
<td>11.47</td>
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<tr>
<td>SE</td>
<td>0.25</td>
<td>0.45</td>
<td>0.31</td>
<td>0.22</td>
<td>0.66</td>
<td>0.54</td>
<td>0.61</td>
</tr>
</tbody>
</table>

** means with different superscripts in each column differ significantly (P<0.05)

S = Grain Sorghum, COC = Cottonseed Oiacle, SOC = Sunflower Oiacle, M = Maize Grain
more, ADG and FCR (average per diet) had no apparent effect on the subcutaneous fat content of the carcasses.

The average subcutaneous fat cover of the carcasses reported in this study was higher than the 10 % obtained by Strydom (1991). However, Strydom (1991) used Mutton Merino lambs in his study, whilst Merino crossbred lambs were used in the present study. The average subcutaneous fat cover of 12 %, and bone content of 14 %, reported in this study (Table 3), is in agreement with the 13.8 % and 12.8 % (respectively) found by Casey (1982) for Merino lambs weighing 41 kg. Table 4 is a summary of the 7 commercial cuts into which each carcass was split. Diet had no significant effect on the size of the various commercial cuts (Table 4), when compared between diets (Table 5), which also had a low meat and high fat percentage. There is no clear-cut evidence that protein had an effect on the ratio of meat-to-fat yield in the commercial cuts (Tables 5 & 6). However, there is a trend for the maize diets to have the lowest meat yield and the 3 cuts discussed.

Diet had no effect on the dissectable bone content (11 %) in the loin (Table 7). The bone content in the leg cut, for the maize-urea diet was 15 %, which was significantly lower than the 16 % for the sorghum-soya diet. The small but significant variation in bone content in the leg (1 %) partially counteracts the significant change in subcutaneous fat content (3 %) obtained for these two diets (10 % for the maize-urea and 7 % for the sorghum-soya diet). Therefore, the high subcutaneous fat cover on the legs of sheep fed the maize-urea diet is highly significant, stressing the fact that feeding urea as a protein source, could lead to the production of apparently fat carcasses, judged visually. The maize-urea diet resulted in the lowest bone content in the shoulder (16 %), which differed significantly from the 23 % and 24 % obtained for the sorghum-urea and sorghum-COC diets respectively.

Sensory quality characteristics

The sensory analysis of the roasted loins taken from each carcass, is summarized in Table 8. The results of the fat odour evaluated by the sensory panel, indicate that loins obtained from the maize-fishmeal diets had the most pleasant odours. Although the maize-urea diet had a relatively high fat content, it was scored as extremely unpleasant. In fact, both the urea diets (maize and sorghum) obtained the lowest score (unpleasant) for fat odour, possibly due to the fact that urea is a chemically pure component, without any inherent long-chained carbohydrates and fatty acids that might contribute to fat odour.

Meat tenderness (Table 8) does not seem to be influenced by the ADG of the lambs, as the sorghum-soyabean diet which had the highest ADG, had an intermediate score for tenderness. The maize-urea diet had the highest score for tenderness, but only an intermediate ADG. Protein quality of the diet had no definite effect on tenderness. However, if the maize grain diets were to be ignored, the sorghum-urea and sorghum-COC diets respectively.
highest bypass protein content, tended to have the highest score for tenderness (were more acceptable).

Meat flavour (Table 8) was significantly influenced by the diet fed. Urea seemed to be a over-riding factor, as both the urea diets (maize and sorghum) had the lowest score for flavour (unpleasant). Furthermore, the sorghum diets, except the sorghum-urea diet, had a more pleasant meat flavour. It is possible that an investigation into the fat content and or composition of protein sources might resolve a protein effect on meat flavour and fat odour, rather than protein quality.

CONCLUSION

Using maize grain rather than grain sorghum, as the energy component in feedlot diets for lambs, had no significant advantage in terms of animal performance or carcass quality. In fact, maize grain had a negative effect on carcass fat and sensory acceptability of the meat, when compared to grain sorghum in this trial.

Protein quality, in terms of rumen bypass, tended to affect animal performance. Fishmeal diets had a higher ADG, but this was non-significant. From an economical point of view, the high protein quality sources (fishmeal) were too expensive and their use could not be justified by the slight increase in ADG obtained.

The use of whole soyabeans, in combination with grain sorghum, resulted in the optimal response in terms of animal performance, carcass quality and acceptability of the meat.

ACKNOWLEDGMENT

Grateful thanks is expressed to Mrs L. Fourie (née Szombati) & Dr I.B. Zondagh for their valuable sensory evaluation work which is also being presented separately at this symposium (Fourie, Zondagh, Illsley & Boshoff, 1992).

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The development of a restraining system to accommodate the Jewish method of slaughter (Shechita)

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INTRODUCTION

The manner in which ritual slaughterings are executed in the R.S.A. is unknown to the majority of the population. The requirements with which religious slaughterings must comply as well as the facilities used for that purpose are even less familiar. The subject of the Jewish method of slaughter (Shechita) has especially elicited much discussion, due to the major divergence of opinion between the Jewish community and animal welfare organisations, as far as the slaughter technique and restraining facilities are concerned.

Although the restraining systems meet with, and are used in accordance with, the Standing Regulations under the Animal Slaughter, Meat and Animal Products Hygiene Act (1967), a visual assessment resulted in the decision that animals suffer unnecessary discomfort, pain and stress and are not humanely treated during Shechita.

The existing facilities make provision for the lower limbs or pasterns of cattle and calves to be clamped in a casting pen of the North British rotary type, whereby the animal is cast 110° to its left side. The head of the animal is pulled back with the aid of an instrument so that the skin of the neck is stretched to be taut. The shochet makes an incision by a downward movement without pressing to sever the neck arteries and veins with a single uninterrupted sweep.

The complaint of the animal welfare organisations is that animals endure too much stress before, as well as during the restraining and casting process.

Their request is that the animals should be in an upright position when the throat is cut. This, however, means that the incision should be made in a more or less horizontal or upward movement. The horizontal or upward incision is unacceptable to the Orthodox authorities in Israel who are totally opposed to upright Shechita. Most ultra-orthodox Jews in the U.S.A., however, accept meat from the ASPCA pen where the upward incision is made at an angle of 30° - 45°. A study was undertaken in an endeavour to find a solution to the problems in the form of restraining facilities acceptable to both groups.

OBJECTIVES

Attainment of the following goals would ensure successful completion of the project:

To minimise stress of the animals before, as well as during the restraining period.

To prevent dangerous conditions in order to enable the shochet to perform the throat incision without hindrance.

To provide a restraining system which will be completely acceptable to the Beth Din (the Jewish ecclesiastical court which among others supervises and approves the production of kosher food commodities), Chief Rabbi (the religious head of the Jewish community) of South Africa and the animal welfare organisations.

To provide a restraining system which will conform to the rules and regulations of Shechita, as approved by the Chief Rabbi of Israel, in view of the possible exporting of kosher carcasses from South Africa to Israel.
To drain the blood from the animals after the throat incision has been made, in such a manner as to ensure minimal contamination of the carcass and the equipment.

METHOD

No automated head clamp and centre-track restrainer combination is currently in use anywhere in the world. It was necessary to provide facilities for animals to be restrained in such a manner as to simulate the centre-track restrainer in order to design a head clamp. A restrainer and head clamp was designed to fulfill the above-mentioned objectives. This system for Shechita had to be developed and implemented to comply with the needs and requirements of all interested parties with minimising of stress as an additional benefit.

SHECHITA (PRACTISED BY JEWS)

Shechita is a Hebrew word meaning “the slaying of animals for food” (Bell, 1951). Shechita, the act of killing for food, is a religious rite deriving authority from the Tora (Bible). Biblical reference to Shechita is in Deuteronomy X11, 21: “Thou shalt kill of thy herd and of thy flock, which the Lord hath given thee, as I have commanded thee ...” The specific laws dealing with Shechita are to be found in the Babylonian Talmud (code of Jewish Religious, Civil and Social Law comprising the Mishna and Gemara).

The method of slaughter is by a single rapid incision into the neck of a fully conscious animal. A razor-sharp knife, the length of which must be twice the width of the throat of the animal to be slaughtered, with a perfect edge free from the slightest notch or flaw, must be used. The knife must also be examined for any unevenness immediately before and after each operation.

The incision takes a fraction of a second and cuts through the soft structures anterior to the cervical spine, severing the trachea, the oesophagus, the two vagus nerves, as well as both carotid arteries and jugular veins (Munk, Munk & Levinger, 1976).

The following five rules of Shechita have to be observed during the correct ritual slaughtering (Munk et al., 1976):

1. “Shehiya - There must be no pause. The incision must be continuous until all the vital parts are severed. A pause for an instant, voluntarily renders the killing improper.
2. “Derasa - There must be no pressing upward or downward, nor any hacking. The object is to secure positive and swift action in the incision.
3. “Chalada - There must be no burrowing. The knife must not be introduced under the skin, as in stabbing, or covered by the wool of the sheep or hair of the steer. The incision must be free, open and exposed, so as to drain the brain quickly and thus render the animal unconscious immediately.

4. “Hagrama - The incision must be made in a prescribed region of the neck, namely through the trachea, preferably below the cricoid - the cartilaginous ring immediately below the larynx - but not through the larynx, nor through that part of the neck which is close to the chest, where the muscles are very thick and the trachea is deep-seated. The reason is that the complete ring is hard, sometimes almost completely ossified, and might blunt or nick the instrument and thus cause delay in cutting and inflict pain. Similarly, the muscles near the chest are thick and stout, and to cut through them would be attended with delay.

5. “Ikkur - There must not be a laceration, but an incision, a clean cut, not a tear; hence the knife is examined after the operation, as well as before, to make sure that it is perfectly smooth. If a roughness is found the beast is declared to have been improperly killed, and its flesh is treifa (unkosher). The explanation is evident. It is well-known that a tear is infinitely more painful than an incision. The prescribed incision, must be made by an instrument sufficiently long and broad, exceedingly sharp and perfectly smooth.”

SHECHITA RESTRAINING SYSTEMS

A wide variety of restraining systems are being used throughout the world for Shechita. Animals are being slaughtered in the upright position (30° - 45° upward incision) as well as in the downward position (downward incision).

Weinberg casting pen

The first restraining system which was developed for large cattle was the Weinberg Casting Pen of 1927 (Munk et al., 1976).

After entering the casting pen a sliding door is used to ensure that the animal remains in the pen. The roof and the side walls can be adjusted according to the size of the animal. After entering the pen and with the animal's head protruding through the front opening, the entire pen is rolled over and tilted 180° with the animal lying on its back, its legs pointing upwards, ready for the throat incision. The head of the animal is pulled back with the aid of an instrument so that the skin of the neck is stretched to be taut. This casting pen has a slaughtering capacity of 30 animals per hour.

A major disadvantage of the pen is that the animal suffers gross discomfort due to the mass and size of the rumen which presses upon the diaphragm and thoracic organs (Farm Animal Welfare Council, 1984).
The number of vocalisations of the animals is significantly greater in the Weinberg pen than in the ASPCA pen. The animals also spend more time in the Weinberg pen than in the ASPCA pen. (Dunn, 1990).

**Facomia combined casting pen type F4**

The Facomia Combined Casting Pen Type F4 which is similar to the Weinberg pen is also currently being used by the French Ministry of Agriculture (Facomia, 1981). The major difference between the two pens is that the type F4 has a chin lift which the Weinberg pen does not have. The chin lift ensures that the head is properly restrained which enables the shochet to make a clear incision.

**Knocking pen**

The Knocking Pen is also used for Shechita (Munk et al., 1976). After the animal has entered the pen a sliding gate behind the animal is closed to prevent the animal from leaving the pen. The floor is then dropped to the one side, which causes the animal to slip and fall to the floor with one front and one hind leg protruding through the opening between the bottom of the floor and the wall.

The front leg is then shackled and tied to a pole, while the rear leg is shackled and tied to a hoist.

The animal is then hoisted until the hindquarter is off the floor. The head of the animal is pulled back with the aid of an instrument so that the skin of the neck is rendered taut. After the incision by the shochet the animal is hoisted further and transferred onto the overhead bleeding rail. Up to 80 animals per hour can be slaughtered by this method.

The animal suffers a great deal of stress, visually observed by the researcher. The animal's eyes are filled with fear whilst the legs and head are hurt during the process.

**Yugoslavian knocking pen**

Another restraining system being used is the Yugoslavian Knocking Pen at Marbek Abattoir, Tel Aviv. This knocking pen is similar to the above-mentioned knocking pen. While the animal is still in a standing position all four legs are shackled with a chain which is then connected to the hoist. The animal is then pulled out of the knocking pen and raised upside down. The animal is then lowered onto a cradle fixed to the floor. The head of the animal is then pulled backwards with a pneumatic apparatus. An instrument can also be used to pull the head back. The throat is then cut while the hind legs are still connected to the hoist. After the incision has been made the animal is transferred onto the bleeding rail. Up to 30 cattle per hour can be slaughtered in such a restraining system.

The main disadvantage of this type of Knocking Pen is that the animals suffer a great deal of stress. The animal's eyes are filled with terror whilst its legs are hurt by the chain during the shackling process. The biggest advantage of this system is that the neck of the animal is in a perfect position while the incision is being made to comply with the five rules of Shechita.

**ASPCA pen (Cincinnati pen)**

According to Grandin (1983), a major advance in restrainer design was the ASPCA Pen. Peter Hood of Canada Packers Ltd invented the pen while Cross Brothers Packing in Philadelphia added the belly lift (Grandin, 1983).

The all steel self-contained pen with pneumatic controls for high-volume humane slaughtering of cattle consists of a stall with an opening in the front for the animal's head.

A bumper pushes the animal forward after it has entered the stall. As the animal's head protrudes through the front opening, a restraining gate descends on the animal's neck to lock the head in position while the belly lift moves up to support the animal under its belly.

A chin lift raises the animal's head to expose the throat to the shochet. With the animal in a completely stationary position the trachea, oesophagus, carotid arteries, jugular veins, the pneumogastrics and the main or upper cardiac branches of the sympathetic nerves are severed at an angle of 45° upwards. After the throat has been cut the rear leg is shackled, the side door of the ASPCA pen is opened and the animal is pulled out of the pen and transferred onto the overhead bleeding rail.

Sufficient clearance of the chin lift should be ensured so that the shochet's knife (Chalaf) will not touch the metal frame, while the incision is made. In the case of the knife touching the frame, it will not be perfectly smooth, which will render the meat unkosher.

Up to 75 cattle per hour can be slaughtered in the ASPCA pen.

Problems might arise if an unskilled and less conscientious person operates the ASPCA pen. The rear bumper and the belly lift could hurt the animal if too much air pressure is applied.

Animals spend less time in the ASPCA pen while being slaughtered compared to animals in the Weinberg pen.
Another major innovation was the V-restrainer conveyor patented by Regensburger in 1940 (Grandin, 1987).

Cattle enter the system by walking down a non-slip ramp until the V-shaped conveyor moves the animal forward. The animal is moved to the discharge end of the restrainer until it reaches the head holder. The entire length of the conveyor restrainer is covered with a hold-down rack. The operator can start, stop and reverse the conveyor restrainer. The animal’s head is caught in a clam shell-like cage.

The cage lifts the animal’s head in order to stretch the neck enabling the shochet to perform the incision. Hydraulics and compressed air are employed to operate this system.

After the incision, the head restrainer opens and releases the head. The animal is then ejected from the conveyor restrainer onto a downward-sloping, take-away sterilised conveyor. Water used to rinse the conveyor is collected in a stainless steel tray which is placed under the take-away conveyor. This prevents the water from diluting blood in the blood tank.

The rear leg is attached to a bleeding roller with a chain hook to ensure that the animal is transferred onto the incline conveyor immediately after it has been discharged.

Up to 200 cattle per hour can be slaughtered in this system by means of Shechita.

A reduction in bruises was observed over a period of two years (1987 and 1988) at the Pyramid Abattoir, North of Pretoria, R.S.A. Savings in terms of labour costs are amongst the advantages of this system. The labour cost per cattle unit is reduced by using a faster slaughter speed. When a slaughter speed of 300 cattle per hour is exceeded, the labour complement should be increased. Disadvantages of this system are the difficulty calves experience in entering the V-conveyor (Lambooy, 1986); the difficulty of holding small calves in the V-restrainer (Giger, Prince, Westervelt & Kinsman, 1977) and bloodsplash sometimes caused by the conveyor (Thornton, Blackmore, Jolly, Harris & Marsdea, 1979) and (Lambooy, 1986, as quoted by Grandin, 1987). The clam shell-like cage, if applied incorrectly, can fracture the jaw of the animal.

Centre-track restrainer


Grandin (1989) conducted a project in a commercial calf slaughter plant. The system was constructed and has been successfully completed. Calves entering the restrainer, straddle a stationary bar as they walk down a cleated ramp. Cleats prevent calves from slipping. A hold down rack prevents the calves from jumping up. After walking into the restrainer, the calves quietly settle on the double rail. Adjustable sides can accommodate small and large calves. For Shechita the double-rail conveyor is stopped when the animal reaches the end. Before the incision is performed the one hind leg of the calf is shackled.

A vertical sliding gate with a U-shaped back holder, holds the animal’s back down. The head is then manually held to enable the shochet to perform the incision. After the throat is cut the animal is discharged onto a table conveyor as described in the V-restrainer conveyor. A slaughter speed of 150 calves an hour can be obtained.

A centre-track restrainer for large steers was designed by Grandin Livestock Handling Systems Inc. and constructed by Swilley Equipment Co. in Logan, IA. The project was funded...
by the Humane Family Foundation, formerly known as Humane Information Services of St. Petersburg, FL. (Grandin, 1989). A centre-track restrainer has been installed at the Excel Plant in Schyler, Nebraska, U.S.A.

This system has many advantages over the V-restrainer conveyor. These advantages are:
1. it is less expensive;
2. steers enter more easily;
3. the operator can stand closer to the animal for easier and more accurate stunning;
4. separation of the legs facilitates easier shackling and
5. a wider range of adjustment for different sized animals.

This system is being used for conventional slaughtering. At present Shechita of large animals does not take place in this system. A head holder can be designed and used with this system in order to restrain the animal for Shechita.

STRESS REACTIONS OF CATTLE UNDERGOING RITUAL SLAUGHTERING, USING TWO METHODS OF RESTRAINT

Dunn (1990) studied the behavioural and physiological reactions of cattle undergoing ritual slaughtering in the Weinberg holding pen, in which the animal is inverted and the ASPCA pen, in which the animal is standing. He made a comparison of the reactions of cattle with particular reference to the animal’s behavioural, neuroendocrinial and sympathetic nervous system responses. Blood samples were analysed for cortisol levels and haematocrit. Average times were also recorded of the time the animals spent in the two different restraining systems. An average time of 103.8 seconds was recorded for an animal in the Weinberg pen, from securing the rear gate until its throat was cut. The animal was inverted for 70 % of this time. In contrast the average time for animals in the ASPCA pen was only 11.1 seconds.

Cattle in the Weinberg pen also struggled for a significantly longer period than those in the ASPCA pen.

The number of vocalisations was significantly greater in the Weinberg pen than in the ASPCA pen. A significantly higher proportion occurred in the Weinberg pen when the animals were inverted and most were open mouth vocalisations.

The mean haematocrit values and serum cortisol concentrations of animals slaughtered in the Weinberg pen were significantly greater than that of the cattle slaughtered in the ASPCA pen and conventionally (Dunn, 1990). A well-established part of the stress response is hypothalamo-pituitary-adrenal activation leading to raised cortisol concentrations (Dunn, 1990). The major cause of raised haematocrit values is splenic contraction under the influence of circulating catecholamine and sympathetic nervous system activation. According to Dunn (1990) haematocrits were similar to those found by Mitchell, Hattingh & Ganha (1988).

A study was carried out by Petty, Hattingh & Ganha (1991) to ascertain whether the different methods of slaughter result in different levels of blood variables which were known to change when animals are exposed to stressors. Petty et al. (1991) took blood samples from cattle slaughtered in the conventional way and from cattle undergoing Shechita at the Johannesburg Abattoir. For Shechita the legs of cattle were clamped and the animals then tilted 110 degrees in a North British rotary type pen. The animal’s throat was then cut while still conscious and only then stunned with a captive bolt pistol after a few seconds and hoisted up on the bleeding rail. The method for conventional slaughter was performed in the same pen. The animal was stunned with a captive bolt pistol while standing, slaughtered, released from the tilted pen whereafter it was then hoisted by one hind leg up on the bleeding rail and bled 20 to 60 seconds. Cattle used in their study were steers which had been standing at the abattoir for 60 hours prior to slaughter.

There was no significant difference between cortisol levels of the two groups of cattle at any one abattoir. Cattle most probably reacted in the same way to the handling procedures prior to slaughter at each abattoir. Cortisol levels might not be affected as a result of the rapid slaughter procedure. Catecholamine levels were significantly higher in both groups of cattle undergoing Shechita at the different abattoirs than those of the cattle undergoing conventional slaughter. The absence of stunning before exsanguination and the use of the rotary pen may have been responsible for the high levels.

According to Gracey (1988) the stressful unnatural recumbent position could have caused the raised blood catecholamine levels (quoted by Petty et al., 1991). Maintenance of the brain function for a longer period after Shechita than in the conventional method might be the reason for the differences in the blood catecholamine levels between the groups. A sympathetic discharge and concomitant increase in the blood catecholamine level will be possible as long as the blood supply to the brain is sufficient to allow brain function (Petty et al., 1991).

Petty et al. (1991) also suggested that the greater response to Shechita in cattle is mainly due to the use of the rotary pen and not the perception of hypoxia and or pain which may occur in the absence of stunning before exsanguination.
EXPERIMENT 1: SURVEY TO VISUALLY ASSESS THE DISCOMFORT OF SLAUGHTER CATTLE

Introduction

There are two sections to this study. Firstly the current technique was assessed to identify problem areas and highlight the requirements of such a system and secondly a prototype of a centre-track restrainer was designed and tested. The motivation to manufacture a prototype restrainer and head clamp was based on the fact that no centre-track restrainer exists in the RSA.

Procedure

A panel of four people took part in this experiment. The number 7 casting pen at the Johannesburg Abattoir was used for the visual assessment of the discomfort of the slaughter cattle before and during Shechita and conventional slaughter. Time measures, stunning counts, tippings and escapes of the animals were also monitored.

Different operators, two for conventional and three for Shechita, assisting and performing the slaughtering, were used throughout the experiment.

Categories describing the visual discomfort assessment of slaughter animals

The following categories were used to describe the visual discomfort and/or stress of the animal and its behaviour just prior to stunning.

1. CALM Animal shows little or no hesitation and comes into the pen calmly and quietly. Usually no problem with stunning which can be done quickly and effectively. Reasonably easily clamped.

2. NERVOUS Animal is obviously nervous. Keeps lowering or turning the head and moves backwards and forwards in the pen. Takes longer to stun/clamp. Definite struggling when being clamped by moving backwards and forwards or attempting to pull its feet out of the clamp.

3. WILD Animal excited and attempts to jump out of the pen with definite effort and purpose. Very difficult to clamp or stun.

4. FRANTIC Animal struggles frantically and tries to jump out repeatedly with considerable force and effort. Usually almost impossible to clamp and has to be pre-stunned.

Results and discussions

A comparison between Shechita and conventionally slaughtered animals, to distinguish between the different categories of visual discomfort and/or stress of the animal, is set out in Table 1.

It is clear that animals slaughtered by the conventional method were calmer than animals slaughtered by means of Shechita. Animals undergoing Shechita were more nervous, wild and frantic than animals slaughtered by the conventional method. It can therefore be concluded that animals slaughtered by means of Shechita undergo more stress than animals slaughtered by the conventional method, judged by a visual assessment.

An analysis of deviation (GENSTAT V, 1984) was performed on the assessment of anxiety of animals slaughtered according to Shechita and the conventional method. Employing the Chi-square test for statistically significant differences, it was found that the distribution of animals, according to state of anxiety as judged by three independent observers on approximately 500 animals in each of the two slaughter systems, was significantly different (P<0,005 with a Chi-square value of 12,84 at 3 degrees of freedom) in the two systems. The distribution was found not to be independent on the method of slaughter. The distribution (500 animals each for shechita and conventional slaughtering; 3 observers) was as shown in Table 1.

A comparison of the average time spent in the casting pen, from time of entry to time of stunning or incision, was made between animals slaughtered by the conventional method and Shechita respectively. The average time for the different categories is set out in Table 2.

It is interesting to note that the time spent in the casting pen corresponds with the categories. The wilder the animals became the more time were spent in the casting pen. This is mainly due to the nervous, wild and frantic animals struggling more than the calmer animals.
An analysis of variance (GENSTAT V, 1984) was performed on the observed time spent in the restrainer when animals were slaughtered according to the two methods, Shechita and conventional. It was found that the distributions of time measured in each of the two methods were not similar, hence weighted values had to be calculated on which an analysis of variance could be performed. The overall average time for 1 000 animals was 41.72 seconds. The time for Shechita was 69.17 seconds and for the conventional method 14.28 seconds being statistically significantly different at P<0.001 (Table 3).

During Shechita notes were made of the number of animals which managed to escape from the casting pen, the number of animals which had to be stunned, and the number of times animals were tipped more than once. This information is set out in Table 4.

With 3.8 % of the animals escaping from the casting pen, it is clear that the operators and shochtim are in danger while performing Shechita. Most of the animals that managed to escape were large or struggled frantically. In the case of a drop in compressed air pressure, the feet clamps could not hold the animal. Animals with wet feet can also easily slip out of the clamps.

Animals which had to be stunned were 6 %. The stunning of the animals was necessary because the operator was not always able to clamp the legs of the animal, as the animals were struggling in the casting pen or attempting to jump out of the pen.

Some of the animals had to be tipped a few times before they were ready for the incision. As can be seen, 11 % had to be tipped twice, 3.4 % three times and 0.6 % four times. The tipping of these animals was necessary because the feet were not clamped properly or the animals managed to pull their feet from the clamps.

In Table 5 the number of animals stunned and repeat stunning are set out during conventional slaughtering.

The reasons for the animals being stunned more than once are as follows: the incompetence of the operator; animals struggling frantically and trying to jump out of the casting pen; animals that keep lowering or turning their heads or that move backwards and forwards.

It is interesting to note that there was a marked difference between the two operators which were used for stunning the animals during conventional slaughtering. Table 6 shows the difference:

The reason for the difference in time between the operators is the method being used. Operator no.1 allowed the animal to enter the casting pen before the previous animal was shackled and still lying on the floor. He then waited for the previous animal to be hoisted and transferred onto the bleeding rail before attempting to stun the animal already in the casting pen. Because of the delay the animal tends to become nervous resulting in the animal turning its head away from the captive bolt pistol. Operator no. 2 only allowed the animal to enter the casting pen after the previous animal was shackled and still lying on the floor. He then waited for the previous animal to be hoisted and transferred onto the bleeding rail before attempting to stun the animal already in the casting pen. Because of the delay the animal tends to become nervous resulting in the animal turning its head away from the captive bolt pistol.

<table>
<thead>
<tr>
<th>Category</th>
<th>Conventional</th>
<th>Shechita</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Escaped</td>
<td>19</td>
<td>33</td>
<td>511</td>
</tr>
<tr>
<td>Stunned</td>
<td>30</td>
<td>1 min 2 sec</td>
<td>868</td>
</tr>
<tr>
<td>Tipped x 2</td>
<td>55</td>
<td>1 min 21 sec</td>
<td>208</td>
</tr>
<tr>
<td>Tipped x 3</td>
<td>17</td>
<td>1 min 39 sec</td>
<td>41</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Escaped</td>
<td>19</td>
<td>3.8%</td>
</tr>
<tr>
<td>Stunned</td>
<td>30</td>
<td>6.0%</td>
</tr>
<tr>
<td>Tipped x 2</td>
<td>55</td>
<td>11.0%</td>
</tr>
<tr>
<td>Tipped x 3</td>
<td>17</td>
<td>3.4%</td>
</tr>
<tr>
<td>Tipped x 4</td>
<td>3</td>
<td>0.6%</td>
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<table>
<thead>
<tr>
<th>Number of times</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>455</td>
<td>91.0%</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>6.4%</td>
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<td>3</td>
<td>11</td>
<td>2.2%</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0.2%</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>0.2%</td>
</tr>
<tr>
<td>Total</td>
<td>500</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
casting pen once the previous animal was already shackled and hoisted.

Three different operators were used for Shechita and the results are set out in Table 7:

The reasons for the difference between the operators are: incompetence; different methods used and the physical capabilities of the operators. The operator with the shortest average time to point of cutting applied the clamps immediately after the animal entered the casting pen, but before closing the horizontal sliding gate. By this method the animal struggled less and time was saved. With the method of first closing the sliding gate before clamping the animal's feet, the animal jumps and moves backwards and forwards, thus causing a delay before the feet are clamped. The operator with the shortest average time was also more competent in holding the head. He was also physically stronger than the operator with the longest average time.

EXPERIMENT 2: INSTALLATION OF A PROTOTYPE RESTRAINER AND DESIGN OF THE HEAD CLAMP

GENERAL INTRODUCTION

In order to design the head clamp for Shechita it was necessary to provide facilities for the animals to be restrained in such a manner as to simulate the centre-track restrainer.

The motivation to manufacture a prototype restrainer and head clamp was based on the fact that no centre-track restrainer exists in the RSA. No automated head clamp and centre-track restrainer combination is in use anywhere in the world.

A head clamp can only be used if the animal is properly restrained.

At the front end of the restrainer a vertical sliding gate with head support and chin lift similar to the one used with the ASPCA pen was installed to restrain the animal's head. The chin lift could be manually operated by means of a large handle.

The vertical sliding gate was lowered into the correct position. The chin lift was put into use to prepare the animal for the incision. A shochet performed the incision but unfortunately damaged his knife when the cutting surface touched the chin lift.

Since the animal's front legs were free and in a different position to which the animal finds itself when slaughtered in the ASPCA pen, it was possible to bend its head back much further than is the case in the ASPCA pen. This position causes a problem in that the neck is not stretched properly, which makes it difficult to perform the incision. This necessitated changing the design of the head clamp.

It was decided to change the design and do away with the vertical sliding gate and chin lift. The design of a new head clamp was discussed with Maciver (1990) who suggested a head-tilting restrainer. Technical personnel of the Johannesburg Abattoir manufactured the head-tilting restrainer and attached it to the front of the prototype restrainer.

Further attempts of shechita were carried out when the new head-tilting restrainer was in place.

The various modifications and experiments undertaken on the prototype and head restrainer resulted in a solution whereby the animal's head could be properly restrained while performing Shechita. It was, however, not all that easy for animals to enter the prototype restrainer. Calm animals entered without difficulty but the Brahman type was too wild and not used for this study. It is essential to note that the measurements used can not be taken as final. Alterations may be necessary after the installation of the centre-track and head restrainer combination to perfect the system.

Discussion

Advantages in the case of implementing the recommended restraining system

The following advantages for the proposed restraining system are as follows:

1. The stress to which animals are subjected will be reduced to a great extent because the animals will be restrained with all feet off the floor and unable to jump. The animal is

<table>
<thead>
<tr>
<th>Operator</th>
<th>Average time of animals in casting pen from entry to point of stunning</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14 seconds</td>
<td>156</td>
</tr>
<tr>
<td>2</td>
<td>7 seconds</td>
<td>344</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operator</th>
<th>Average time of animals in casting pen from entry to point of incision</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62 seconds</td>
<td>156</td>
</tr>
<tr>
<td>2</td>
<td>59 seconds</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>52 seconds</td>
<td>284</td>
</tr>
</tbody>
</table>
suspended in the restraining conveyor on the centre-track. Head movement is restricted by means of the head-tilting restrainer.

2. Animals will be slaughtered as humanely as possible because the animal is effectively restrained with the minimum stress. The loss of consciousness will be almost immediate because a proper incision can be made ensuring that all the veins and arteries are severed with a single uninterrupted sweep.

3. Dangerous conditions will be eliminated in that the shochtim can perform the throat incision without hindrance and in safety, because the animal will be properly restrained without any chance of escaping from the system.

4. The new recommended system will be acceptable to the animal welfare organisations, Beth Din and the Chief Rabbi of South Africa.

5. The post-stunning of animals after Shechita will not be necessary to the great satisfaction of the Jews, especially the ultra Orthodox Jews. The chance of an improper incision is virtually nil.

6. Labour can be reduced from the present ten operators per two slaughter lines to only three which will result in labour cost savings.

7. With a labour complement of three, a line speed of 150 carcasses per hour can be achieved which is two and a half times more than the present throughput for Shechita. This is an increase of 18 carcasses per hour on the present speed of 132 carcasses per hour for the fast lines at Johannesburg Abattoir for conventional slaughter. The Beth Din only accepts a throughput of 60 - 65 head of cattle per hour.

8. The Jewish community can thus be assured that all their needs for kosher meat will be met. It must be stressed that, should the need arise, the shochtim will have to be increased for the post mortem Jewish Religious Inspection (Bedika) in the case of a faster line speed.

9. The physical strain experienced at present by the operators while performing Shechita will also be eliminated to a great extent because the proposed restraining system is designed with the emphasis on ergonomics.

10. Maintenance costs for the centre-track restrainer will be less than for the present system.

11. The centre-track restrainer can manage a throughput of more than 300 head of cattle per hour for conventional slaughtering. Should a cattle slaughter line with a line speed of 300 cattle per hour be implemented in future at the Johannesburg Abattoir, one centre-track restrainer could be used with a considerable labour saving.

CONCLUSIONS AND RECOMMENDATIONS FOR A CENTRE-TRACK RESTRAINING SYSTEM WITH HEAD CLAMP

Literature indicates that post-stunning of animals after Shechita should not be necessary. This highly satisfies the Orthodox Jews, however, the SPCA’S National Council of Southern Africa does not agree that post-stunning of animals after Shechita is not necessary (Meredith, 1991).

A restraining system has to be provided which would be acceptable to the Beth Din, Chief Rabbi of South Africa and the animal welfare organisations.

It is recommended that a centre-track restrainer with head clamp be installed at the Johannesburg Abattoir. This abattoir presently accommodates more than 70 % of all animals destined for Shechita in the R.S.A. The centre-track restrainer can be used for both Shechita and conventional slaughtering. A head clamp can be used to restrain the animal’s head for Shechita.

The head-tilting restrainer will be mounted at the end of the conveyor. The head-tilting restrainer will comprise the following: air cylinder; static slide frame; back press roller; cam roller; sliding frame; cam; head tilt and stops.

In order to restrain the animal’s head for Shechita, the frame is lowered to the receiving position while the back press roller is up and the head tilt is on the bottom stops. The animal is then delivered by the conveyor and stopped when the animal’s head is in position. The back roller is then pushed down by the air cylinder while the cam is pushed down by the cam roller starting to tilt and lift the head. Further downward movement continues to move the head upwards in order for the head roller to contact the neck. After a full down travel a full head tilt of 60° will be reached. The back of the neck and jaw will be restrained, ready for the incision.

After the completion of the incision the air cylinder will be reversed raising the back roller and allowing the head tilt to lower so that the head can be released. As the back roller continues to rise the whole frame, complete with the head tilt, is lifted clear allowing the animal to be moved forward.

After the animal is ejected, the back roller and frame are lowered to the starting position allowing the next animal to be positioned by the centre-track conveyor.

 Alterations may be necessary after the installation of the centre-track and head restrainer combination to perfect the system. It must also be borne in mind that a shochet will most probably find it strange and awkward to make an incision at an
upward angle when a new system is introduced. It must be stressed that the Jewish community will only accept this system if all difficulties can be overcome (Harris, 1991).

Stress caused to animals entering the prototype restrainer will be eliminated by the use of a centre-track restrainer. Results determining stress by means of hormone levels of animals during Shechita in the prototype restrainer will not present a true reflection thereof. It is suggested that further research be done on stress of animals during Shechita after the implementation of the proposed restraining system in South Africa.

With the proposed restraining system stress can be minimised to a great extent due to the upright position. With the animal's legs off the floor, movement is restricted with the advantage that the head can be properly restrained. Because the animal's head is properly restrained the major blood vessels can be perfectly severed which will render the animal unconscious within a few seconds and therefore post-stunning will serve no purpose. It has not yet scientifically been proved beyond doubt that pre- and post-stunning eliminates stress and pain and this matter should be further investigated.

Dangerous conditions during Shechita can be minimised. The chance of the animal escaping is eliminated because the animal's legs are shackled before the incision is made. The animal is also unable to escape from the system because all four legs are off the floor. The animal is ejected onto the landing table after the shochet has completed the incision.

Another objective was to persuade the Chief Rabbinate of Israel to accept upright Shechita with the expectation of exporting kosher beef from South Africa to Israel, in spite of the fact that the Orthodox authorities in Israel are totally opposed to upright Shechita. This goal could not be achieved at this point in time. Further discussions in this regard should be encouraged with the aim of having the proposed restraining system approved by the Chief Rabbinate of Israel in order to export kosher meat to Israel.

The last goal was to minimise pollution by the blood to the carcass and equipment. During Shechita the blood will be directed to a drain by means of a stainless steel chute which will be swivelled in under the animal by the same mechanism which lowers the head clamp into position. Most of the blood will be collected in the chute which will be swivelled away before the animal is ejected onto the landing table. The landing table will be washed on the return circuit to minimise contamination of the hide.

REFERENCES


A pilot study on the effects of spray-chilling on carcass mass loss and bacteriology

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INTRODUCTION

An integral part of traditional meat processing includes air chilling of pre-rigor carcasses at 1 °C for 18 hours or longer. Of the disadvantages cited for this classical chilling regime, evaporative losses are economically the most significant (Jones, Murray & Robertson, 1988). The restriction of microbial growth is one of the main reasons for rapid chilling of carcasses. The meat industry therefore has to comply with prescribed chilling conditions in terms of air velocity, temperature and relative humidity. Under these fixed chilling conditions Kerens & Visser (1978) reported carcass mass losses (moisture) ranging from 1,3 % for large (390 kg), fat carcasses to 3,2 % for small (100 kg), lean carcasses in South Africa. Similar figures were reported for North America (0,75 % to 2,0 %) and the UK (1,2 % to 1,7 %) (Jones & Robertson, 1988). Since carcasses are traditionally smaller and leaner (average carcass mass 210 kg) in South Africa than in the UK, for example (average carcass mass 280 kg), one would expect carcass mass losses in the upper range set by Kerens & Visser (1978). A loss of 2 % is equivalent to roughly 4 kg/carcass. This translates to a loss of 8 900 tons in carcass mass for 1991 (RSA: Livestock and Meat Statistics). The monetary value of this loss is in the order of R 44,5 million, or as high as R 23 per 210 kg carcass (R5,00/ kg, mean for all ages and fat codes; RSA: Livestock and Meat Statistics).

Spray-chilling (the application of water to beef carcasses in timed cycles during chilling), was adopted by most major slaughter plants in North America in 1987. Carcass mass loss caused mainly by relatively high air speeds in the chiller, can be reduced by spray-chilling (Jones & Robertson, 1988). According to Kerens & Visser (1978) variation in carcass mass and fat cover have the greatest effect on mass loss, while the effects of varying the air velocity, air temperature and relative humidity are found to be small. Therefore, South African abattoirs in particular should benefit from spray-chilling, as the typical South African carcass is small with little fat cover. It is for this reason that the South African Abattoir Corporation requested the Meat Industry Centre (MIC) of the Irene Animal Production Institute (IAPI) to investigate spray-chilling on a small scale.

PROCEDURES

A flow diagram of the trial procedure is presented in Figure 1. Thirty cattle were slaughtered by standard procedure at the IAPI, yielding carcasses of medium fat cover (Klingbiel, 1984) and average carcass mass of 210 ± 10 kg. The carcasses were split into sides and allocated to different chilling procedures, as described in Table 1. Each sub-trial (A, B, C, D, E, F) was executed separately. Following slaughtering, the carcasses were split and their respective side masses determined (M1). One side of each carcass was submitted to spray-chilling and the other to conventional chilling. Chilling conditions for both chilling methods were identical in terms of air velocity (0,75 m/s) and air temperature (3 °C ± 3 °C). The water flow at the inlet was set at 8 litres per minute (adopted from Jones & Robertson, 1988). The nozzles (12) (placed halfway between two consecutive sides) consequently each delivered 0,67 litres per minute. The spraying schedule (Table 1) was controlled by an automatic timer.

Deep temperature (on the surface of the femur shaft) and the muscle temperature of the M. longissimus thoracis, as well as room temperature were continuously monitored and recorded (Fig 2). Differences in carcass mass loss between the two chilling methods were determined. The difference between M1 and M2 indicated the mass loss of either the conventional or spray-chilled sides over the first 18 hours of chilling. At t=1 the carcass sides were removed from the chillers and kept for 6 hours at 10 °C ± 3 °C, representing the period between weigh-
ing and dispatch at a commercial abattoir. The difference between M2 and M3 represents the mass loss over this period. At t=2 the carcasses were chilled again for 18 hours, i.e. over-night at 3 °C ± 3 °C, and processed further. The effect of spray-chilling on mass loss of vacuum-packaged cuts, retail cuts (steaks) and during the cooking process was also determined.

The effect of chilling method on the microbiological status of the carcass was determined by comparing total aerobic counts as well as Enterobacteriaceae counts, both before and after chilling. Sample ar-chilled carcass sides lost significantly less moisture (P<0.05) than did conventionally chilled carcasses at any stage (T1, T2, T3) after commencement of initial chilling (T0), regardless of spray-chill duration (10, 14 & 17 h) or application period (60 & 120 s).

The average moisture saving achieved by spray-chilling carcass sides was 1.10% (T1=1.10%) for the present trial, which is very similar to the 1.14% reported by Allen, Hunt, Luchiari, Danler & Goll (1987). A higher average figure of 1.43%, reported by Jones & Robertson (1988), was achieved by spray-chilling heavier carcasses (317 kg vs. 200 kg) over a shorter period of time (8 hours vs. 10 hours minimum). Nevertheless, the moisture saving achieved in all the treatments of the present trial was significant. Moreover, none of the conserved moisture was lost during aging of vacuum-packed primerib cuts, retail display of rib steaks or cooking the M.longissimus steaks (Table 3). Jones & Robertson (1988) reported similar findings for vacuum-packaging and aging of cuts.

In contrast with these findings, Allen et al. (1987) reported a significantly (P<0.05) higher drip loss for topside cuts of spray-chilled carcasses, vacuum-packed and aged for 15 days, than for similar cuts of conventionally chilled sides (1.98% vs 1.72%). Both Allen et al. (1987) and Jones & Robertson (1988) agree that retail cuts displayed for 4 or 5 days under simulated retail conditions tended to have similar moisture losses independent of treatment. Steaks cut from the M. longissimus thoracis and M. semimembranosus and wrapped with PVC film lost between 6.3 % and 7.6 % moisture over 5 days at 3 °C, which is slightly more than the losses recorded for prime and wingrib steaks in this trial (2.56 and 2.15 % respectively).

### Table 1: Trial outlay

<table>
<thead>
<tr>
<th>Chilling method</th>
<th>Conventional chilling</th>
<th>Spray-chilling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-trial number</td>
<td>Sides per treatment</td>
<td>Sides per treatment</td>
</tr>
<tr>
<td>A</td>
<td>5*</td>
<td>5*</td>
</tr>
<tr>
<td>B</td>
<td>5 5</td>
<td>10h</td>
</tr>
<tr>
<td>C</td>
<td>5 14h</td>
<td>60 sec</td>
</tr>
<tr>
<td>D</td>
<td>5 14h</td>
<td>120 sec</td>
</tr>
<tr>
<td>E</td>
<td>5 17h</td>
<td>60 sec</td>
</tr>
<tr>
<td>F</td>
<td>5 17h</td>
<td>120 sec</td>
</tr>
</tbody>
</table>

* Sides of the same carcass are subjected to different chilling methods.
** Period of intermittent spraying (60 or 120 seconds, 4 times per hour)

Data in Tables 4 & 5 are presented as differences in mass loss (percentage units) between conventional and spray-chilled subjects, as these mean values give a clearer indication of the saving achieved through spray-chilling than do the individual means for mass loss of sides between the two treatments.

Regarding the main effects, intermittent spray-chilling for 10 hours conserved significantly (P<0.05) less moisture than spray-chilling for 14 and 17 hours. A spraying period of 120 seconds every 15 minutes also saved significantly (P<0.05) more moisture than the 60 second option. There were no sig-

### Table 2: Mean carcass mass loss (%) for conventionally and spray-chilled carcass sides at various periods post slaughter

<table>
<thead>
<tr>
<th>Treatment</th>
<th>10 h,60 sec</th>
<th>10 h,120 sec</th>
<th>14 h,60 sec</th>
<th>14 h,120 sec</th>
<th>17 h,60 sec</th>
<th>17 h,120 sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time*</td>
<td>C S</td>
<td>S C</td>
<td>S C</td>
<td>C S</td>
<td>C S</td>
<td>C S</td>
</tr>
<tr>
<td>T0-T1</td>
<td>1.63*</td>
<td>0.88*</td>
<td>1.73</td>
<td>0.66**</td>
<td>1.43*</td>
<td>0.45**</td>
</tr>
<tr>
<td>T1-T2</td>
<td>1.92*</td>
<td>1.25*</td>
<td>1.98</td>
<td>0.99**</td>
<td>1.69*</td>
<td>0.73*</td>
</tr>
<tr>
<td>T2-T3</td>
<td>2.07**</td>
<td>1.56*</td>
<td>2.30</td>
<td>1.53*</td>
<td>1.95*</td>
<td>1.25*</td>
</tr>
</tbody>
</table>

\* Means with different superscripts in the same row differ significantly (P<0.05)

* Treatment: 10 h, 60 sec; 10 h, 120 sec; 14 h, 60 sec; 14 h, 120 sec; 17 h, 60 sec; 17 h, 120 sec.

For all carcass sides conventional and spray-chilled sides were submitted to intermittent spraying (60 or 120 seconds 4 times per hour) for either 10, 14 or 17 hours within the 18 hours.

C: Carcass mass loss (%). T0-T3: Period of overnight chilling (3 °C ± 3 °C, 18h) in which conventional or spray-chilling took place.

** T0-T1,T2-T3 plus 6 hours hanging at dispatch (10 °C)
Fig. 1: Flow diagram of trial procedure (Sub-trial a: Table 1)

5 Cattle

Slaughter

5 Sides

Enter chillers (chiller temperature = 3 °C ± 3 °C)
Thermocouples placed in position

Spray-chilling
Spraying 60 seconds
every 15 minutes for 10 h

Conventional chilling
No spraying

Remove from chillers and keep at 10 °C ± 3 °C

Keep at 3 °C ± 3 °C overnight

Carcass processing

Remove prime- and wingrib cuts

Vacuum pack prime rib
Age for 7 days at 0 - 7 °C

Process wingrib immediately

Cut 4 steaks from prime- and wingrib cuts and weigh

Two steaks placed singly on styrofoam trays, overwrapped with PVC and displayed in a cabinet for 4 days at 0 °C. Mass loss determined

Two steaks deboned. Meat and subcutaneous fat ground and moisture content determined

Remove M. longissimus thoracis, weigh.
Place in plastic bag in water for 60 min. at 70 °C. Determine mass loss

M7 - M6 = Mass loss during display at retailer
M9 - M8 = Mass loss during the cooking process
Table 3: Mean mass loss (%) of wholesale and retail cuts of conventionally and spray-chilled carcass sides at various periods post slaughter

<table>
<thead>
<tr>
<th>Cut</th>
<th>Treatment</th>
<th>10 h,60 sec.</th>
<th>10 h,120 sec.</th>
<th>14 h,60 sec.</th>
<th>14 h,120 sec.</th>
<th>17 h,60 sec.</th>
<th>17 h, 120 sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>S</td>
<td>C</td>
<td>S</td>
<td>C</td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>PR-vacuum</td>
<td>0.56a</td>
<td>0.42b</td>
<td>0.69c</td>
<td>0.74d</td>
<td>0.72e</td>
<td>0.67f</td>
<td>0.66g</td>
</tr>
<tr>
<td></td>
<td>0.60h</td>
<td>0.44i</td>
<td>0.72j</td>
<td>0.99k</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR-display</td>
<td>2.20a</td>
<td>2.07b</td>
<td>2.68c</td>
<td>2.81d</td>
<td>2.43e</td>
<td>2.47f</td>
<td>2.54g</td>
</tr>
<tr>
<td></td>
<td>3.93m</td>
<td>3.74n</td>
<td>3.87o</td>
<td>3.69p</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR-cooked</td>
<td>29.9a</td>
<td>29.2b</td>
<td>29.8c</td>
<td>29.3d</td>
<td>28.3e</td>
<td>28.7f</td>
<td>38.7g</td>
</tr>
<tr>
<td></td>
<td>30.7m</td>
<td>30.1n</td>
<td>31.0o</td>
<td>31.9p</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WR-display</td>
<td>1.79a</td>
<td>1.82b</td>
<td>1.82c</td>
<td>2.0d</td>
<td>1.9e</td>
<td>2.5f</td>
<td>1.7g</td>
</tr>
<tr>
<td></td>
<td>32.9m</td>
<td>31.9n</td>
<td>31.9o</td>
<td>31.9p</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WR-cooked</td>
<td>30.7a</td>
<td>30.1b</td>
<td>31.0c</td>
<td>31.9d</td>
<td>27.7e</td>
<td>29.4f</td>
<td>32.9g</td>
</tr>
</tbody>
</table>

***M*** **Means with different superscripts in the same row differ significantly (P<0.05)**

Cut: PR-Vacuum Mass loss (%) of prime rib vacuum-packaged and aged for 7 days
PR/WR-Display Mass loss (%) of prime rib or wing rib steaks displayed in retail cabinet for 3 days
PR/WR-Cooked Mass loss (%) of M. longissimus dorsi of prime or wing rib steaks when cooked in plastic bags at 70 °C for 60 minutes

The differences between this treatment and the 10h120s and 17h60s schedules. Although not significantly other factors besides moisture preservation (such as running costs and carcass appearance), the 14h120s schedule treatment proves to be a better option, based on the following information:

1. In the present trial of only 5 carcass sides, the 14h120s option used 192 litres less water than did the 17h120s option in a commercial abattoir the savings will obviously be far greater.
2. The 14h120s option did not differ significantly from the 17h120s one at any stage (T<sub>1</sub> to T<sub>5</sub>) of chilling.
3. Due to insufficient drying time between the end of spraying (17 hours) to the end of chilling, the spray-chilled carcasses appeared pale and wet, characteristic of “wet carcass syndrome”. This was observed to a far lesser extent with the 14h120s schedule at T<sub>1</sub>. By T<sub>5</sub> these carcasses could not be distinguished from conventionally chilled carcasses. In a commercial abattoir where carcasses are handled intensively after chilling, excessive

Table 4: Means for differences in carcass mass loss (percentage units) between conventionally and spray-chilled carcasses

<table>
<thead>
<tr>
<th>Parameter#</th>
<th>Spray-chill duration</th>
<th>Application period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 h</td>
<td>14 h</td>
</tr>
<tr>
<td>T&lt;sub&gt;1&lt;/sub&gt;-T&lt;sub&gt;1&lt;/sub&gt; (%)</td>
<td>0.90&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.12&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;1&lt;/sub&gt;-T&lt;sub&gt;2&lt;/sub&gt; (%)</td>
<td>0.70&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.04&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;2&lt;/sub&gt;-T&lt;sub&gt;3&lt;/sub&gt; (%)</td>
<td>0.61&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.88&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

***M*** **Means with different superscripts in the same row and within the same treatment factor (spray-chill duration and application period), differ significantly (P<0.05)**

# T<sub>1</sub>-T<sub>1</sub>/Period of normal overnight chilling (3 °C ± 3 °C, 18h) in which conventional or spray-chilling took place
T<sub>1</sub>-T<sub>1</sub>/T<sub>5</sub>-T<sub>5</sub> plus 6 hours hanging at dispatch (10 °C)
T<sub>5</sub>-T<sub>5</sub> plus 18 hours conventional chilling at wholesaler or retailer (3 °C ± 3 °C)
Regarding the effect of application period on carcass bacteriology, the 60s spray-chill applications resulted in significantly lower total and Enterobacteriaceae counts after 18 h chilling than did the 120s applications.

Although it seems that the spray-chilling treatments resulted in very similar final microbiological counts, it is imperative to note that if proper hygiene management is lacking, either during slaughter or further processing, the microbial quality of the moist beef carcass will definitely be adversely affected.

The recommendations with regard to the microbial analysis are as follows:

1. The 17h120s spray-chill treatment is microbiologically more risky.
2. Although all the final (18h) total counts were acceptable, total counts in the 10, 14 or 17h120s applications tended to increase, compared to those of the 60s applications, following 18h of chilling.
3. Regarding microbiological quality, either 10, 14 or 17 hours spray-chilling for 60s is acceptable, the choice depending on the desired respective moisture conservation.
4. Effective hygiene control during and after slaughter, processing and distribution is imperative.

**Chilling rate**

There were no differences in chilling rates, as reflected by the M.longissimus and the deep temperatures (muscle against the shaft of the femur). Jones & Robertson (1988) reported that the temperatures of both the M. longissimus thoracis and the M. semitendinosus of spray-chilled carcasses were significantly (P<0.05) lower than those of conventionally chilled carcasses, following 8 or 24 hours of chilling. It must be kept in mind that the two chiller rooms in the present trial were not loaded to full capacity and could, therefore, handle the heat load very easily. In conventional abattoirs, with large chillers loaded to capacity, spray-chilling may improve the chilling rate through evaporation, which is a more effective way of dispensing of heat energy than is the circulation of chilled air.

**REFERENCES**

Table 6: Microbiological counts obtained from conventionally and spray-chilled carcass sides before (0 h) and after (18 h) chilling

<table>
<thead>
<tr>
<th>Chilling method</th>
<th>Spray period</th>
<th>Before or after chilling</th>
<th>Total count (log/cm²)</th>
<th>Std. error</th>
<th>Enterobacteriaceae (log/cm²)</th>
<th>Std. error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray- chilled</td>
<td>10H60s</td>
<td>0h</td>
<td>2.83</td>
<td>0.54</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18h</td>
<td>0.69</td>
<td>0.33</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0h</td>
<td>1.60</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>18h</td>
<td>1.17</td>
<td>0.51</td>
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<tr>
<td>Control</td>
<td>14H60s</td>
<td>0h</td>
<td>3.42</td>
<td>0.74</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18h</td>
<td>2.71</td>
<td>0.63</td>
<td>0.93</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0h</td>
<td>3.18</td>
<td>0.61</td>
<td>0.67</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18h</td>
<td>2.44</td>
<td>0.62</td>
<td>0.91</td>
<td>0.37</td>
</tr>
<tr>
<td>Spray- chilled</td>
<td>17H60s</td>
<td>0h</td>
<td>1.91</td>
<td>0.67</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18h</td>
<td>0.67</td>
<td>0.37</td>
<td>0.24</td>
<td>0.24</td>
</tr>
<tr>
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Meat tenderness: a review

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INTRODUCTION

Eatability is a term referring to the physical and aesthetic sensations associated with meat in the course of mastication. The characteristics of meat which influence eatability are tenderness, juiciness, aroma and flavour (Preston & Willis, 1970).

Tenderness, identified by consumers worldwide as the most important eatability characteristic of meat (Brady, 1957; Deatherage, 1963; Naudé, 1970; Khan, 1977; Locker, 1982; Harris & Shorthose, 1988; Morgan, Savell, Hale, Miller, Griffin, Cross & Shackelford, 1991; Meat Trades Journal, 1991), is defined as the ease of mastication (Deatherage, 1963). As such, it is primarily a subjective trait or human perception. The overall tenderness of meat to the palate involves three aspects:

1. the initial ease of penetration of meat by the teeth,
2. the ease with which the meat breaks into fragments and
3. the amount of residue remaining after mastication (Devine & Chrystall, 1992).

The word “tenderness”, however, does not completely describe this quality attribute. From the palate’s point of view, tenderness and texture are inextricably linked. Indeed, tenderness (mechanical shear) and visual texture rating are related by a correlation coefficient of -0,54 (Kropf & Graf, 1959). The tenderness/texture quality is, therefore, a very individual characteristic which is governed, in turn, by a complex relationship between the various components of muscle structure (Devine & Chrystall, 1992).

Although muscle structure is complex, it can be regarded as a two-component system of muscle fibre (myofibrillar) and connective tissue proteins (mostly collagen). Muscle contains about 75 % water and 19-20 % protein, of which ≤5 % is collagen (Shorthose & Harris, 1992).

The muscle fibres (myofibrils), responsible for muscle contraction, are closely associated with a three dimensional supporting network of connective tissue. The latter encompasses the muscle as a whole (epimysium: Fig. 1b), complete muscle fibre bundles (perimysium: Fig. 1b) and even single muscle cells (endomysium: Fig. 1c). This combined network performs the joint functions of holding the muscle fibres together, attaching the muscle to the skeletal framework and allowing coherent movement.

Broadly speaking, tenderness is more closely allied to the properties of the myofibrillar components of muscle structure, while the properties of the connective tissue elements contribute largely to meat texture, as well as modifying meat tenderness (Devine & Chrystall, 1992).

Thus, the tenderness-texture relationship basically reflects the summation of properties of the various protein structures of skeletal muscle. These properties are ultimately determined by the action of many physiological and physical factors, both singly and interactively, on muscle and muscle proteins. Many of the effects are mediated through the functions that these proteins perform in muscle.

The following discussion of various aspects of meat tenderness will concentrate on beef and mutton/lamb. These red meats are eaten mostly in the unprocessed form, whereas 75 % of pork is eaten as further processed products. As further processing radically alters many tenderness characteristics of meat discussed below, pork will be excluded for the purpose of this paper.

CONNECTIVE TISSUE ASPECTS OF MEAT TENDERNESS

Animal age

As an animal ages, increasing in both size and weight, structural and functional demands are placed on its connective tissue. It is via these age-related developmental changes in
muscle connective tissue characteristics (particularly collagen) that animal age exerts its effect on meat tenderness.

Collagen ages by increasing the number of thermo-stable cross-links between molecules (polymerization), resulting in a radical modification of its physical and physiological properties (Boccard, 1973). As the collagen molecules possess an extremely long biological half life compared with most other proteins, changes in the number and type of cross-links tend to be retained, causing the properties of collagen to change with animal age (Devine & Chrystall, 1992). As polymerization proceeds, therefore, collagen becomes progressively less able to swell when heated in water, and its solubility and ability to gelatinize decrease (Boccard, 1973).

Results from a growth experiment (Bruwer, Grobler, Smit & Naudé, 1987) indicate that after only 4 months of age there is a marked decline in muscle collagen solubility in lambs. Fur-
thermore, older animals do not have greater amounts of connective tissue per muscle unit compared to younger animals. In fact, Heinze, Smit, Naudé & Boccard (1986b) found that, for breeds of sheep and goat studied, there was generally a decrease in collagen content with age.

Muscle differences

Muscles of the carcass differ in their content and concentration of connective tissue (Heinze et al., 1986b), depending mainly on their anatomical location and hence their function. The increasing cross-linking (decreasing solubility) with advancing age influences the tenderness of meat (Price & Schweigert, 1971, as quoted by Bruwer et al., 1987), to a degree dependent on the collagen content of such meat.

In muscles containing little connective tissue (M. longissimus thoracis (LT) & M. longissimus lumborum (LL)), the major contributor to their toughness is likely to be the myofibrillar proteins (Shorthose & Harris, 1990). The effects of slaughter procedure and post mortem factors are therefore more pronounced than is the effect of age on the tenderness of such muscles.

Differences due to sex condition

General agreement exists that bulls tend to have less tender meat than oxen of a similar age (Hedrick Thompson & Krause, 1969; Forest, 1975; Crouse, Ferrell & Cundiff, 1985). The earlier toughening in bulls is related to an earlier increase in cross-linking (Cross, Schanbacher & Crouse, 1984).

Species differences

Schönfeldt (1989) has found the collagen content of the Mm. longissimus thoracis et lumborum (LTel) to be significantly higher (P<0.01) in the Boer goat than in the sheep, while the collagen solubility of the LTEL in the latter species was significantly higher (P<0.01) than that of the corresponding cuts in the Boer goat.

Post mortem aging/conditioning of meat

Aging post-rigor muscle has been shown to enhance tenderness by reducing myofibrillar strength (Locker & Wild, 1982; Locker, Wild & Daines, 1983) and is generally considered to have little effect on connective tissue. Recent work (Mills, Smith & Judge, 1989) has found, however, that collagen solubility increased significantly (P<0.01) during the first 6 h after slaughter, then remained unchanged (P<0.05) through 24 h (Fig. 2). The authors offer this as an explanation for the tenderness improvement found with intermediate rates of chilling and glycolysis in a previous study (Marsh, Lochner, Takahashi & Kragnesset, 1981), attributed at that stage to an 'as-yet unidentified mechanism' rather than via the prevention of cold-shortening.

Plane and quality of nutrition

It is suggested that growth rate of cattle affects meat palatability, particularly tenderness, and that growth rate may be a more important determinant of tenderness than the length of time that cattle are fed a high energy diet (Aberle, Reeves, Judge, Hunsley & Perry, 1981). These workers link a high rate of protein synthesis in rapidly growing cattle to the production of meat with a high proportion of newly synthesised, heat-labile collagen. This is due, supposedly, to a decreased rate of cross-linking. Results of Hall & Hunt (1982) support this supposition in that they found the decrease in growth rate at the attainment of a specific degree of maturity to be associated with decreased rates of collagen synthesis and increased stability of existing cross-links.

Similarly, cattle undergoing compensatory growth to a mass of 440 kg (after periods of feed restriction), have been shown to have meat similar in tenderness to younger animals which had not been restricted and therefore reached the target mass at an earlier age (De Bruyn, 1988).

It is therefore possible to slow the rate at which collagen becomes less soluble during the growth of the animal by controlling energy intake (Hall & Hunt, 1982).
Marbling

Fat that is deposited within muscles (intramuscular adipose tissue) appears as a delicate pattern of wavy lines in the meat - hence its common name, marbling fat (Swatland, 1984). According to the latter, it is traditionally maintained that marbling fat contributes to the juiciness of cooked meat because it melts away from between bundles of muscle fibres to make the meat seem more tender and succulent.

In a study by Tatum, Smith & Carpenter (1982) marbling had a low, but positive, relationship to all of the palatability traits of beef; more than 90% of the steaks with “slight” or higher degrees of marbling were “desirable” in overall tenderness, flavour and overall palatability. Savell & Cross (1988) found a small change in overall meat palatability over the intramuscular fat range 3-7 %, but a sharp increase in palatability over the range 1.5-3 %. The latter authors consequently recommend a minimum fat content in beef muscle of about 3 % to ensure acceptable palatability and nutritional merit. The intra- 1.5 %) to overall meat palatability (tenderness, juiciness, flavour and overall acceptability) is therefore expected to be low (De Bruyn, 1991). Similarly, changes above 3 % intramuscular fat are unlikely to contribute significantly to meat palatability, but variation ranging from <3 % to >3 % might influence palatability significantly (De Bruyn, 1991). Both De Bruyn (1991) and Crouse & Smith (1978) have suggested that relatively large changes in intramuscular fat content appear to be necessary to benefit sensory meat quality characteristics, the latter indicating that a 30-fold increase in marbling would be required to yield a single unit change in taste panel response (score: 1-7).

Carcasses containing between 3 and 7.3 % marbling (USA) normally have subcutaneous fat thicknesses between 20 and 30 mm, while those of between 1 and 1.5 % marbling (SA) have fat thicknesses between 3 and 7 mm. It is, however, possible to select against total dissectable fat (subcutaneous & intramuscular) and select for increased marbling (Cross, 1990). In fact, certain Angus breeders in the USA have developed Angus bulls for export which have high marbling percentages and yet are low in percentage dissectable fat (Cross, 1990).

MYOFIBRILLAR ASPECTS OF MEAT TENDERNESS

Muscle is essentially a contractile tissue. The contractile elements (myofibrils) are ideally suited to this function, being composed of myofilaments which interlock and slide relative to each other (Fig. 3).

This theory of sliding myofilaments behind contraction is pivotal to the understanding of post mortem changes in muscle and the resulting effects on meat quality (Devine & Chrystall, 1992).

Muscular contraction is initiated by physical and chemical stimuli (Shorthose & Harris, 1992). While a functional nervous system controls contraction and relaxation in the live animal, the musculature of a slaughtered animal contracts in direct response to various physical and chemical stimuli post mortem. Both contraction and relaxation are driven by energy in the form of ATP (Devine & Chrystall, 1992), supplied by the breakdown of muscle carbohydrates (Shorthose & Harris, 1992).

Oxygen and other nutrients supplied by the circulatory system, and necessary for aerobic energy metabolism, are cut off at slaughter. Glycogen particles, lying between the myofibrils and at various locations beneath the cell membrane, are slowly depleted by anaerobic glycolysis as the muscle’s energy requirements are maintained. This may continue for a considerable period post-slaughter, depending on the perimortem status of the glycogen stores. The depletion of muscle energy stores leads to a drop in muscle pH and eventually to rigor mortis, in which the muscle is practically inextensible. This signals a change in status, i.e. the muscle is now meat (Devine & Chrystall, 1992).

The pattern and extent of these changes are not the same for every muscle or species of animal, and are influenced by a variety of physiological and physical interventions that have a major bearing on the ultimate quality of the meat (Devine & Chrystall, 1992).
The physiological and physical factors which determine the ultimate tenderness of meat are most logically discussed, in terms of the meat production chain, as pre- and post-slaughter factors.

**PRE-SLAUGHTER FACTORS**

Most of these factors are biological, lending meat an intrinsic degree of tenderness.

**Age at slaughter**

Most studies of the relationship between animal age and meat tenderness are in agreement that a decrease in the latter occurs with increasing animal age (Buchter, 1971). This is true, provided cold-shortening (which occurs during pre-rigor chilling) is avoided. Carcass mass tends to increase with animal age and the smaller surface area to volume ratio means that larger carcasses chill more slowly. Cold-shortening is, therefore, not as marked as in lighter (younger) carcasses. A greater degree of carcass fatness (particularly subcutaneous) also slows chilling rate, so that carcasses of similar fatness should be compared.

**Genotype**

Tenderness is considered to be highly inherited (Shorthose & Harris, 1992), although assigning a heritability figure is extremely difficult.

Numerous literature supports the finding that, regarding beef, the largest between-genotype variation in meat tenderness is due to the influence of Brahman (Bos indicus Zebu) breeding (Palmer, 1963; Ramsey, Cole, Meyer & Temple, 1963; Carroll, Rollins & Kunze, 1964; Kellaway, 1973; Bidner, Luckett, Icaza & Turner, 1973; Luckett, Bidner, Icaza & Turner, 1975; Hawnkins, Davis, Seidemann & Crouse, 1984; McKeith, Savell, Smith, Dutson & Carpenter, 1985 and Riley, Smith, Cross, Savell, Dreyer, Long & Cartwright, 1986). In these studies, Brahman (B) or B crosses consistently yielded meat with the highest shear force resistance values and lowest sensory panel scores (i.e. the least tender meat).

Similar detrimental effects on meat tenderness have been noted for the Simmental breed and Simmental-sired crosses, in contrast with the Afrikaner (Bos Indicus Sanga) (Von La Chevallerie, 1964; Boccard, Naudé, Cronjé, Smit, Venter & Rossouw, 1979), Afrikaner-sired crosses (Von La Chevallerie, 1969; Boccard et al., 1979 and De Bruyn, 1991) and the Hereford (De Bruyn, 1991).

The detrimental effect of Brahman breeding has been related to post mortem changes in the muscle (McKeith et al., 1985), being regulated through a genotypically larger red muscle fibre with an altered proteolytic enzyme activity (Seidemann & Koohmaraie, 1986; Johnson, Calkins, Huffman, Johnson & Hargrove, 1990).

**Sex condition**

Buchter (1971) found the sex condition of animals of similar age to have minimal influence on meat tenderness, in contrast to Griffin, Stiffler, Smith & Savell (1985) who found the meat from bulls to be significantly less tender (higher shear force resistance values and lower sensory scores) than that from steers. The fact that red muscle fibres have been positively correlated with tenderness (Calkins, Dutson, Smith, Carpenter & Davis, 1981) and that bulls have a higher percentage of these fibres (Dreyer, Naudé, Henning & Rossouw, 1977) but less tender meat than steers, suggests that the relationship of muscle fibre type characteristics to carcass and meat palatability attributes might be different between the two sex conditions (Seidemann & Crouse, 1986). Indeed, the latter authors' results suggest that muscle fibre characteristics do not relate to tenderness measurements in bulls; however, in steers a high percentage of red muscle fibres and large muscle fibres, irrespective of type, are related to meat tenderness.

**Fibre Type**

Classified by Lawrie (1977) into 2 broad classes, viz. red and white fibres. Of the former, an alpha and a beta fibre have been identified. The alpha-red fibre is an intermediary stage in the development of a white fibre and, as such, is often called an intermediate fibre (Ashmore & Addis, 1972, quoted by Viljoen, 1989).

Muscle composition, in terms of fibre type and fibre dimension, is characteristic of breed and sex condition, and is influenced by age and diet (Seidemann & Crouse, 1986). Fibre diameter, larger in white fibres (Dreyer et al., 1977), increases with age and has been found to be negatively correlated with sensory tenderness values of white fibres, but positively correlated with that of red fibres (Calkins et al., 1981). The latter researchers also found an increased percentage of white fibres to be associated with decreased sensory tenderness. Dreyer et al. (1977) found a greater percentage of white fibres in the less tender muscles of the Friesland than in the more tender muscles of the Afrikaner.

Regarding the sex condition influence, the more tender meat of heifers has a greater ratio of alpha-red to white fibres than does the meat of oxen (Johnston, Moody, Boling & Bradley, 1981). Although bulls have a greater percentage of alpha-red fibres in their musculature than do oxen (and should therefore have more tender meat) this relationship is masked by the pre-
cocous cross-linking of the collagen in the muscles of bulls (mentioned previously). This renders the meat of the latter tougher than that of oxen of the same age (Dreyer et al., 1977; Seidemann & Crouse, 1986). Johnston et al. (1981) also correlated an increased dietary energy level with a decreased percentage intermediate (alpha-red) and an increased percentage white fibres. Furthermore, a positive correlation exists between average fibre area (irrespective of type) and meat tenderness (Seidemann & Crouse, 1986).

Fibre type is, therefore, associated with meat tenderness via the influence of age, breed, sex condition and diet.

Contraction of red fibres is performed aerobically, whilst white fibres (with less mitochondria) have the ability to contract under anaerobic conditions (Lawrie, 1977). The enzymes that enable these processes, oxidation and glycolysis respectively, are indicators of the metabolic profile of a particular muscle. This metabolic profile has been linked to tenderness of pork by Essén-Gustavsson & Fjelkner-Modig (1985). From the discussion on breed, it follows that metabolic profile differs between breeds and that tenderness is enhanced by a higher percentage of oxidative alpha and beta-red fibres, this being confirmed by Calkins et al. (1981).

Fibre types will, therefore, react differently to conditions conducive to cold-shortening of muscle, owing to differences in their metabolic profiles. In effect, only red fibres are susceptible to cold-shortening and the resultant toughening (Lawrie, 1977).

Besides the above biological parameters, a few extrinsic husbandry practices and pre-slaughter handling can influence (either alone or by interactions) the biologically determined, intrinsic tenderness of meat. Their effects are largely indirect and result because they influence the rate and extent of lactic acid production (and hence pH fall) in muscles post mortem (Shorthose & Harris, 1992).

Stress prior to and during slaughter

When muscle glycogen concentrations at slaughter are decreased below about 0,6 % of muscle wet weight, post mortem production of lactic acid, via glycolysis, is progressively decreased and the ultimate pH of muscle increases (Shorthose & Harris, 1992).

The pH of such meat usually remains above 6 and although the tenderness thereof is generally accepted to be better than meat of below pH 6 (Dutson, 1983, as quoted by Viljoen, 1989), the former is unacceptable to the consumer because of its dark, firm and dry (DFD) characteristics.

The relationship between ultimate pH and meat tenderness varies, depending on whether muscles are free to shorten and how rapidly carcasses and muscles are cooled post mortem. In muscles that are free to shorten, the relationship is curvilinear (Fig.4); meat with a low ultimate pH is tender, meat with an ultimate pH near 6,0 is tough and meat with a very high ultimate pH (~6,6) is tender (Howard, 1964a, as quoted by Preston & Willis, 1970).

The relationship between ultimate pH and tenderness is discussed in more detail further on.

POST-SLAUGHTER FACTORS

These factors are subdivided into those that occur before the onset of rigor mortis (pre-rigor) and those occurring post-rigor. The former include those factors which can affect myofibrillar shortening, such as rate of cooling, muscle restraint and electrical stimulation. Examples of the latter are aging/conditioning, ultimate pH and cooking.

Pre-rigor

Rate of Cooling

The repeating unit of a regular series of transverse striations of skeletal muscle fibrils is termed the sarcomere (Fig.3), considered to be the structural unit from Z line to Z line (Swatland, 1984).

Sarcomere length is a major factor affecting meat tenderness (Locker, 1959 & 1960, quoted by Swatland, 1984). Stimulated by a too-rapid decline in muscle temperature, this functional unit of muscle fibre contraction undergoes rapid and irreversible contraction, known as cold-shortening (Lawrie, 1977).
The amount of shortening that could occur in the critical pre-rigor period is dependent on the temperature at which unrestrained muscles go into rigor. The amount of deleterious shortening can be limited by:

1. temperature conditioning, so that muscles go into rigor at temperatures between 10 and 20 °C,
2. restraining muscles from shortening, or
3. electrical stimulation (Shorthose & Harris, 1992).

The reason for cold-shortening is given by Bendall (1972) as the lower activity of the calcium pumps at lowered muscle temperatures, thus an increasing Ca++ concentration in the sarcoplasm which would activate the contraction of muscles, provided sufficient energy is still available. Heinze, Naudé & Van Rensburg (1986a) found a progressive increase in shear force values of muscle with an increase in chilling temperature, corresponding with a lower muscle temperature 10 h post mortem. Thus, the more rapidly a carcass is chilled, the tougher the muscles would be due to cold-shortening (Heinze et al., 1986a).

Many muscles in the carcass are attached to the skeletal structure, and when carcasses are hung via the Achilles tendon during the slaughter process some of these muscles, including the premium cuts in the hindquarter (rump, topside and loin), are able to shorten and, hence, toughen. By hanging the carcasses from the pelvis (sacrosciatic ligament), however, these muscles are prevented from shortening (Shorthose & Harris, 1992). This method of carcass suspension (called Tenderstretch) is used both in the USA and Australia (Shorthose & Harris, 1992), but does have disadvantages in that the expensive rump cut is chilled, the tougher the muscles would be due to cold-shortening (Heinze et al., 1986a).

Overall, it would seem that electrical stimulation works by reducing the toughening when chilling rates are rapid enough to produce cold-shortening (Harsham & Deatherage, 1951; McKeith, Savell & Smith, 1981; Heinze, Bekker, Coetzee, Pelser & Naudé, 1982; Powell, Dickenson, McPhail, Bouton & Harris, 1984; Shorthose & Harris, 1990 & 1992; Powell, 1991). Under less rapid chilling conditions it accelerates tenderization due to aging (Savell, Smith & Carpenter, 1978; Savell, McKeith & Smith, 1981; Taylor & Cornell, 1985).

Observations made by Marsh, Ringkob, Russell, Swartz & Pagel (1987) appear to be incompatible with the view that lysosomal enzymes contribute significantly to ES-induced tenderization: Panel and Warner-Bratzler shear evaluations showed that tenderness was highest when glycolysis had proceeded at an intermediate rate (corresponding to the attainment of a 3h pH of about 6.1) and was appreciably lower on both sides of this mid-value. The toughening effect of rapid glycolysis (relative to that of a moderately increased glycolytic rate) persisted through 14 days of aging at 2 °C.

These observations indicate that the effect of ES on tenderness is highly dependant on the subsequent cooling rate, very slow chilling sometimes accelerating the already high rate of pH fall to such an extent that the tissue is significantly toughened. The goal of maximizing the early-post mortem rate of pH decline in bovine muscles is, according to Marsh et al. (1987), misguided and, if attained, will cause suboptimal tenderness.

An important drawback is that the effect of ES is very limited with muscles of stressed animals (pH<5.9) (Shorthose & Harris, 1992).

Post-rigor

Post mortem aging

The practice of holding meat in a chilled condition for certain periods of time post-slaughter, allowing various biochemical processes to occur which affect meat quality (Lawrie, 1977). According to Valin, Monin, Ouali & Ferra (1991), improvement in meat tenderness is of myofibrillar origin, and the meat tenderizing process probably involves two sets of mechanisms affecting the myofibrils. The first to be established was proteolysis of muscle proteins, still considered to be the primary mechanism of meat tenderization. The second mechanism is physicochemical in nature and mainly concerns the large increase in post mortem muscle osmotic pressure (Ouali, 1990).
Proteolysis of Muscle Proteins

The conditions which facilitate these processes and the manner in which they occur, are explained according to the cyto- logical (cellular) region affected.

Gap Filaments

The unit stretching from one side of and through the A band, through the Z line, between the I filaments, terminating at the following A band (Locker, 1982). Seeing as these gap fila- ments remain intact in meat which has been heated to 100 °C (at which temperature collagen has already been converted to gelatin), Locker (1982) postulated that they are largely responsible for the structural integrity and tensile strength of cooked meat. Although detail of the exact proteinase system is unknown, post mortem aging sensitizes the gap filaments to attack and damage, so that the filaments disintegrate on subsequent cooking (Orcutt & Dutson, 1985). For this reason the latter researchers regard the contribution of gap filaments to tenderness of conditioned (aged) meat as minor.

Z lines

The post mortem fragmentation and subsequent weakening of the junction between two consecutive myofibrils is seen by many as the reason for the increased tenderness of meat which has been aged for a time following slaughter (Lawrie, 1983 and Robson, O’Shea, Hartzer, Rathbun, La Salle, Schrei- ner, Kasang, Stromer, Lusby, Ridpath, Pang, Evans, Zeece, Parish & Huiatt, 1984, quoted by Viljoen, 1989; Goll, Otsuka, Nagainis, Shannon, Sathe & Muguruma, 1983).

One or more structural proteins are hydrolysed by proteolytic enzymes (cathepsins and Calcium-activated Proteases (CAP’s)) during post mortem aging (Johnson et al., 1990), thereby weakening the myofibril (Zeece, Robson, Lusby & Parrish, 1986) at the Z lines. Two neutral CAP’s, currently named calpains, are activated by μM (calpain I) and mM (calpain II) Ca++ concentrations, and have been reported to be responsible for specific degradation of tropomyosin, C-protein, troponin T and troponin I, as well as the cytoskeletal proteins titin and nebulin, during the meat aging process (Azanza, Raymond, Robin, Cottin & Ducastaing, 1980, as quoted by Cena, Beltran, Jaime & Roncales, 1991; Lusby, Ridpath, Parrish & Robson, 1983; Goll et al., 1983; Zeece et al., 1986; Cena et al., 1991).

However, although changes of those proteins can be consid- ered indicators of meat tenderization, they are not likely to be directly related to the post mortem changes involved in tender- ness (Ducastaing, Valin, Schollmeyer & Cross, 1985), which are to be accounted for by degradation of high molecular weight proteins (Goll et al., 1983; Ouali, 1990).

Intrinsic Proteinases

Differences in meat tenderness among breed types may be partially explained by differences in proteolytic enzyme activity (Johnson et al., 1990). During investigation of various periods of post mortem aging (1, 5 & 10 days), the level of cathepsin B+L activity increased as the percentage of Angus breeding in- creased in the carcasses, possibly contributing to the differ- ences in tenderness perceived between Angus and Angus x Brahman crossbred steers. Therefore, in vivo control of en- zyme activities and genetic selection of animals with a propen- sity for proteolysis may improve meat tenderness (Johnson et al., 1990).

Physicochemical Mechanisms

In all bovine muscles investigated by Winger & Pope (1980), osmotic pressure increased rapidly after death, sometimes twice as high as in live tissue. Valin et al. (1991) consider such ionic strengths to be high enough to weaken the myofibrillar structure and make it more sensitive to proteolysis.

Ultimate pH, post mortem temperature decline and associated enzyme activity

As previously demonstrated (Fig.4), a significant curvilinear re- lationship exists between the final pH of meat and both sen- sory and shear-resistance tenderness values (Bouton, Carroll, Fisher, Harris & Shorthose, 1973). According to Yu & Lee (1986), tenderness varies with the relative value of the final pH, reflecting the degree to which structural changes have oc- curred via the degradation of muscle proteins by various en- zymes. The most tender meat has a relatively high ultimate pH (above 6.3), allowing removal of the Z lines by neutral prote- inases. Acid proteinases digest the M-lines and miosin chains in meat of relatively low ultimate pH (below 5.8), resulting in an intermediate tenderness. Intact Z-lines and very restricted M-line and myosin degradation, associated with an intermedi- ate final pH value (5.8-6.3), yields the least tender meat.

The above relationship between ultimate pH and meat tender- ness is, however, modified by the rate of post mortem tem- perature decline. Of those carcass muscles subject to the effects of cold-shortening (not prevented from contracting), those of higher ultimate pH carcasses (low glycogen reserves) will be less affected by cold-shortening than those of low ulti- mate pH carcasses (large glycogen reserves), the former hav- ing entered rigor mortis at an earlier stage (Bouton et al., 1973).
Besides the indirect relationship between rate of post mortem temperature decline and meat tenderness, via ultimate pH, there is also a direct linear relationship. By postponing chilling, Lochner, Kaufman & Marsh (1980) found that the noted improved tenderness was more closely related to the slow drop in muscle temperature between 2 and 4 h post mortem than to the prevention of cold-shortening for the first 10 to 12 h post mortem. Tenderness was found to be highly dependent on and almost linearly related to muscle temperature at 2 h post mortem. Carcass mass and finish have a direct bearing on the rate of muscle temperature decline and can, therefore, influence this relationship.

A direct relationship also exists between post mortem muscle temperature and the rate of pH decline, in that a higher muscle temperature post mortem results in a more rapid pH drop (Cassens & Newbold, 1967). Higher post mortem muscle temperatures increase the activity of proteolytic enzymes, promoting tenderness (Dutson, 1983, as quoted by Viljoen, 1989). The higher temperature is not only closer to the optimum of 37 °C for calpains and the lysosomal enzymes, but the lysosomal membranes tear more easily, releasing their enzymes and increasing lysosomal activity (Dutson, 1983, as quoted by Viljoen, 1989).

Whipple, Koohmaraie, Dikeman & Crouse (1990) found that by holding carcass sides at 22.3 °C for 6 h (high temperature conditioning, HTC) post mortem and then chilling them at -1 °C for 18 h, shear forces of M. longissimus dorsi (LD) steaks were lower (P<0.05) than those of steaks of control carcass sides chilled at -1 °C for 24 h. The LD temperatures of HTC sides remained higher (P<0.01) for up to 12 h post mortem and the rate of pH decline was faster, resulting in pH differences (P<0.01) at 6, 9 and 12 h compared with controls. HTC caused a more rapid decline in the activities of both calcium-dependent protease (CDP) and CDP-inhibitor than that in the control sides. This possibly provided a more suitable environment for proteolysis, to which the tenderness improvement may be related.

Concerning the significance of a pH reading 3 h post mortem (pH3), Jones and Tatum (1991) found pH3 to be indicative of variability in tenderness and the incidence of "tender" vs "tough" steaks. These results suggest that pH3 may have potential for assuring consistency of product tenderness.

**Degree and method of cooking**

Bouton & Harris (1972) quote Visser, Harrison, Goertz, Bunyan, Skelton & Mackintosh (1960) and Lawrie (1966) as having summarized the effects of cooking on meat structure as producing a softening of the connective tissue by conversion of the collagen to gelatin, accompanied by a toughening of the meat fibres due to heat coagulation of the myofibrillar proteins.

Tuomy, Lechnir & Miller (1963) and Tuomy & Lechnir (1964) found that tenderness was independent of cooking time for temperatures up to 80 °C for beef and 60 °C for pork, but was strongly dependent upon both temperature and cooking time for higher temperatures. Machlik & Draudt (1963) and Draudt, Machlik & Rimstidt (1964) found that shear values changed little in samples cooked at temperatures up to 50 °C, but decreased in samples cooked at 54 °C and reached a minimum in those cooked at 60-64 °C. These changes were less marked for the M. longissimus thoracis and M. semimembranosus than for the M. semitendinosus muscles. The decrease in shear value was interpreted in this study as related to the collagen shrinkage reaction.

A review of studies by Draudt (quoted by Shorthose & Harris, 1992) relating temperature and tenderness concludes that the decrease in shear values, as cooking temperature is increased from 50 to 60 °C, is due to collagen shrinkage and that changes in the myofibrillar structure accounted for the increase in shear force values observed as cooking temperature was raised from 60 to 75 °C. Bouton, Harris, Shorthose & Ratcliff (1974) found a positive relationship between shear force and sarcomere length at a cooking temperature of 50 °C. At 60 °C the characteristic increase in shear force was observed, with a decrease in sarcomere length from 1.9 to 1.3 μm.

For stretched muscles or those that had not shortened, shear force values decreased as cooking temperature was raised from 50 to 60 °C, but this effect was reversed for cold-shortened muscle. In the latter, the structural component determining toughness is likely to be predominantly myofibrillar, since the thick myosin filaments abut; when they coagulate during heating they could form fibres of considerable strength (King, 1984).

Shear force values of tender-stretched muscle of young animals decreased as cooking temperature increased from 50 to 60 °C, but in older animals this increase did not commence until temperatures were raised above 55 °C. This illustrates that increasing animal age brought about changes in a structural component (connective tissue) (Harris & Shorthose, 1988).

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INTRODUCTION

The Federal Centre for Meat Research in Germany is situated in Kulmbach, Bavaria, a town also known for its excellent beer. In Germany, the first research institute of this kind was established in 1938 in Berlin with the primary objective of increasing meat production and to combat the spoilage of meat. In 1944 the institute was moved to Kulmbach, where it is still situated. This research facility is one of the research centres of the Federal Ministry of Agriculture.

The Centre is divided into four institutes, namely:
- Institute for Meat Production and Market Research
- Institute for Technology
- Institute for Microbiology, Toxicology and Histology
- Institute for Chemistry and Physics.

These four institutes are supported by an administration and a service section.

The general theme recognised in the research at the centre is aimed at the production of safe meat and meat products (free of toxic substances and residues), and meat which should be of high quality. Germany is a highly developed country and also a country within a community of developed countries (EC), and therefore the emphasis has changed from being primarily production-orientated (1938) towards being quality-driven. Most of the research is therefore aimed at market-related problems.

RESEARCH PROJECTS AT THE FEDERAL CENTRE FOR MEAT RESEARCH

I would like to present some of the research done at the Federal Centre for Meat Research which caught my attention, and which was presented at the 27th Kulmbacher Woche, an annual symposium during which research results from the Centre are presented to other researchers and to the meat industry.

Using hurdle technology and HACCP together in the manufacture of meat products

A most interesting project, now finalised, is the bringing together of the two systems of hurdle technology and HACCP (Hazard Analysis Critical Control Point) to ensure the manufacture of safe meat products (Hechelmann & Leistner, 1992). We have to remember that technologies within the food industry have undergone vast changes during the last few decades. We just have to think about changes in manufacturing, transportation, packaging, etc. Traditional regional products are now consumed internationally, therefore requiring transportation which may need to be refrigerated (efficiency, cold chain), changes in traditional packaging and also being presented in consumer portions. All of these changes are potential areas of contamination, recontamination and of stimulating microbial growth. The potential hazard areas have to be identified and controlled. The researchers in Kulmbach had the task of setting the hurdles and the critical control points in order to ensure a shelf life of various meat products of at least 6 days at 30 °C, with the products still tasting fresh and being safe for human consumption. This was indeed, a phenomenal task!

The researchers took 100 meat products manufactured by 24 manufacturers which tasted “fresh” and did not need chilled storage. These products were evaluated and 75 of these products were found to be stable and safe, meeting the general specifications set. According to these 75 products, the researchers were able to define 8 different meat product stability categories in which the stability and safety of each category correlated with the different principles of hurdle technology.
With the knowledge of the different manufacturing processes involved in the production of the different meat products, the researchers were able to define the manufacturing process according to the concept of HACCP. The aim was to be able to define critical points which should be controlled by manufacturers, even without having a microbiological control laboratories, to ensure "fresh" and safe meat products. Only four variables were introduced that should be controlled. The variables introduced were temperature, time, pH value and the water activity (a\text{w}) value. Even the a\text{w} value could now be monitored on line with an a\text{w} meter developed in Kulmbach in which the a\text{w} value could be determined reproducibly within a few minutes and which is now available commercially as the a\text{w}-Kryometer. The combination of the hurdle technology and HACCP concept is a viable one, and probably essential during the whole manufacturing process of meat products. It is applicable to both the developed and developing countries, and of vital importance in manufacturers' quality control systems. Daily records of the four named parameters would also be invaluable in the settling of possible claims arising from unsafe or perished products.

**Electrical stunning of pigs**

The humane handling of slaughter animals, as well as practising humane stunning methods are current issues in the European media. Stunning of pigs is one of the stages in slaughtering where unecessary stress could occur, as was found in a survey in South Africa (Heinze & Klingbiel, 1991), generally as a result of there being no standard to adhere to, differences in opinion as evident from the literature and as a result, therefore, generally perceiving that the stunning of pigs is not controllable and/or measurable.

In Germany, as is the case in South Africa, the most often used stunning method for pigs is the manual electrical stunning method. This is, however, a very important stage regarding both meat quality and animal welfare (Woltersdorf, 1992). For a 100 % successful electrical stunning the following criteria are essential:

- the electrodes must be placed correctly as to permit the current to flow through the brain via the shortest path
- that the state of unconsciousness is reached within the first second of stunning. This is only possible with at least 1,25 Amperes and at least 240 Volts
- the pigs should be exsanguinated within 30 seconds after termination of stunning.

Results of experiments indicated that manual stunning of pigs is very difficult to standardise. Different electrodes connected to the same power supply delivered different currents during stunning and had to be checked. For this reason plotters are needed to capture the current that flowed, as well as the Voltage and time span. Also, the correct placing of the electrodes is essential. According to the researchers at the Centre, the best are earbase/earbase and orbital region/earbase. Placing the electrodes on the neck/neck, forehead/breast bone and cheek/cheek is both unacceptable and inefficient. Also, it has been shown that the electrode points must be sharp and not worn, and they must be clean. Maintenance of the electrodes is essential and this is usually an area frequently neglected. For the correct placing of the electrodes the pigs have to be restrained, and a short restrainer should be used. However, the pigs must remain in these restrainers for the minimum period of time to prevent a deterioration of meat quality. Pigs should stand still before stunning takes place or else leg and back breaks could occur, which of course, should be avoided.

Furthermore, new results indicate that the time between termination of stunning and sticking should not exceed 15 to 20 seconds. Although this is not easy to maintain if the sticking and bleeding is done vertically, this is possible if it is done horizontally. The researchers indicate that this way of bleeding is more efficient, and results in better meat quality. If pigs are hoisted before sticking, the hanging leg has a lower pH value (average 0,1) than the other leg. If pigs have to be hoisted, this should take place after at least 2 minutes after sticking. The researchers indicate that by using correct the stunning technique and the horizontal method of sticking and bleeding they were able to raise the average pH\text{1} at one abattoir from 5,9 to 6,2.

**The iodising of nitrite curing salt (NCS)**

The population of the middle European region has an average under-supply of iodine (in the order of 100 μg per day), and this leads to various diseases. To alleviate the problem, salt is usually iodised. In Germany iodisation is exclusively done by iodate (KIO\text{3} or NaIO\text{3}) and not with iodide (KI) as in most other countries. With the relative high consumption of meat products in Germany, the question was asked whether the use of iodised NCS could help alleviate this problem and that through the meat products in which NCS's are used, the manufacturer could actively help to combat this problem (Kühne, 1992). Because it is known that iodide is converted to gaseous iodine at higher temperatures and/or if in contact with nitrate, and that iodate is converted to iodide by nitrite, the iodine could escape as gaseous iodine and therefore have no positive effect on the health status of the individual.

Questions that had to be answered were:

- how stable would the iodate in the NCS be
- in what form would the iodine be found in meat the products
- would it lead to an increase in the nitrosamine concentration in the manufactured meat product, as this is suspected of being a carcinogenic agent.

The results indicate that iodate in NCS was stable for more than 2 years and that no iodine was lost during the manufacture of the meat products containing the NCS. The iodised NCS did not influence technological (curing, heating and fermentation) and sensory properties of meat products. Most of the iodate was reduced to iodide, although no gaseous iodine was found. In the meat products (Brühwurst, liver sausage and raw sausage) 75 to 80% of the iodine was found as inorganic iodine which could be extracted in the aqueous phase, whilst the rest was bound to fat and protein. The use of the iodised NCS did not lead to higher nitrosamine concentrations. Hence the use of iodated NCS could lead to a better health status of the population. Legislation was changed so that iodated NCS may now be used in the manufacture of meat products.

**Warmed-over flavour**

Another interesting subject being investigated is the problem of warmed-over flavour (WOF) (Hofmann & Vasundhara, 1992). This is usually found after meat is reheated after being cooked and cold-stored, and is therefore a major problem in cafeteria meals, meals served during air travel, etc. The flavour is usually described as being rancid, old, oxidised and in general unacceptable. However, this WOF is not found after the first or initial cooking of the raw, cold stored meat.

Results indicate that the phospholipids may be involved in the development of the WOF, and that triglycerides may not be involved. As the phospholipids are important components of the cell membranes, factors influencing the destruction of the membranes may influence the severity of WOF. Therefore, the initial cooking method must play an important role in the development of the WOF. The researchers therefore investigated the influence of various initial cooking methods (cooked in water, grilled in an oven, grilled with a contact grill, and cooking in a microwave oven) of pork on the occurrence of WOF during the second reheating stage using a microwave oven, as is commonly the case. Furthermore, the correlation between sensory evaluation and chemical methods (GC and TBA) was investigated in order to develop methods enabling researchers to predict WOF.

The results indicate that the initial cooking of the pork by the contact grill lead to almost no WOF during the second reheating phase, whereas the initial microwave oven cooked pork had the highest incidence of WOF, independent of initial cooking time or energy intensity, and the initial cooking-in-water being intermediate. Although WOF might be evaluated similar to rancidity by taste panels, it has no correlation with TBA values. However, using GC and mass spectrometry it was clear that phospholipids might be responsible for the WOF, as they are poly-unsaturated, and WOF is also more prevalent if the meat was minced before initial cooking, and thereby increasing the surface area of the meat. The inclusion of antioxidants limits the development of WOF. Although it was found that all precursors of the WOF are present after each of the cooking methods used, the relative concentrations of the precursors varied, and were higher in samples after initial microwave cooking. Therefore, precursors of the WOF are already produced during the first heating of the meat, but are only noticed during the second heating of the meat. Possible production of aldehydes and ketones responsible for WOF may be produced as a result of free radicals.

It must be concluded that the use of microwave energy should not be used during the first cooking process if the meat is to be reheated after an extended cold storage period.

**The quantification of haemoglobin and myoglobin in meat**

Research is also carried out with the aim of the quantification of both myoglobin and haemoglobin in meat (Hofmann, 1992). This separate quantification is important in terms of meat colour (mainly as a result of myoglobin), and the level of residual blood in the meat (which, in turn, influences shelf life and sensory properties). The traditional way of determining the pigment (haeme) concentration was developed by Hornsey (1956), but this method does not discriminate between the two haeme proteins.

With the use of PAGE electrophoresis (Laemmli, 1970) it seems possible to differentiate between myoglobin and haemoglobin in meat samples. During the initial experiment it was found that the myoglobin concentration of beef muscles is 3 to 4 times higher than that of pork, although the haemoglobin concentrations were similar. The relative higher haemoglobin concentration of pork (30 to 35 % higher) may therefore play an important role in the appraisal of pork colour. This methodology may become important in the evaluation of different bleeding techniques during the slaughtering process and could influence differences between meat (especially pork) samples.

**Spray chilling of chickens**

An interesting development regarding the chilling of broilers was mentioned (Ristic, 1992). Within one hour post mortem the internal temperature of the carcass must be lowered from 40 °C to under 4 °C. For the fresh market, carcasses have to be air chilled after slaughter. However, carcasses meant for the frozen market could be chilled after slaughter either by dipping...
in a cold waterstream, or by water spray chilling. Using spray chilling, carcases are sprayed during chilling with water. The benefits of the spray chilling methods are given as:

- less foreign water (1.4 %) is added to the carcase, therefore less drip occurs during thawing (2.6 %)
- physiological quality parameters were better after spray chilling relative to dipping in a cold water stream
- better hygiene
- improved sensory evaluation results.

It is claimed that not only is a safer product of a better level of hygiene found, but also a better quality product due to improved sensory properties and less absorbed water which would have been lost during thawing. However, legislation in Germany requires that the method of chilling has to be indicated on the package.

Near infra-red transmittance for determining protein, moisture and fat content in meat

An exciting new instrument is currently being evaluated in Kulmbach. The moisture, fat and protein levels in meat can be determined simultaneously (Freudenreich, 1992). The technology used is near infra-red transmission spectroscopy (NIT). Some years ago near infra-red reflection (NIR) spectroscopy was introduced for the determination of moisture, fat and protein in foodstuffs. However, the NIR always had the drawback in that the surface of the sample had to be extremely smooth, and that only the surface could be used for analysis. Usually a microscope slide is used to cover the sample in order to maintain a smooth surface. This leads to a capillary action beneath the glass surface resulting in a higher water content directly beneath the glass, which could influence results. Furthermore, only a few wavelengths could be used for the prediction of the various components. With the introduction of this new instrument using NIT, not only the surface, but also the height, usually 15 mm, of the cylinder of the homogenated meat sample used for prediction. The spectrum 850 to 1050 nm is used in intervals of 2 nm, therefore 100 measurements. All of these measurements are used in the calculations of the different components.

While I was visiting the Federal Centre for Meat Research, the calibration curves, which are very important in the use of the instrument, were being constructed. Using the calibration curves and traditional proximate analysis, the following correlation coefficients and standard errors of prediction (SEP) were found (Table 1).

The whole determination takes about 60 seconds for 5 replicates of each sample during a single run. However, not only can moisture, fat and protein content be predicted, but even collagen content (still under investigation), Minolta L*-value (beef r=0.94) as well as Minolta a-value (pork r=0.93).

This instrument or technology could become very important in predicting the quality of raw material as well as on-line quality control in the manufacture of meat products. The technology ensures a quick and environmentally friendly (no chemicals are used) prediction of the various important components of meat and meat products with the same level of accuracy as the traditional methods.

CONCLUSION

These are only a few examples of the research projects currently under investigation at the Federal Centre for Meat Research at Kulmbach. The cited examples clearly show that research at this Research Centre is directed towards the humane handling and slaughtering of animals, health of the consumer and the improvement of the quality of meat and meat products, as well as the development of quality control systems.

REFERENCES


Table 1: Correlation coefficients (r) and standard errors of prediction (SEP) for intramuscular fat, moisture and/or protein contents of beef or pork as estimated with near infra-red spectroscopy.

<table>
<thead>
<tr>
<th>Component</th>
<th>r</th>
<th>SEP</th>
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<tr>
<td>BEEF:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intramuscular fat</td>
<td>0.99</td>
<td>0.25</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.98</td>
<td>0.34</td>
</tr>
<tr>
<td>Protein</td>
<td>0.93</td>
<td>0.27</td>
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<tr>
<td>PORK:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intramuscular fat</td>
<td>0.98</td>
<td>0.20</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.91</td>
<td>0.34</td>
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<6.00 in die Mm. longissimus thoracis et lumborum in Suid-Afrika, 1990/91. Unpublished confidential report.


Centralised bulk pre-packaging of fresh pork retail cuts in various gas atmospheres

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INTRODUCTION

Fresh meat packaging is developing rapidly, both for large scale distribution and for retailing purposes. The growing dominance of supermarkets and self-service retailing in Europe has encouraged the centralised preparation and packaging of meat with techniques being developed to lengthen the shelf life accordingly (Taylor, 1990). The S.A. meat industry has only just started to look into the concept of centralised prepackaging. It is thus essential that research be initiated to assist the meat industry in launching this concept with special reference to the advantages and disadvantages concerning the quality of the end product. The shelf life of such packaged products could be influenced by the raw materials and processing and be extended by the packaging process and materials used.

During a previous trial (Scholtz et al., 1992) it was concluded that pork retail cuts could be bulk stored in a 100 % CO₂ at 0 °C for 21 days, with a subsequent retail shelf life of 4 days (0 °C). The commercial storage life of the 100 % CO₂ bulk stored pork chops was, however, limited owing to a loss in the colour of the pork chops. According to Taylor (1990) a system which successfully combines bulk pre-packaging with the high CO₂ of modified atmosphere packaging (MAP) and low meat temperature conditions could provide colour stability of bulk pre-packaged samples. The present study was designed to evaluate the bulk pre-packaging technique (utilising various gas mixtures, i.e. 100 % CO₂; 75 % CO₂ : 25 % N₂; 80 % O₂ : 20 % CO₂ and 25 % CO₂ : 50 % N₂ : 25 % O₂) in terms of quality attributes such as microbiology, colour, odour and consumer acceptability.

Bulk gas flushing

Fresh red meat samples are placed on polystyrene foam trays, and overwrapped in stretchable, high oxygen-permeable, packaging films (PVC). The overwrapped trayed products (primary package) are then placed into a secondary master package (a large bag or pouch), which is vacuum packed, then filled with selected modified atmospheres and sealed.

During distribution, the gas in the master package migrates into the overwrapped tray (through the highly permeable film covering) and provides the necessary pederastically effects to insure reasonable (14 day) shelf life (Cole, 1986). At the store level master packages are opened and the tray PVC overwrapped packages are placed directly into retail display cases. The oxygen in the atmosphere then migrates into the permeable package, allowing the meat products to bloom. The relative short shelf life of overwrapped fresh red meat has prevented this system from becoming widespread, although packing costs are reduced since a large number of retail cuts are included in a single gas pack (Cole, 1986; Sheridan, 1988).

Gas mixtures

Since some gasses produce beneficial results relative to meat colour while others only inhibit bacterial activity, mixtures of two or more gasses are used in research programs as a feasible method of extending the shelf life of fresh meats. Atmospheres containing both oxygen and CO₂ are used commercially to approximately double the storage life of chilled meat, compared to the normal storage life in air (Gill & Harrison, 1989). In these gas mixtures the CO₂ will inhibit spoilage bacteria while oxygen keeps the meat surface oxygenated, but fat oxidation may be a problem (Walters, 1975). Optimum results are obtained relative to meat colour when low carbon dioxide concentrations (10 - 25 %) are used in conjunction with high concentration of oxygen (75 %). It is also suggested that sufficient oxygen must be used to produce a thick bright red surface layer of oxymyoglobin to mask the brown underlying
layer of metmyoglobin and also a sufficient carbon dioxide concentration to inhibit spoilage bacteria. (Clark & Lentz, 1973 and Taylor & MacDougall, 1973). Nitrogen, an inert gas, is used instead of vacuum packaging to reduce the stress on the barrier tissue. N₂ is also dissolved in meat tissue and is present in the gas headspace around meat, but it does not affect meat colour or inhibit bacteria.

Fresh meat will retain a bright red colour if packaged in a nitrogen atmosphere and is used to displace small concentrations of oxygen (Seideman & Durland, 1984).

MATERIALS AND METHODS

Meat

Twelve pig carcasses were selected according to a ca. 30 minute post mortem pH (> 6, in the M. longissimus thoracis, in the area of the last three ribs) and a carcass mass of ca. 65 kg. The 12 carcasses represented three repetitions of the experimental design. Only the loin cuts were used.

Packaging Treatments

Both loins of each carcass were randomly allocated to a specific bulk pack treatment (100 % CO₂: 75 % CO₂: 25 % N₂: 80 % O₂: 20 % CO₂: 25 % CO₂: 50 % N₂: 25 % O₂) and each loin cut into 18 chops. Each chop was placed in a shallow styrofoam trays and overwrapped with PVC (OTR - ca. 5 000 ml/m²/24h/1 atm at 22 °C 75 % RH).

Bulk Packaging (Mother bag): Twelve of the PVC-overwrapped chops from each loin were bulk packed, six per bulk pack (BB4L Cryovac barrier bag, OTR - 39 ml/m²/24h/atm at 23 °C 75 % RH). Twelve bulk packs, representing three repetitions, were vacuum packed, heat sealed (Röchermatic vacuum machine) and subsequently filled with 100 % CO₂ and 25 % CO₂: 50 % N₂: 25 % O₂) and each loin cut into 18 chops. Each chop was placed in a shallow styrofoam trays and overwrapped with PVC (OTR - ca. 5 000 ml/m²/24h/1 atm at 22 °C 75 % RH).

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Storage and Shelf life study

Bulk Packaging (Mother bag): Three replicate bulk packs from each treatment (100 % CO₂: 75 % CO₂: 25 % N₂: 80 % O₂: 20 % CO₂: 25 % CO₂: 50 % N₂: 25 % O₂) were opened after ca. one hour of saturation with the specific gas mixture. One set of PVC-overwrapped samples from each bulk pack was assessed 30 minutes after opening the bulk pack. The remaining four samples were displayed in an open deck retail display cabinet (ca. 0 °C) for 2 or 4 days. The remainder of the bulk packs (36) were stored at 0°C for either 7, 14 or 21 days. After each relevant storage period, three replicate bulk packs from each treatment were opened and assessed as noted above.

Foamtray/PVC overwrap controls: The Day 0 PVC-overwrapped control samples were assessed without a display period, while the rest of the samples were displayed in an open deck retail display cabinet (ca. 0 °C) for 2 or 4 days.

Quality Attributes

Following the 0, 7, 14 and 21 days bulk pack storage periods, the PVC-overwrapped samples were displayed for each specified period, withdrawn and assessed according to microbiological, colour, odour and acceptability parameters.

Microbiological analysis: A measured area of ca. 12 cm² was removed aseptically to a depth of ca. 5 mm from the upper surface of the sample (Nortjé et al., 1982). This was homogenised in a Stomacher 400 (DHK (Pty) Ltd) with a 100 ml of 1/4-strength Ringer's (Merck) diluent. Counts were obtained as follows: Total aerobic counts on Standard 1 nutrient agar (Std 1; Merck), incubated for 3 days at 25 °C; total anaerobic counts on Std 1 agar, incubated for 5 days at 25 °C, in an anaerobic jar using BBL GasPack plus gas generator envelopes (Bactlab Systems (Pty) Ltd) as H₂ and CO₂ generators, while MRS agar (de Man, Rogosa & Sharpe, 1960) was used for determination of lactic acid bacteria (5 days at 30 °C).

Pseudomonas spp. were monitored on Kielwein agar (Kielwein, 1971) incubated for 3 days at 25 °C and DHL agar (Sakazaki et al., 1960) was used to determine Enterobacteriaceae (2 days, 37 °C). Brochothrix thermosphacta count was only determined on the bulk packed samples after each specified storage period, the counts being done on streptomycin-thallous acetate agar (STAA, Gardner, 1966) following incubation 25 °C for 5 days.

Colour: The colour of each unopened sample was assessed by a trained panel consisting of 10 people 30 minutes after each pack was opened. A colour chart was provided and the colour scored on a 5 point scale ranging from 1 = Extremely
pale'; 2='Pale'; 3='Normal'; 4='Dark' to 5='Extremely dark' (Anon, 1981).

Odour: Samples were assessed by a trained panel of 10 people 30 minutes after each pack was opened. Odour was scored on a 6 point scale which ranged from 1='No odour'; 2='Fresh meat'; 3='Slightly off'; 4='Moderately off'; 5='Strongly off' to 6='Completely off'.

Acceptability: Acceptability of each unopened sample was assessed by an untrained panel of 10 people to give an indication of the consumer acceptability of the PVC-overwrapped sample. This was done 30 minutes after each pack was opened, according to an 8 point scale ranging from 1='Extremely unacceptable'; 2='Unacceptable'; 3='Moderately unacceptable'; 4='Slightly unacceptable'; 5='Slightly acceptable'; 6='Moderately acceptable'; 7='Acceptable' to 8='Extremely acceptable'.

Statistical analysis

The data was analysed by analysis of variance to determine which factors (bulk packaging, storage period, display period) and interaction between factors contributed significantly to the different parameters determined. Levels of P≤0,05 were taken to be significant.

Table 1: Individual microbiological counts for centralised packaged PVC-overwrapped control pork loin cuts

<table>
<thead>
<tr>
<th>Display time (days)</th>
<th>Total count (log cm⁻²)</th>
<th>Stnd. error</th>
<th>Anaerobes (log cm⁻²)</th>
<th>Stnd. error</th>
<th>Lactic acid bacteria (log cm⁻²)</th>
<th>Stnd. error</th>
<th>Pseudomonads (log cm⁻²)</th>
<th>Stnd. error</th>
<th>Enterobacteriaceae (log cm⁻²)</th>
<th>Stnd. error</th>
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<td>Day 0</td>
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<td>2.45</td>
<td>0.51</td>
<td>0.76</td>
<td>0.41</td>
<td>0.57</td>
<td>0.40</td>
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<tr>
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<td>2.95</td>
<td>0.75</td>
<td>2.93</td>
<td>0.66</td>
<td>3.21</td>
<td>0.91</td>
<td>1.86</td>
<td>0.57</td>
</tr>
<tr>
<td>Day 4</td>
<td>6.90</td>
<td>0.49</td>
<td>6.01</td>
<td>0.41</td>
<td>5.68</td>
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<td>0.42</td>
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<td>0.64</td>
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<tr>
<td>Day 0</td>
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<td>1.60</td>
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<td>3.09</td>
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<td>5.76</td>
<td>0.47</td>
<td>5.02</td>
<td>0.40</td>
<td>4.46</td>
<td>0.23</td>
<td>5.40</td>
<td>0.54</td>
<td>1.89</td>
<td>0.73</td>
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</tbody>
</table>

RESULTS

PVC-Overwrapped Control Samples

The mean total counts of the four control groups did not differ significantly over the whole retail shelf life period (Days 0, 2 and 4) (P=0.6867), although they did on the individual sampling days (0 vs. 2 vs. 4) (P=0.0001). The results obtained for the mean pseudomonad (P=0.8788) and mean lactic acid (P=0.1412) counts were similar. These results indicated that no significant differences were encountered regarding the mean total count of the different pig carcasses used, although the population structure differed significantly regarding the mean anaerobe (P=0.0060) and Enterobacteriaceae (P=0.0024) counts.

The initial total count (24h post mortem, Day 0) for the first control group (PVC-control 1) was log 2.57 cm⁻², which steadily increased throughout display to reach log 6.90 cm⁻² on Day 5 (P=0.0001) (Table 1). The total counts of the second and fourth control groups, as well as the lactic acid bacteria, pseudomonad, anaerobe and Enterobacteriaceae counts, followed a similar trend i.e. steadily increasing from Day 0 onwards (Table 1). The third control group had a higher initial total count (log 4.71 cm⁻²) which did not increase over a subsequent 2 days display but reached higher levels on Day 4 of display.

Similar trends were also observed for all the other counts recorded for the third control group (Table 1). Therefore PVC-overwrapped control samples could serve as a general control to compare the results of the four packaging treatments that were assessed.
Table 2a: Microbiological counts obtained for centralised bulk packaged (stored 0 °C) and a subsequent retail shelf life study (0 °C) of pork retail cuts

<table>
<thead>
<tr>
<th>Bulk pack application</th>
<th>Display time (days)</th>
<th>Total count (log cm(^{-2}))</th>
<th>Stnd. error Anaerobes (log cm(^{-2}))</th>
<th>Stnd. error Lactic acid bacteria (log cm(^{-2}))</th>
<th>Stnd. error Pseudo monads (log cm(^{-2}))</th>
<th>Stnd. error Enterobacteriaceae (log cm(^{-2}))</th>
<th>Stnd. error B. thermo sphacta (log cm(^{-2}))</th>
<th>Stnd. error</th>
</tr>
</thead>
<tbody>
<tr>
<td>120% CO(_2) &amp; 0 N(_2)</td>
<td>0 DAYS</td>
<td>Day 0 3.40 1.11 1.92 1.11 1.66 1.11 1.72 1.11 1.47 1.11</td>
<td>Day 2 3.78 1.19 1.95 1.19 1.66 1.19 1.72 1.19 1.47 1.19</td>
<td>Day 4 4.66 1.11 4.58 1.11 4.04 1.11 4.60 1.11 3.70 1.11</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>7 DAYS</td>
<td>Day 0 2.41 1.11 1.34 1.19 1.90 1.19 1.69 1.19 1.21 1.19</td>
<td>Day 2 4.42 1.11 3.96 1.11 1.98 1.11 2.16 1.11 1.46 1.11</td>
<td>Day 4 6.75 1.19 5.02 1.19 4.88 1.19 5.97 1.19 2.07 1.19</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>14 DAYS</td>
<td>Day 0 5.18 1.19 3.67 1.19 2.03 1.19 3.37 1.19 1.86 1.19</td>
<td>Day 2 4.97 1.11 3.87 1.11 3.51 1.11 1.24 1.11 2.19 1.11</td>
<td>Day 4 5.28 1.19 2.73 1.19 1.88 1.19 2.54 1.19 1.89 1.19</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>21 DAYS</td>
<td>Day 0 4.40 1.11 3.22 1.11 4.12 1.11 1.12 1.11 1.00 1.11</td>
<td>Day 2 5.24 1.19 4.23 1.19 3.20 1.19 2.57 1.19 1.15 1.19</td>
<td>Day 4 5.77 1.11 4.59 1.11 4.58 1.11 2.53 1.11 1.13 1.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Bulk Packaging**

**Microbiological assessment**

**Mean Total count**

Although the packaging treatments did not influence the mean total counts significantly, significant differences were found regarding the different bulk storage days (P<0.0134) and retail shelf life days (P<0.0001).

The total counts obtained from the retail cuts from all the applications (100 % CO\(_2\); 75 % CO\(_2\): 25 % N\(_2\); 80 % O\(_2\): 20 % CO\(_2\) and 25 % CO\(_2\): 50 % N\(_2\): 25 % O\(_2\)) after 0 days bulk storage were initially (Day 0) at low levels, namely log 3 cm\(^{-2}\) (Tables 2a & 2b). These counts increased to reach significantly higher levels after a subsequent 4 days retail display. The only exception was the retail cuts from the 80 % O\(_2\): 20 % CO\(_2\) treatment which reached an unacceptable high total count on Day 4 of the retail shelf life study (log 7.24 cm\(^{-2}\); P<0.0001). The mean total counts recorded for the retail samples after seven days bulk storage followed a similar trend as the counts recorded initially (0 days bulk storage) for all four the bulk packaging treatments. The initial total counts (0 days display) after 14 and 21 days bulk storage were still at acceptable levels for all four bulk packaging treatments. These counts increased over a subsequent 2 days of retail display and then remained stable for the following 2 days of retail display (Tables 2a & 2b).

**Mean Anaerobe and Lactic Acid Bacteria counts**

The statistical analyses for the main effects of the anaerobe and lactic acid bacteria counts were similar to that noted for the total counts. The packaging treatments X storage days interaction (P<0.05) and storage days X display period (P<0.05) interactions of these counts were however also significant. According to the packaging treatments X storage days interaction...
The mean anaerobe counts of the samples stored in 25% CO₂: 50% N₂: 25% O₂ for 0 days had lower mean anaerobe counts (log 2.07 cm⁻²) after display (Day 0, 2 and 4) than the samples from all the other treatments (log 3.00 cm⁻²). After 14 and 21 days storage and subsequent display the latter, however, had lower mean counts (log 4.00 cm⁻²) than those stored in 25% CO₂: 50% N₂: 25% O₂ (log 5.60 cm⁻²). A similar observation was made for the packaging treatments X storage days (P=0.0140) interaction of the lactic acid bacteria counts. The mean anaerobe and lactic acid bacteria counts (for all the packaging treatments) followed the same increasing trend as the mean total counts after 0 days bulk storage (Tables 2a & 2b).

**Mean Enterobacteriaceae count**

The statistical analysis of the mean Enterobacteriaceae counts was similar to that recorded for the mean total counts. The mean Enterobacteriaceae counts of the samples from all the packaging treatments (100% CO₂; 75% CO₂: 25% N₂; 80% O₂: 20% CO₂ and 25% CO₂: 50% N₂: 25% O₂) following 0 days bulk storage were initially (Day 0) low (log 0.79 cm⁻²) (Tables 2a & 2b). This count steadily increased to reach significantly (P=0.0001) higher levels after 4 days display (log 3.70 cm⁻²). Even after 21 days bulk storage the retail cuts from all the treatments still had low initial Enterobacteriaceae counts (Day 0) of log 1.30 cm⁻². Although these counts increased over the subsequent 4 day display period, the recorded count was still low (log 2.18 cm⁻²).

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**Table 2b: Microbiological counts obtained for centralised bulk packaged (stored 0°C) and a subsequent retail shelf life study (0°C) of pork retail cuts**

<table>
<thead>
<tr>
<th>Bulk pack application</th>
<th>Display time (days)</th>
<th>Total count (log cm⁻²)</th>
<th>Stnd. error</th>
<th>Anaerobes (log cm⁻²)</th>
<th>Stnd. error</th>
<th>Lactic acid bacteria (log cm⁻²)</th>
<th>Stnd. error</th>
<th>Pseudomonads (log cm⁻²)</th>
<th>Stnd. error</th>
<th>Enterobacteriaceae (log cm⁻²)</th>
<th>Stnd. error</th>
<th>B. thermo sphacta log cm⁻²</th>
<th>Stnd. error</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% CO₂: 25% O₂ &amp; 50% N₂</td>
<td>0 DAYS</td>
<td>Day 0</td>
<td>1.96</td>
<td>1.19</td>
<td>1.18</td>
<td>1.19</td>
<td>0.86</td>
<td>1.19</td>
<td>0.59</td>
<td>1.19</td>
<td>0.00</td>
<td>1.19</td>
<td>0.00</td>
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<td>0.53</td>
<td>1.19</td>
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<tr>
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<td>7 DAYS</td>
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<td>1.19</td>
<td>2.50</td>
<td>1.19</td>
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<td>21 DAYS</td>
<td>Day 0</td>
<td>4.40</td>
<td>1.19</td>
<td>3.18</td>
<td>1.19</td>
<td>2.49</td>
<td>1.19</td>
<td>2.06</td>
<td>1.19</td>
<td>0.69</td>
<td>1.19</td>
<td>1.31</td>
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<tr>
<td></td>
<td>Day 2</td>
<td>5.50</td>
<td>1.11</td>
<td>4.17</td>
<td>1.11</td>
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<td>4.24</td>
<td>1.11</td>
<td>0.70</td>
<td>1.11</td>
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<tr>
<td></td>
<td>Day 4</td>
<td>6.33</td>
<td>1.19</td>
<td>5.64</td>
<td>1.19</td>
<td>4.21</td>
<td>1.19</td>
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<td>1.19</td>
<td>1.41</td>
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</table>

(P=0.0140) of the anaerobic counts, the samples stored in 25% CO₂: 50% N₂: 25% O₂ for 0 days had lower mean anaerobe counts (log 2.07 cm⁻²) after display (Day 0, 2 and 4) than the samples from all the other treatments (log 3.00 cm⁻²). After 14 and 21 days storage and subsequent display the latter, however, had lower mean counts (log 4.00 cm⁻²) than those stored in 25% CO₂: 50% N₂: 25% O₂ (log 5.60 cm⁻²). A similar observation was made for the packaging treatments X storage days (P=0.0140) interaction of the lactic acid bacteria counts. The mean anaerobe and lactic acid bacteria counts (for all the packaging treatments) followed the same increasing trend as the mean total counts after 0 days bulk storage (Tables 2a & 2b).
Mean *Brochothrix thermosphacta* count

The mean *Br. thermosphacta* counts were significantly influenced by the packaging treatments (P=0.0014) and storage period (P=0.0018) main effects. The packaging treatments X storage period (P=0.0014) interaction was also significant. According to the packaging treatments X storage periods (P=0.0014) interaction the mean *Br. thermosphacta* counts of the different packaging treatments did not differ from each other after 0 days storage (log 0.10 cm$^{-2}$) (Tables 2a & 2b).

After 14 days storage the count recorded for the samples bulk packed in 75 % CO$_2$ : 25 % N$_2$ : 80 % O$_2$ was higher (log 1.34 cm$^{-2}$) and differed from the count recorded for all the other treatments (log 0.48 cm$^{-2}$). Following 21 days storage the samples bulk packed in 75 % CO$_2$ : 25 % N$_2$ : 80 % O$_2$ (log 3.31 cm$^{-2}$) and in 80 % O$_2$ : 20 % CO$_2$ (log 1.31 cm$^{-2}$) had significantly higher mean *Br. thermosphacta* counts than the samples from the other two bulk pack treatments (log 0.00 cm$^{-2}$).

Quality assessment

**Colour assessment**

The statistical analysis of the colour scores indicated that the packaging treatments (P=0.0001), storage period (P=0.0001) as well as the display period (P=0.0007) main effects all had a significant influence on the colour of the retail samples. The packaging treatment X storage period (P=0.0002) and packaging treatment X display period (P=0.0009) interactions were also significant. The colour of the samples from the 0 Day storage, 100 % CO$_2$ packaging treatments was normal during the subsequent display period (Fig. 1). After 7, 14 and 21 days bulk storage in 100 % CO$_2$ and subsequent display the colour of the samples was found to be pale to normal. The samples stored in 75 % CO$_2$ : 25 % N$_2$ and 25 % CO$_2$ : 50 % N$_2$ : 25 % O$_2$ followed the same trend. The colour of the samples stored in 80 % O$_2$ : 20 % CO$_2$ for 0 days was also found to be normal initially (Day 0), but as display progressed colour paled. This trend seemed to persist throughout the rest of the storage period (Days 7, 14 or 21) and subsequent display periods.

**Odour assessment**

The statistical analysis of the odour scores indicated that the packaging treatments (P=0.0004), storage period (P=0.0001) and display period (P=0.0001) exerted the odour of the samples significantly. This was also true for the packaging treatment X storage period (P=0.0001) and storage period X display period (P=0.0024) interactions. A fresh meat odour of the samples stored in 100 % CO$_2$ and in 75 % CO$_2$ : 25 % N$_2$ persisted through the whole extended bulk storage period (Days 0, 7, 14 or 21) and subsequent display periods, except on Day 4 of display following 21 days storage when the odour was judged as slightly off (Fig. 1). The samples from the 80 % O$_2$ : 20 % CO$_2$ and 25 % CO$_2$ : 50 % N$_2$ : 25 % O$_2$ bulk packaged treatments had a fresh meat odour until after 14 days bulk storage. Thereafter the odour scores increased as time progressed, i.e. after 14 days storage from fresh meat odour (Day 0) to slightly off (Day 4) and after 21 days storage from slightly off (Day 0) to moderately off (Day 4; 25 % CO$_2$ : 50 % N$_2$ : 25 % O$_2$) and slightly off (Day 4; 80 % O$_2$ : 20 % CO$_2$).

**Acceptability assessment**

According to the statistical analysis of the acceptability scores the packaging treatments (P=0.0001), storage period (P<0.0001), display period (P=0.0001), packaging treatment X storage period (P=0.0001), packaging treatment X display period (P<0.0001) and storage period X display period (P=0.0001) interactions all influenced acceptability significantly. All the samples were initially acceptable after 0 days storage (Fig. 1). The samples from the 100 % CO$_2$ and 25 % CO$_2$ : 50 % N$_2$ : 25 % O$_2$ packaging treatments were judged moderately acceptable to slightly acceptable as the storage and subsequent display periods progressed. Only after 21 days storage and 2 days subsequent display were these samples moderately unacceptable to the consumer panel. The samples from the 75 % CO$_2$ : 25 % N$_2$ bulk packaging treatment also became unacceptable as time progressed, but were already slightly unacceptable after 7 days storage and moderately unacceptable after 14 days storage. The acceptability score for the samples from the 80 % O$_2$ : 20 % CO$_2$ followed the same trend as observed for the colour assessment. After 0 days storage the samples were acceptable but became slightly acceptable as display progressed (Day 4). Similarly, after 7 days storage, the samples were found to be moderately acceptable to the panel, but after 4 days of display they judged the samples to be slightly unacceptable. This trend persisted throughout the remaining storage (Day 14 or 21) and subsequent display periods.

**DISCUSSION**

The statistical analysis of the total bacterial counts indicated that the different bulk packaging treatments (100 % CO$_2$ vs. 75 % CO$_2$ : 25 % N$_2$ vs. 80 % O$_2$ : 20 % CO$_2$ vs. 25 % CO$_2$ : 50 % N$_2$ : 25 % O$_2$) did not differ significantly over the whole bulk storage period. According to the mean total counts the 100 % CO$_2$ and 75 % CO$_2$ : 25 % N$_2$ stored bulk packed samples could be stored for 21 days (ca. 0 °C) with a four day shelf life (ca. 0 °C) and the 25 % CO$_2$ : 50 % N$_2$ : 25 % O$_2$ and 80 % O$_2$ : 20 % CO$_2$ bulk packed samples could be stored for 21 days with a two day shelf life.

The mean total count was used as an indication of the end of retail shelf life, because according to Dainty *et al.* (1983), lean meat off-odours become evident during aerobic storage of lean
meat when microbial numbers reach ca. log 7 cm$^{-2}$. It is thus assumed that the end of shelf life is reached when the retail cut reaches a psychrotrophic count of log 5 cm$^{-2}$. This criterion is based on the fact that after being sold, the retail cut might still have a 1-2 day shelf life in a commercial refrigerator.

The lactic acid bacteria counts did not differ significantly between bulk packaging treatments. This might indicate that the inclusion of 20 - 25 % CO$_2$ in a gas mixture is sufficient to effectively inhibit the aerobic spoilage organisms and thus to prolong the storage and shelf life of fresh pork retail cuts. Sei-
All the samples were found to be normal to pale during the extended storage period and subsequent display periods, although the panel described the colour of the 100 % CO$_2$ and 75 % CO$_2$ : 25 % N$_2$ bulk packed samples as “greyish” pale and the colour of the 25 % CO$_2$ : 50 % N$_2$ : 25 % O$_2$ and 80 % O$_2$ : 20 % CO$_2$ bulk packed samples as “reddish” pale. This is demonstrated in the acceptability scores where the 25 % CO$_2$ : 50 % N$_2$ : 25 % O$_2$ and 80 % O$_2$ : 20 % CO$_2$ bulk packed samples were found to be more acceptable than the samples from the other two treatments.

An interesting trend observed for the acceptability scores of the 80 % O$_2$ : 20 % CO$_2$ bulk packed samples is that the samples were more acceptable one hour after each bulk storage period than on the subsequent display days. This trend was also observed for the colour scores. As this trend was not observed for the other bulk packaging treatment which had O$_2$ in the gas mixture (25 % CO$_2$ : 50 % N$_2$ : 25 % O$_2$), it might be that storage in high percentages O$_2$ and subsequent display in air could adversely affect the colour of retail PVC-overwrapped pork chops.

To conclude, it seems that according to the bacterial counts recorded, all four packaging treatments were successful in prolonging the storage life (21 days, ca. 0 °C) of centralised bulk pre-packaged pork retail cuts, while still ensuring a subsequent shelf life of at least 3 days (ca. 0 °C). Silliker et al. (1977) previously reported that the exposure of pork to CO$_2$-enriched atmospheres not only resulted in anti-microbial effects but residual effect as evidenced by continued inhibition of microbial growth after such meat is placed in an air atmosphere. The 100 % CO$_2$ bulk packaging treatment was the most successful, regarding storage and subsequent shelf life extension of fresh pork at ca. 0 °C, but as previously reported the colour-life (9 days) of these pork samples was shorter than the microbial shelf life (21 days) (Silliker et al., 1977; Gill & Harrison, 1988; Seideman & Durland, 1984; Scholtz et al., 1992). It thus seems that the 25 % CO$_2$ : 50 % N$_2$ : 25 % O$_2$ gas mixture was the most successful bulk packaging treatment regarding acceptability and colour scores, although a storage period of 14 days (ca. 0 °C) and subsequent shelf life of 2 days (ca. 0 °C) is recommended regarding the odour scores. According to Taylor (1990) bulk pre-packing with high O$_2$/CO$_2$ gas mixtures, which is less expensive than individually packed MA trays, could be equally effective in prolonging the red meat colour and could provide a serious challenge to some of the longer established methods used in the centralised packing and distribution of fresh meat.

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Foodborne pathogens in the South African meat industry

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INTRODUCTION

Food safety and quality issues fall into two categories: Microbiological and Chemical. Although there is a general consensus among the American and European regulatory agencies and food industries that microbiological issues should receive a higher priority, consumer perceptions suggest that more attention be given to chemical residues in the food supply (Heldman, 1990). One example of misplaced public concern is a group of chemicals, generally called pesticides, which heads the phobia list of the American public. A major menace to public health in these countries, which is overlooked amidst the outcry against pesticides, is the 6.5 million cases of illness caused by microbial contamination which are confirmed annually by the Centres for Disease Control (Shank, 1990).

There are probably well over 5 million cases of disease and over 9000 deaths each year in the U.S. attributable to the following meat and poultry borne pathogens: Salmonella spp, Campylobacter spp, Yersinia enterocolitica, Escherichia coli, Staphylococcus aureus, Listeria spp and Bacillus cereus (Mening, 1988).

In Europe, the overall picture is an increasing incidence of foodborne illnesses with an average incidence of more than 1200 cases/million inhabitants (Knowels, 1991).

THE SITUATION IN SOUTH AFRICA

I am using statistics of other countries because we do not have these statistics available in South Africa.

As foodborne diseases have been notifiable in our country since December 1989 (Dept. Nat. Health and Pop. Dev.), there is currently a lack of information on their occurrence. Five hundred and two food poisoning outbreaks are reported for the period January to December 1991 (Küstner, 1992).

These numbers do not reflect the actual occurrence of foodborne diseases, since notification is required only when 5 or more cases are simultaneously reported at one physician or medical institution. In most of these outbreaks, pathogens known to cause foodborne illness may not have been identified because laboratory investigations were late or incomplete. In others, the responsible pathogen may have escaped detection even after a thorough laboratory investigation, either because the pathogen may not have been recognized as a cause of foodborne disease or because the pathogen could not be identified by available laboratory techniques. As a result, the food vehicle of transmission and causative organisms are not known in most cases.

Although we do not have statistics available in our country, it cannot be inferred that we do not have a problem. In a survey done by the MIC most of the organisms causing meat-borne disease were isolated from meat and broilers bought from different supermarkets and butchers in the Pretoria area.

Listeriae were often found in fresh meat (minced beef, broilers), occurring in 65.6 % (n = 96) and in 56.7 % (n = 26) samples respectively. Of all the ready-to-eat processed meats examined (47 vienna sausage, 43 shoulder ham, and 44 cervelat samples), 7 (5.2 %) were positive for Listeria. Salmonella was isolated from 19.2 % (n = 26) broiler, 4.7 % ham and 2.3 % cervelat samples. S. aureus was isolated from minced meat (23.4 %), broilers (39.5 %), ham (6.7 %), vienna sausages (3.6 %) and cervelat (6.5 %). E. coli occurred often in all these products - minced meat (74.5 %), broilers (79.1 %), ham (17.8 %), vienna sausages (38.0 %) and cervelat (26.1 %). Bacillus cereus and Yersinia enterocolitica were also isolated. Bacillus cereus occurred in 2.0 % broiler, 9.8 % vienna and 5.9 % cervelat samples; Y. enterocolitica in 11.8 % minced meat, 15.7 % broiler and 3.9 % ham samples.
The results are similar to those of surveys conducted in Europe and America and suggest that the South African consumer should not eat raw or partially cooked mince and broilers. The products should be sufficiently heated before consumption, thereby killing any organisms present. However, heating alone might not be sufficient to destroy S. aureus enterotoxin or B. cereus spores, if present in the food. Another problem is the cross-contamination from a pre-cooked product to a “ready-to-eat” product.

Ham, viennas and cervelat are processed meat products. As these products are ready to eat and are generally not reheated before consumption, there is reason for concern.

Food illness caused by *Staphylococcus, E. coli* and *B. cereus* should be prevented by keeping food refrigerated at all times and ensuring that no cross-contamination occurs in the kitchen. *Listeria* and *Yersinia*, on the other hand, grow at refrigerated temperatures and therefor present a very special problem. The introduction of these two organisms into refrigerated temperatures and therefor present a very special problem. The introduction of these two organisms into refrigerated foods, especially through cross-contamination or by food handlers, appears very possible, and in each case multiplication during refrigerated storage can occur.

The problem of contamination begins on the farm. It proceeds to accumulate and aggravate with each step, ultimately leading to the consumer, who indeed can make it worse. A short shelf life is a consumer’s protection. As the shelf life is extended, so are dangers.

It is important to ensure that a product is safe, even more so when the shelf life is extended (Collins-Thompson, 1980).

**ELIMINATING OR MINIMIZING THE RISK OF CONTAMINATION**

Let’s get back to basics. Important measures to prevent food illnesses include educating food workers in safe handling techniques, proper personal hygiene, properly heating foods to kill pathogens and holding foods under appropriate conditions to avoid bacterial multiplication.

Microbiological safety of food depends on:
- Careful selection and handling of raw materials.
- Products and processes designed to eliminate harmful microorganisms or to prevent their growth.
- Design of equipment and food premises with hygiene in mind.
- Training staff to apply validated control procedures.
- Specific requirements being incorporated into a food before marketing.

The trend towards more convenient and so called “healthy” foods (lower calories, no preservatives etc.) can reduce microbiological safety and therefor require greater care in manufacture and distribution. They demand greater knowledge to control microbiological hazards inherent in food raw materials and products.

The traditional approach to Quality Control normally requires microbiological examination of raw materials and final product and monitoring of process parameters and hygiene standards. This type of approach is unstructured, relying heavily on the skills and experience of the personnel involved and is rarely preventative in nature.

The Hazard Analysis Critical Control Point (HACCP) concept is a more structured alternative. The aim is to identify stages in processing or distribution where lack of control could lead to a safety hazard, thereby allowing preventative control measures to be implemented (Baird-Parker, Mayes, 1991).

The HACCP system is a management technique that allows suitably trained persons to examine the many processing operations involved in the preparation of a food product, and identify those processes/operations that are critical to the safety of the product. Most importantly, the application of HACCP allows a company to move from a retrospective, Quality Control based philosophy of inspection and sampling/testing, to a contemporaneous, Quality Assurance based philosophy. The latter’s design gives assurance of key raw materials and control of all critical operations (Baird-Parker, Mayes, 1991).

The application of HACCP to the inspection and control of foodborne disease has been recommended by the World Health Organization (1990).

**Development of HACCP**

A HACCP study can be applied at the product concept stage, or to existing processes and products. Each process as well as processing conditions are unique to each establishment. The study requires the collection, collation and evaluation of technical data. This requires that the evaluation be carried out by a microbiologist or other appropriate specialist who is an expert on the process/product under study. However, it is strongly recommended that HACCP studies should be carried out by multi-disciplinary study teams. The study team should consist of:

A Quality Assurance/control specialist: An individual able to understand the hazards and associated risks.
A production specialist: An individual who has responsibility for, or is closely involved with the process under study.

An engineer: An individual who has working knowledge of the design and operation/performance of the process equipment under study.

Others: Other relevant specialists e.g. buyers, packaging and distribution specialists may be co-opted onto the study team.

The team should include local personnel from the establishment, because they will be the most knowledgeable about the actual processing conditions (Baird-Parker, Mayes, 1991).

Other reasons for involving local personnel include:
- Developing a HACCP plan is educational and this opportunity for educating local personnel should not be overlooked;
- There will be a sense of local ownership of the plan if plant personnel participate;
- The plan must be understood and implemented after the "experts" leave;
- Someone, most likely a local person, should be responsible for assuring that the HACCP plan is properly updated (Tompkin, 1990).

The study team should then conduct a hazard analysis. Hazard has been defined as "the unacceptable contamination, unacceptable growth and/or unacceptable survival by microorganisms of concern to safety or spoilage and/or the unacceptable production or persistence in foods of products of microbial metabolism (e.g. toxins, enzymes)" (ICMSF, 1988).

Having defined the terms of reference (hazards) for the study, the team must audit the process under study and produce a flow diagram around which the study can be based. Once a flow diagram has been produced, it is used to allow the study team to identify where hazards can be introduced into the product and to identify Critical Control Points (CCP's). A Critical Control Point is defined as "a location, practice or procedure at which control can be exercised over one or more factors to minimize or prevent a hazard from occurring" (ICMSF, 1988). This definition is particularly suitable for fresh meat and poultry as well as ready-to-eat products. In particular, the definition allows for and encourages the adoption of CCP's to minimize contamination with enteropathogens during the slaughtering process and subsequent handling of raw meat and poultry. The definition is realistic in its recognition of a gradient in the ability to control a hazard. The gradient ranges from partial control to absolute control. This has led to two general classifications of CCP's, based on the level of confidence the hazards can be prevented.

A CCP1 will assure control while a CCP2 will minimize but cannot assure the control of a hazard. Conversely, at a CCP2 the risk of the hazard can be significantly higher if no attempt is made to control the hazard. Both types of CCP's are important, and both must be controlled (Tompkin, 1990).

Examples of CCP1 in meat and poultry operations are:
- Cooking to 63 °C ensures the destruction of Salmonella in raw meat.
- Storage at less than 10 °C prevents the growth of C. botulinum in meat and poultry.
- Controlled fermentation prevents the formation of S. aureus enterotoxin during the production of raw sausage.
- Acidifying to pH < 4.6 prevents pathogen growth in shelf-stable pickled sausages.
- Drying to Aw < 0.86 prevents bacterial pathogen growth in snack meats.

Examples of CCP2 in meat and poultry operations:
- Proper care during carcass evisceration reduces the incidence of Salmonella and Campylobacter on fresh meat and poultry.
- Separating raw meat from cooked meat processing reduces the risk of pathogen contamination of cooked products.
- Following correct personal hygiene practices reduces the risk of product contamination.
- Cleaning, sanitizing, and drying the environment reduces the risk of Listeria contamination of cooked products.
- Refrigerating cooked products reduces the risk of pathogen growth between cooking and serving.

The study team leader should proceed through the process, using the audit data as a guide, and ask the team to identify:

where the specific microorganisms under consideration could be introduced into the product;
those characteristics (e.g. pH, Aw, structure) that are essential to the safety of the product;
those processes that specifically render raw materials/products safe by removing, inhibiting or preventing contamination and/or growth of the specific microorganisms concerned.

The study team should also consider equipment design, process management and realistic process malfunctions. Identification of a CCP is made simpler by following the flow diagram. Each CCP identified will be specific for a particular process/product combination. Following identification of a CCP, the study team must also identify a control procedure (indicating how each CCP will be controlled) and a limit, which is the
target or standard required at each CCP. Finally, the team must identify a suitable monitoring system for each CCP, which will allow management to ensure that all the above are operating within specification (Baird-Parker & Mayes, 1991).

A key element of the HACCP system is the use of rapid measurements to monitor whether established criteria are being met at each CCP. Examples of rapid measurements used in the meat and poultry processing industries include visual observations and measurements for fat, moisture, pH, time, temperature, humidity and air pressure or vacuum. Since the results are quickly available, the data can be used to make adjustments during processing, thereby maintaining continuous control of the operation. Measurements which require too much time to allow adjustments while an operation is in process are not suitable for monitoring. Such measurements, however, can be useful for verification (Tompkin, 1990).

Verification has been defined as “the use of supplementary information to check whether the HACCP system is working” (ICMSF, 1988). Examples of measurements used for verification include microbiological assays; official methods of fat, moisture and protein de-to-eat meat and poultry products perform a hazard analysis, five factors (with their control) should be considered for reducing the risk of microbiological hazards. Firstly, the processing procedure must be designed and controlled to eliminate hazards, wherever possible. Secondly, the characteristics of a product should be modified to improve microbial stability during processing and during subsequent storage, distribution and use. Thirdly, contamination must be prevented between the time products are processed (e.g. cooked) to when they are packaged. In the fourth, appropriate packaging design and labelling information should be used to instruct the consumers in proper handling of the product (e.g. keep refrigerated). In the fifth, a combination of as many factors as possible should be used (Tompkin, 1986).

Examples of product characteristics influencing the microbial stability of ready-to-eat meat and poultry products are: Brine content or \( A_w \), carbohydrate content, acid content (pH), smoke, phosphate content, metallic ion content (e.g. iron, manganese, nitrite), microbial content of ingredients, browning of the products surface (hot oil, flame), seasonings added after processing, sodium lactate and potassium sorbate.

The following is an example of the use of a flow diagram and application of HACCP to a process for producing canned hams which are subsequently sliced and packaged as sliced ham:

At the present time, no greater microbiological issue faces the meat and poultry industry than the potential pathogen, *Listeria*. HACCP can be an effective system to control this organism, but inadequate technology and the prevalence and character-

istics of this organism combined, make it difficult to eliminate it from the cooked product environment of meat and poultry establishments. For the present, a realistic assessment is that the control of *Listeria* in the cooked product environment is a CCP2.

This assessment and recognition of the potential severity of the hazard (i.e. listeriosis with a high rate of fatality among certain segments of the population) means greater effort than now must be applied in the industry to minimize the risk of post-process contamination (Tompkin, 1990).

CONCLUSION

Major points to remember are:
- Disease from meat/poultry is a serious and complex problem;
- This is not a new problem, though it does have new facets;
- This is a problem with all raw meats, of which poultry is but one;
- This is a problem for feed manufacturers, animal producers, slaughtering plants, processing plants, transportation, retail sales and consumers alike;
- The extent of this problem can be reduced.

Quality control attitudes must change from an assessment of appearances to a concern for safety via quality assurance.

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Effect of age and fatness on tenderness of beef cuts cooked according to a dry heat cooking method

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INTRODUCTION

Factors affecting the tenderness of meat have been the subject of continuous research for many years. It is a well-established fact that tenderness is of paramount importance in the enjoyment of eating meat and that varying degrees of this quality factor usually dictate the method of cooking. Normally only inherently tender meat is cooked by dry heat cooking methods. In meat that is inherently tough, the main aim is to obtain a reasonably tender cooked product, usually obtained by heating the meat at relatively low temperatures in the presence of moisture for several hours (Ledward in Priestley, 1979).

Two separate phases of toughness are associated with increasing cooking temperature. In the first phase, there is a three- to four-fold toughening of muscle proteins (associated with denaturation of the myofibrillar structure) as the cooking temperature rises from 40 to 50 °C. Toughness is doubled further in the second phase (linked with collagen shrinkage) as cooking temperatures rise to between 60 and 75 °C (Davey & Gilbert, 1974). Shrinkage of collagen, conversion of collagen to gelatin, melting of fat, changes in pH and loss of water-holding capacity occur during heating. Chemical changes in the heat-labile compounds include the breaking of many of the myofibrils at the Z-lines and the virtual disintegration of the I-bands (Jones, 1977). Collagen varies between muscles within a carcass, between carcasses for individual muscles, with animal age and breed, and with cooking conditions (Harris, 1976).

The relationship of age of the animal with the palatability traits of beef has been investigated by numerous researchers (Hill, 1966, Bailey, 1972, Dutson, 1974). Results of these studies have consistently shown that as the physiological age of the carcass advances beef palatability (in terms of tenderness) decreases, due to decreasing amounts of heat-labile collagen. According to Kingston, Congram, Hopkins, Harris, Powell, Shorthose & Swain (1987) in Shorthose & Harris (1990), results of a survey on consumer preferences for the physical properties of beef loin and topside steaks from animals of different ages (dentition group), fat class, sex and breed, indicated that consumers generally preferred electrically stimulated meat of 0 - 2 tooth animals. Shorthose & Harris (1990) confirmed that animal age is an important factor determining tenderness and acceptability of meat. These findings showed that the mean tenderness of 12 beef muscles from animals of 8 different age groups (ranging from 1 to about 60 months old), decreased significantly (P<0.001) with age. The rate of toughening of individual muscles was related to their connective tissue strength.

The effect of fatness on the eating quality of meat is still not clear, although it is generally associated with increased palatability. According to Savell & Cross (1986) there are four theories regarding the mechanism by which intramuscular fat (marbling) influences meat tenderness: the bite theory (marbling decreases the bite force by replacing protein with lipid, resulting in less bulk density); the strain theory (increased marbling deposition in the perimysium or endomysium results in connective tissue membranes becoming thinner and less resistant to fragmentation); the lubrication theory (marbling serves to lubricate muscle fibres and fibrils, thus increasing...
juiciness and the sensation of tenderness) and the insurance theory (high levels of marbling help to prevent the dryness and toughness of meat that is cooked too long, too rapidly or by the wrong method).

Dolezal, Smith, Savell & Carpenter (1982) found progressive improvement in cooked beef palatability as carcass subcutaneous fat thickness increased from less than 2.5 mm up to 7.6 mm. Subcutaneous fatness regardless of genotype. Only steers and heifers were selected for the small proportion of bull carcasses presently on the market in South Africa.

Carcasses

Five beef carcasses of each fat code within each of the age groups were procured, having been selected by qualified classifiers at the Johannesburg Abattoir in City Deep and/or at the Pyramid Abattoir in Pretoria. The carcasses were electrically stimulated within 10 minutes of stunning, dressed, halved, chilled overnight at between 0 and 5 °C, labelled and transported to the IAPI in a refrigerated truck.

In order to ensure that visually assessed carcasses were correctly placed into the various fat code classes, it was decided to first determine the % chemical fat in a sample joint, the prime rib cut of each carcass, then measure the fat thickness of each carcass (between the 10 and 11th thoracic vertebrae, 5 cm from the midline of the carcass) and finally determine the subcutaneous fat content of both the prime rib cut and the total carcass (Table 2). This procedure led to the final selection of 108 instead of 90 carcasses (Table 3). All were used in the assessment of tenderness characteristics.

Sample preparation for sensory analysis and shear force measurements

On arrival at the Meat Industry Centre, IAPI at least three left beef sides (Table 3) within each fat code and age group were cut into 15 wholesale cuts and trimmed into retail cuts, the rump and topside cuts being deboned before trimming. The mode of jointing into retail cuts was determined in collaboration with the Meat Board’s Home Economists during a pilot study.

The cuts were then vacuum-packaged, aged at 4 °C for 10 days post-slaughter and stored at --40 °C prior to sensory analysis and shear force resistance measurements.

Table 1: The six fat codes of the south african beef carcass classification system

<table>
<thead>
<tr>
<th>Fat code</th>
<th>Fat thickness(mm)</th>
<th>Subcutaneous fat (%)</th>
<th>Total fat in prime rib (%)</th>
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<tr>
<td>1</td>
<td>&lt;1,0</td>
<td>3,58</td>
<td>&lt;11,5</td>
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<tr>
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<td>1,1-3,0</td>
<td>3,64-4,66</td>
<td>11,7-14,6</td>
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<td>3,1-5,0</td>
<td>4,71-5,73</td>
<td>14,7-17,6</td>
</tr>
<tr>
<td>4</td>
<td>5,1-7,0</td>
<td>5,78-6,81</td>
<td>17,8-20,7</td>
</tr>
<tr>
<td>5</td>
<td>7,1-10,0</td>
<td>6,86-8,52</td>
<td>20,8-25,2</td>
</tr>
<tr>
<td>6</td>
<td>&gt;10,0</td>
<td>&gt;8,42</td>
<td>&gt;25,2</td>
</tr>
</tbody>
</table>

The following cuts (muscles) were used: Prime rib -- 8th to 10th rib (M. longissimus thoracis (LTP)); Loin (M. longissimus lumborum (LL)); Wing rib -- 11th to 13th rib (M. longissimus thoracis (LTW)); Rump (M. gluteus medius (GM)); Topside (M. semimembranosus (SM)); Silverside (M. semitendinosus (ST)) and Fillet (M. psoas major (PM)).

At each session (three sessions per day for six days) a particular cut from one of the three carcasses of a fat code and age group (3 age x 6 fatness = 18 cells x 3 repetitions) were evaluated simultaneously. Tasting was then performed on the next cut, without any particular cooking order (63 muscle samples (Table 3) x 7 cuts = 441 samples). Cuts were defrosted at 6 -- 8 °C for periods varying between 24 and 36 hours (depending on mass) until the internal temperature reached 2 -- 5 °C (American Meat Science Association, (AMSA), 1978).

All the cuts, excluding the loin, were cooked in primal form. The loin cut is traditionally divided into steaks. Before cooking commenced, therefore, all the frozen wholesale loin cuts were portioned into beef steak retail cuts of 25 mm thickness (AMSA, 1978) vacuum packaged and stored at --40 °C. Defrosted steaks were cooked according to an oven--broiling method whereby the meat is cooked by direct radiant heat. An electric oven, door closed, was set on “Broil” 10 minutes prior to use (200 °C). Steaks were placed on an oven pan (to collect meat juices expelled during cooking) and then placed in the oven, 7 -- 10 cm below the heat source, with the oven door remaining closed. Two J--type thermocouples, placed in the geometric centre of two identifiable steaks, were used to record internal temperature. A hand--model Kane--Mane probe, equipped with a T--type thermocouple, was used to monitor the temperature of the other steaks. All steaks were

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removed as soon as the designated internal temperature of 70 °C was reached.

The other cuts were roasted whole at 160 °C, on a rack in an open oven pan, to an internal temperature of 70 °C. A J–type thermocouple, placed in the geometric centre of each muscle was linked to a centrally controlled computer system and used to record internal temperature. During the various pilot studies it became quite clear that the internal temperature of certain muscles (e.g. M. semimembranosus) differed considerably from to that of the rest of the topside cut, due to it's more exposed anatomical position. It was therefore decided to only measure the internal temperature of the muscle to be evaluated. A hand–model Kane–Mane probe equipped with a T–type thermocouple was used to check the final temperature (70 °C) of the cut prior to removal from the oven.

All cuts were held for a standing period of 10 minutes at room temperature following cooking. Thereafter, all the different muscles were dissected and halved for sensory analysis and shear force measurements respectively. The shear force portions were wrapped in aluminium foil and stored at 6 - 8 °C for 24 hours. They were then removed from the refrigerator and allowed to stand for up to 4 hours to reach room temperature (centrally controlled at 22 °C) before samples were cored. The exceptions were the prime rib (LTP) cuts, which were allowed (on an experimental basis), to stand at room temperature following cooking until they reached room temperature, before they were cored. Crouse & Koohmaraie (1990) found that neither time of storage nor storage temperature appreciably affected shear force values or variation of shear force within treatments.

Half of the muscle designated for sensory analysis was immediately portioned. Ten cubed samples were taken from the middle of each muscle and immediately individually wrapped in foil marked with randomly chosen three digit codes. These samples were then served at an internal temperature of 60 °C, within 30 minutes of the whole cut being removed from the oven.

The following data were recorded during the study:

**Descriptive palatability attributes**

A ten-member, trained, descriptive attribute panel was used to evaluate palatability attributes of each cut. Panelists were selected and trained in accordance with the AMSA Guidelines for Cooking and Sensory Evaluation of Meat (AMSA, 1978) and the procedures of Cross, Moen & Stanfield (1978). Samples were evaluated for tenderness and residue (connective tissue amount) on an 8-point scale (one denoting the least favourable condition and an eight the most favourable).

At each session (three per day for six days) panelists received a set of randomly selected cubes (1 cm/side), representing the three age groups of a single fat code. Distilled water at room temperature was provided to cleanse the palate between samples.

**Tenderness determination**

Tenderness was measured as the maximum force (Newtons) required to shear a cylindrical core of cooked muscle perpen-

### Table 2: Comparison of carcasses conforming to the South African beef carcass classification system, selected for this project

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Prime rib % chemical fat</th>
<th>Subcutaneous fat</th>
<th>Calculated total fat % of carcass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td>0.2458</td>
<td>0.6584</td>
<td>0.3397</td>
</tr>
<tr>
<td>A</td>
<td>22.79</td>
<td>6.32</td>
<td>6.39</td>
</tr>
<tr>
<td>B</td>
<td>23.91</td>
<td>6.17</td>
<td>6.05</td>
</tr>
<tr>
<td>C</td>
<td>23.58</td>
<td>5.92</td>
<td>5.92</td>
</tr>
<tr>
<td>Fat code</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>1</td>
<td>13.72</td>
<td>2.43</td>
<td>3.11</td>
</tr>
<tr>
<td>2</td>
<td>16.64</td>
<td>4.42</td>
<td>4.61</td>
</tr>
<tr>
<td>3</td>
<td>20.22</td>
<td>5.66</td>
<td>5.44</td>
</tr>
<tr>
<td>4</td>
<td>24.92</td>
<td>6.42</td>
<td>6.44</td>
</tr>
<tr>
<td>5</td>
<td>28.97</td>
<td>7.60</td>
<td>7.50</td>
</tr>
<tr>
<td>6</td>
<td>36.10</td>
<td>10.30</td>
<td>9.60</td>
</tr>
<tr>
<td>Interaction</td>
<td>0.4951</td>
<td>0.2679</td>
<td>0.0129</td>
</tr>
</tbody>
</table>

*Means in the same column with different superscripts differ significantly (P<0.05)*

### Table 3: Experimental design for evaluation of beef carcasses

<table>
<thead>
<tr>
<th>Beef carcasses</th>
<th>Age classification</th>
<th>Fat code</th>
<th>A (no permanent incisors)</th>
<th>B (1-2 permanent incisors)</th>
<th>C (8 permanent incisors not worn down)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>SE:COLL</td>
<td>SE:COLL</td>
<td>SE:COLL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total number of carcasses:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>38 (22:16)</td>
<td>35 (20:15)</td>
<td>35 (21:14)</td>
</tr>
</tbody>
</table>

SE:COLL Number of left sides of carcasses respectively used for sensory evaluation (SE) and collagen (COLL) determination.
The significance of the various factors contributing to tender-
ness, evaluated for the three age groups, is summarized in Ta-
ble 4. According to the taste panel age had a significant effect
on the tenderness and residue of the various muscles, irre-
spective of muscle. Shear force resistance was only signifi-
cantly different for the LTW and the ST in the silverside. Age
did not have any significant effect on collagen content, but sig-
nificantly influenced the collagen solubility of all cuts.

The average values of all indicators of tenderness measured,
as influenced by the different age groups and fat codes, are
presented in Table 5. According to the taste panel scores the
M. longissimus thoracis of the A and B age groups were sig-
nificantly (P<0.05) more tender and contained less residue
than those from the C age group. The M. longissimus lumbo-
rum of the A age group was significantly (P<0.05) more tender
and contained less residue than those from the C age group.
The GM, SM, ST and PM of the A age group were significantly
(P<0.05) more tender than those of the B age group, which in
turn were significantly (P<0.05) more tender than those of the
C age group. This was also true for residue except for the GM
where those of the A and B age groups were significantly
(P<0.05) more tender than of the C age group.
The LTW of the A age group showed significantly (P<0.05)
less resistance to shear than that of the C age group, while
the ST of the A group showed significantly (P<0.05) less shear
resistance than those of the B and C age groups.

Age had no significant effect on collagen content for the vari-
ous muscles studied. The collagen of the LTP and GM of the A
age group was significantly (P<0.05) more soluble than that of
the same muscles of the B and C age groups. In comparison,
in the LTW and LLL, only the collagen from the A age group
was significantly (P<0.05) more soluble than that from the C
age group. The collagen of the ST and SM from the A age
group was significantly (P<0.05) more soluble than that from
the B age group which, in turn, was significantly (P<0.05) more
soluble than that from the C age group.

These results are in accordance with Shorthose & Harris
(1990), who reported a significant decrease in tenderness with
increased age (ranging from 1 to about 60 months old). All
their objective measurements (Instron-compression, adhesion,
Warner-Bratzler shear) indicated strong linear (and in some
cases, curvilinear) relationships with animal age. However,
when considering results from taste panel evaluations of the
meat, they found that age did not have a constant effect on
tenderness of the PM muscles and that the results for the
other muscles all showed non-linearity (P<0.001).

Results of the present study are in agreement with Herring,
Cassens and Briskey (1967). They found that collagen solubil-
ity, in both the M. longissimus dorsi and M. semimembranosus

STATISTICAL ANALYSES

Two-way analysis of variance, with age and fat code as the
main effects, was performed on each of the dependent vari-
ables (3 age groups and 6 fat codes were the factorial ar-
rangeent). The intervals for factor means for the main effects
and the two factor interactions were then plotted. A correlation
matrix was constructed to test for correlations between differ-
ent variables.

RESULTS AND DISCUSSION

The effect of age

The significance of the various factors contributing to tender-
ness, evaluated for the three age groups, is summarized in Ta-

Cylindrical cores (25 mm diameter) were cut from the LTP,
LTW, GM, SM, ST and PM. Due to the fact that the LLL was
portioned into 25 mm steaks, a 13 mm core was used.

Collagen content and solubility

At least two left beef sides within each fat code and age group
(18 groups) (Table 3) were used to determine total collagen
content and solubility of each cut (45 left sides x 7 cuts = 325
samples). The carcasses were separated into wholesale cuts
(at 10 °C) on arrival at the Meat Industry Centre, IAPI. These
cuts were vacuum-packaged and aged at 4 °C for 10 days af-
after slaughter. The major muscles of each cut, namely the LTP,
LTW, LLL, GM, SM, ST and PM, were then dissected (including
the removal of the epimysium) as determined during a pilot
study. The muscles were then vacuum-packaged until being
analysed (fresh) for collagen content and solubility.

The total collagen content of each of the respective muscles
was determined according to a method of Weber (1973) and
hydroxyproline according to Bergman & Loxley (1963). Total
collagen content was calculated as the ratio of hydroxyproline
nitrogen relative to the total nitrogen content, expressed as a
numeric value multiplied by 1 000 (Boccard, Naudé, Cronjé,
Smit, Venter & Rossouw, 1979). Collagen solubility was deter-
mained according to a combination of the methods of Hill
(1966) and Bergman & Loxley (1963), being expressed as hy-
droxyproline content of the filtrate as a percentage of total hy-
droxyproline (filtrate plus residue).

The shear force measurements were generated with a Warner
Bratzler shear attachment, fitted to an Instron Universal Testing
Machine Model 1140 (Instron Food Testing Instrument, 1974).
Increasing values indicated greater shear forces and therefore
tougher meat.

Increasing values indicated greater shear forces and therefore
tougher meat.

M. longissimus thoracis

M. longissimus lumbo-
rum

M. semimembranosus

The significance of the various factors contributing to tender-
ness, evaluated for the three age groups, is summarized in Ta-
decreased significantly with advancing maturity. Collagen content did not differ between age groups in the *M. longissimus dorsi* but the *M. semimembranosus* in the E age group had more collagen than in the A and B maturity groups.

Table 4: Significance levels for two-way analysis of variance for sensory characteristics, shear force resistance and collagen measurements of cuts as influenced by age (A) and fat code (F)

<table>
<thead>
<tr>
<th></th>
<th>P-Value Age</th>
<th>P-Value Fat code</th>
<th>Interaction A X F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenderness (8 = Extremely tender, 1 = Extremely tough)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prime rib</td>
<td>0.0046</td>
<td>&lt;0.0001</td>
<td>0.0144</td>
</tr>
<tr>
<td>Wing rib</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Loin</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Silverside (M. semitendinosus)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Rump</td>
<td>0.0001</td>
<td>0.0118</td>
<td>0.0591</td>
</tr>
<tr>
<td>Topside</td>
<td>&lt;0.0001</td>
<td>0.1961</td>
<td>0.0081</td>
</tr>
<tr>
<td>Fillet</td>
<td>&lt;0.0001</td>
<td>0.0003</td>
<td>0.0626</td>
</tr>
<tr>
<td>Residue (8 = None, 1 = Abundant)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prime rib</td>
<td>0.0124</td>
<td>&lt;0.0001</td>
<td>0.0089</td>
</tr>
<tr>
<td>Wing rib</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Loin</td>
<td>0.0002</td>
<td>0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Silverside (M. semitendinosus)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Rump</td>
<td>&lt;0.0001</td>
<td>0.0228</td>
<td>0.0737</td>
</tr>
<tr>
<td>Topside</td>
<td>&lt;0.0001</td>
<td>0.7332</td>
<td>0.0002</td>
</tr>
<tr>
<td>Fillet</td>
<td>&lt;0.0001</td>
<td>0.0014</td>
<td>0.0193</td>
</tr>
<tr>
<td>Instron (N/2.54 cm)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Prime rib</td>
<td>0.6913</td>
<td>0.3045</td>
<td>0.6556</td>
</tr>
<tr>
<td>Wing rib</td>
<td>0.0464</td>
<td>0.0618</td>
<td>0.9793</td>
</tr>
<tr>
<td>Loin</td>
<td>0.4940</td>
<td>0.1597</td>
<td>0.9254</td>
</tr>
<tr>
<td>Silverside (M. semitendinosus)</td>
<td>0.0005</td>
<td>0.3820</td>
<td>0.7332</td>
</tr>
<tr>
<td>Rump</td>
<td>0.4780</td>
<td>0.0063</td>
<td>0.2819</td>
</tr>
<tr>
<td>Topside</td>
<td>0.5677</td>
<td>0.3349</td>
<td>0.6090</td>
</tr>
<tr>
<td>Fillet</td>
<td>0.8449</td>
<td>0.0019</td>
<td>0.5852</td>
</tr>
<tr>
<td>Collagen content (Hypro N/Total N x 10^9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prime rib</td>
<td>0.1767</td>
<td>0.3685</td>
<td>0.0363</td>
</tr>
<tr>
<td>Wing rib</td>
<td>0.7958</td>
<td>0.7619</td>
<td>0.9966</td>
</tr>
<tr>
<td>Loin</td>
<td>0.5321</td>
<td>0.0350</td>
<td>0.0574</td>
</tr>
<tr>
<td>Silverside (M. semitendinosus)</td>
<td>0.1212</td>
<td>0.5696</td>
<td>0.7039</td>
</tr>
<tr>
<td>Rump</td>
<td>0.4034</td>
<td>0.3689</td>
<td>0.4551</td>
</tr>
<tr>
<td>Topside</td>
<td>0.9586</td>
<td>0.3253</td>
<td>0.6982</td>
</tr>
<tr>
<td>Fillet</td>
<td>0.1624</td>
<td>0.9744</td>
<td>0.5388</td>
</tr>
<tr>
<td>Collagen solubility (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prime rib</td>
<td>&lt;0.0001</td>
<td>0.9031</td>
<td>0.5519</td>
</tr>
<tr>
<td>Wing rib</td>
<td>0.0203</td>
<td>0.9831</td>
<td>0.9688</td>
</tr>
<tr>
<td>Loin</td>
<td>0.0048</td>
<td>0.6734</td>
<td>0.9407</td>
</tr>
<tr>
<td>Silverside (M. semitendinosus)</td>
<td>&lt;0.0001</td>
<td>0.0043</td>
<td>0.9470</td>
</tr>
<tr>
<td>Rump</td>
<td>0.0008</td>
<td>0.1746</td>
<td>0.9101</td>
</tr>
<tr>
<td>Topside</td>
<td>0.004</td>
<td>0.1010</td>
<td>0.7881</td>
</tr>
<tr>
<td>Fillet</td>
<td>0.0001</td>
<td>0.0399</td>
<td>0.9708</td>
</tr>
</tbody>
</table>

In agreement with the present study Cross, Carpenter & Smith (1973) also found that initial and fibre tenderness ratings, amount of connective tissue, shear force values, percentage moisture-free fat and amount of soluble collagen differed significantly (P≤0.05) among age groups (1 yr vs. 4 yr vs. 10 yr), with no significant difference in collagen content between the groups. However, Covington, Tuma, Grant & Dayton (1970) did not find any significant difference in shear force measurements between *M. longissimus* steaks for the three maturity groups studied (12 - 18, 18 to 30 and 30 to 38 months).

According to Devine & Chrystall in Hui (1982) recent unpublished studies by Young have shown that for the GM muscle, the proportion of soluble collagen decreases from 60 % in 6-month old ewe lambs to 40 % in 18-month old ewes.

The effect of fat code

The effect of the six different fat code levels on the significance levels for the various tenderness parameters are summarized in Table 4. According to the taste panel, fatness (as defined by the various fat codes) had a significant effect on the tenderness and residue in the various muscles, with the exception of the GM. Shear force resistance was only significantly different for the GM and the PM. Surprisingly fat codes showed a significant effect on the collagen content of the LLL, as well as on the collagen solubility of the ST, SM and PM. The averages of the tenderness measurements are presented in Table 5. Each muscle will be discussed separately.

According to the taste panel, the LTP of fat code 6 were significantly (P≤0.05) more tender and contained less residue than those of fat code 5 which, in turn were significantly (P≤0.05) more tender and contained less residue than that of fat codes 1 to 4. The fat codes of the LTP had no significant effect (P>0.05) on either shear force measurements, collagen content or collagen solubility.

The LTW of fat code 6 were also significantly (P≤0.05) more tender than those of fat codes 1 to 4. The LTW of fat code 5 were significantly (P≤0.05) more tender than those of fat codes 2, 3 and 4, while the LTW of fat code 1 were significantly (P≤0.05) more tender than those of fat code 4. The LTW of fat codes 5 and 6 contained significantly less residue than those of fat codes 1 to 4. Once again, the fat codes of the LTW had no significant effect (P>0.05) on either shear force measurements, collagen content or collagen solubility.

The LL of fat code 5 and 6 were significantly (P≤0.05) more tender than those of fat codes 1, 3 and 4. The LL of fat code 2 were significantly (P≤0.05) more tender than those of fat codes 3 and 4. The LL of fat codes 2, 5 and 6 contained significantly
Table 5: Means for the sensory characteristics, shear force resistance and collagen measurements of muscles as influenced by different ages and fat codes

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th></th>
<th>C</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tenderness (8 = Extremely tender, 1 = Extremely tough):</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prime rib</td>
<td>5.20</td>
<td>5.18</td>
<td>4.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wing rib</td>
<td>5.73</td>
<td>5.51</td>
<td>4.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loin</td>
<td>4.80</td>
<td>4.52</td>
<td>4.28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silverside (M. semitendinosus)</td>
<td>5.82</td>
<td>5.26</td>
<td>4.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rump</td>
<td>5.57</td>
<td>5.29</td>
<td>4.99</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topside</td>
<td>5.29</td>
<td>4.76</td>
<td>4.47</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fillet</td>
<td>6.74</td>
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<td>5</td>
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<td>6.32&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>5</td>
<td>6</td>
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<tr>
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<td>117.5</td>
<td>119.9</td>
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<td>95.8</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
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<tr>
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<td>3.05</td>
<td>3.53</td>
<td>3.77</td>
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<tr>
<td>Wing rib</td>
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<td>2.57</td>
<td>2.70</td>
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<td>2.92</td>
<td>2.77</td>
<td>2.97</td>
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<td>4.58</td>
<td>5.23</td>
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<td>3.32</td>
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<tr>
<td>Collagen solubility (%)</td>
<td>19.88&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>14.98&lt;sup&gt;c&lt;/sup&gt;</td>
<td>12.14&lt;sup&gt;d&lt;/sup&gt;</td>
<td>14.35</td>
<td>16.57</td>
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<td>16.53</td>
<td>15.93</td>
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<td>14.72&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.94&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>15.28</td>
<td>18.32</td>
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<td>18.01</td>
<td>19.12</td>
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<td>11.36&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>15.01&lt;sup&gt;c&lt;/sup&gt;</td>
<td>19.83</td>
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<td>15.79&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
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<tr>
<td>Rump</td>
<td>21.12&lt;sup&gt;c&lt;/sup&gt;</td>
<td>15.97&lt;sup&gt;c&lt;/sup&gt;</td>
<td>11.9&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>12.11&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>13.28&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>15.39&lt;sup&gt;c&lt;/sup&gt;</td>
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</table>

<sup>ab</sup> Means in the same row with different superscripts differ significantly (P<0.05)
The LL of fat codes 5 and 6 were significantly (P≤0.05) more tender than those of fat codes 1, 3 and 4. The LL of fat code 2 were significantly (P≤0.05) more tender than those of fat codes 3 and 4. The LL of fat codes 2, 5 and 6 contained significantly (P≤0.05) less residue than those of fat codes 3 and 4. The fat codes of the LL had no significant effect (P≥0.05) on shear force measurements or collagen solubility. Surprisingly, the collagen content of the LL of fat code 4 was significantly lower (P≤0.05) than that of fat codes 1 and 5.

According to the taste panel the ST of fat code 1 was significantly (P≤0.05) more tender and contained less residue than that from fat code 6 which, in turn was significantly (P≤0.05) more tender and contained less residue than those of fat codes 2 to 5. The fat codes of the ST had no significant effect (P≥0.05) on shear force measurements or collagen content. However, the collagen solubility of the ST of fat code 3 was significantly (P≤0.05) higher than that of fat codes 1, 2, 4 and 6.

The GM of fat code 6 was significantly (P≤0.05) more tender than those of fat codes 1, 3 and 4, while the GM of fat code 6 contained significantly (P≤0.05) less residue than did those from fat codes 1, 2 and 4. The GM of fat codes 1 and 6 showed significantly (P≤0.05) less resistance to shear than those of fat codes 4 and 5. The fat codes of the LTW had no significant effect (P≥0.05) on collagen content or collagen solubility.

Fatness, as determined by fat codes, had no significant effect on the SM as far as tenderness, residue, shear force resistance and collagen content are concerned. However, the collagen of the SM of fat codes 3 and 5 was significantly (P≤0.05) more soluble than that from fat codes 1, 2 and 4.

The taste panel evaluated the PM with a fat code of 1 as significantly (P≤0.05) the most tender. The PM of fat code 6 was significantly (P≤0.05) more tender than that of fat code 3. The PM with a fat code of 1 contained significantly (P≤0.05) less residue than did those of fat codes 2 to 5. The PM of fat code 6 showed significantly (P≤0.05) less resistance to shear than did those from fat codes 1, 3 and 4. The collagen of the PM muscles with fat codes of 3 and 6 was significantly (P≤0.05) more soluble than that from PM muscles of fat codes 1 and 2.

Many researchers have reported that tenderness increases linearly with increasing degrees of marbling (Tatum, Smith, Berry, Murphey, Williams & Carpenter, 1980; Dolezal et al., 1982; Tatum, Smith, & Carpenter, 1982). For instance, Covington et al. (1970) found that *M. longissimus* steaks from the "moderate" marbled (22,69 % ether extract on a dry basis) carcasses were significantly more tender than those from the "small" marbled (17,15 %) carcasses. Davis, Smith, Carpenter, Dutson & Cross (1979) found that the most tender *M. longissimus* steaks had (P≤0.05) more intramuscular fat, less intramuscular moisture, higher water holding capacity, longer sarcomeres, higher collagen solubility and a lower fragmentation index.

However, other researchers have reported very low or non-existent associations (Carpenter, Smith & Butler, 1972; Parrish, Olson, Miner & Rust, 1973; Morgan, Savell, Hale, Miller, Grif-fin, Cross & Shachelford, 1991; Smith, Savell, Cross, Carpenter, Murphey, Davis, Abraham, Parrish & Berry, 1987). For example, Cross et al. (1973) reported that an increase in percentage fat were not associated with significant changes in initial tenderness or muscle fibre tenderness ratings. These results were not anticipated by them, since it has generally been assumed that such relationships existed over wide ranges of maturity. They concluded that their data confirmed the fact that knowledge of chemical parameters did not explain a large portion of the variation in muscle tenderness. Smith, Carpenter, Cross, Murphey, Abraham, Savell, Davis, Berry & Parrish (1984) stated that marbling is of very limited value in explaining differences in sensory panel ratings of round steaks compared to loin and rib steaks.

Goll, Stromer, Olson, Dayton, Suzuki & Robson (1974) postulated that because neither water nor lipid is intrinsically tough, it follows that neither water nor lipid contributes directly in any significant manner to meat tenderness, and that physical changes in muscle proteins are the fundamental cause for variations in meat tenderness.

Dolezal et al. (1982) found that there was progressive improvement in cooked beef palatability of as the fat thickness of carcasses from cattle (fed a high-concentrate diet for 90 - 160 days) increased from less than 2,53 mm up to 7,61 mm, beyond which palatability was not improved further.

**CONCLUSIONS**

Age did not have any effect on collagen content of muscles, but collagen solubility showed a definite age dependance. In general tenderness and collagen solubility decreased, and residue increased significantly with age, irrespective of the muscle. Shear force resistance only decreased significantly with age for the *M. longissimus thoracis* in the wing rib and the *M. semitendinosus* in the silverside.

In general, it would appear that the fat code of the muscle had a significant, although not linear, effect on the various tenderness measurements. The LTP, LTW, LL and GM muscles with a fat code of 6 were the most tender and contained the least amount of residue. However, the ST and PM muscles from fat
code 1 carcasses were the most tender and contained the least amount of residue. The LTP, LTW and LL with a fat code of 5 were more tender and contained less residue than those of fat codes 3 and 4. It seems as if the taste panel evaluated the tenderness of muscles of fat codes 3 and 4 as the toughest and containing the most residue.

The GM of fat codes 1 and 6 and the PM of fat code 6 were the most tender. The LLL of fat codes 1 and 5 contained more collagen than those of fat code 4. The collagen solubility of the ST was the highest in fat code 3 compared to fat codes 1, 2, 4 and 6. Of the SM, solubilities of fat codes 3 and 5 muscles were higher than those of fat codes 1, 2 and 4. Collagen solubilities of the PM fat codes 3 and 6 were higher than those of the PM of fat codes 1 and 2.

Although age had a significant linear relationship with the different tenderness parameters studied, it is strongly recommended that animals of the B age group with 4 and 6 teeth of the various fatness classes should also be evaluated in a similar manor to determine or quantify the influence of these maturity groups on the different parameters determined.

The exact influence of fatness on tenderness is still not known. Further investigation is essential.

REFERENCES


Sensory analysis in service of the meat industry

I.B. Zondagh

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INTRODUCTORY COMMENTS

In order to be able to explain how SENSORY ANALYSIS may be of use to you, the reader, one must first define and describe “Sensory Analysis.” This includes briefly describing the relevant, complex physiological “senses” included in the term “sensory” as well as the different types of evaluation or analysis methods or tests. A description of what each test measures and its uses, is clarified by tabulations indicating the WHY, HOW, WHEN and WHERE they may be applied, interspersed with interesting academic facts to keep updated. To conclude, details/suggestions of how Sensory Analysis may be utilized in your service as well as how your operation might benefit, are outlined.

SENSORY EVALUATION strives to be a SCIENCE but should also be recognised as a TECHNOLOGY because of its intense practicality (Peryam, 1990). The pressing need to solve problems was there long before the tools to facilitate solutions. Early on, several disciplines made contributions that enabled the development of sensory evaluation from converging lines of knowledge. The principal sources were:
1. psychology
2. physiology
3. sociology
4. statistics.

It was a matter of learning how to use the human senses and perceptions, as expressed in behaviour, to gain a deeper understanding of outcomes. An important part of this complex was finding ways to deal with the INHERENT VARIABILITY OF BEHAVIOUR.

A few interesting historical facts relating to Sensory Science:
1. Rating scales. In ca 1800, the British Navy created a scale for measuring wind strength, labelling and describing 12 categories ranging from “calm” to “hurricane” (Peryam, 1990, referring to Guilford, 1936).
2. Peryam (1990) also refers to the “venerable triumvirate” of the psychometric methods, viz., the paired comparison test, rating scales and rank order which were “in place” by the early 1930’s. The food sensory evaluators were next to develop the force-choice methods, typified by the triangle test, first devised by Bengtsson in 1943 & published in English in 1946 by Helm & Trolle, (1946).
3. Arthur D Little developed the flavour profile method in Cambridge, Massachusetts, in the early 1950’s (Peryam, 1990).
4. The Quartermaster Food and Container Institute’s best known contribution was the invention of the 9-point hedonic (liking/disliking) scale in 1957 (Peryam, 1990).
5. The historic work done by Amerine (early 1940’s) and later Rose Marie Pangborn (1950’s) at the University of California at Davis deserves special mention as it resulted, i.a., in the first Sensory Science textbook being written by Amerine et al., 1965.
6. The Sensory Evaluation Division (SED) of IFT was established in 1973 as an official division of IFT. 1964’s Annual IFT meeting had the first papers cementing and advancing our science (Peryam, 1990).

Definition of sensory analysis or sensory evaluation

SENSORY EVALUATION is defined as “a scientific discipline used to EVOKE, MEASURE, ANALYSE, and INTERPRET reactions to those characteristics of foods and materials as they are perceived by the SENSES of SIGHT, SMELL, TASTE, TOUCH and HEARING (IFT, 1975).”

EXPLANATORY NOTES ON THE FIVE SENSES

Table 1 is a summary of the five senses/perceptions and their corresponding sensory properties/characteristics/attributes.
THEREFORE, THE FIVE SENSES

Sense of sight - APPEARANCE

Appearance is perceived through the eyes/sense of vision (Meilgaard et al., 1987; Ford, 1991, chapter 2).

1. COLOUR (hue, chroma);
2. SURFACE TEXTURE (dullness/shininess, roughness/smoothness or evenness/uniformity, wet/dry, soft/hard, crisp/tough);
3. SIZE/SHAPE (length, thickness, particle size, geometric shape (square, circular, etc.), distribution of pieces, e.g., of vegetables, pasta, prepared foods, etc., size & shape, as indication of defects);
4. CLARITY (haze or opacity of transparent liquids or solids, the presence or absence of particles of visible size);
5. CARBONATION (for carbonated beverages, the degree of effervescence observed on pouring).

Sense of smell

OLFACTORY SENSATIONS (AROMA BY MOUTH)

SMELL/OLFACTION is the commonly termed "sense of smell" or the perception of odour by the olfactory epithelium cells located in the roof of the nasal cavity (Meilgaard et al., 1987) and cilia covering the epithelium.

AROMA is the ODOUR of a substance perceived by the olfactory nerve when the volatiles are:
1. SNIFFED through the nostrils or
2. PASSED into the NASAL AREA from the MOUTH (aromatic portion of flavour).

Jellinek (1985) gives a physiological definition of aroma perception as follows:
- the AROMA of a product can be perceived by smelling and tasting, for example, coffee aroma.

Meilgaard et al. (1987) defines odour, aroma and fragrance as follows:

- One talks of ODOUR when the volatiles are SNIFFED through the nose (voluntarily or otherwise).
- AROMA is the odour of a food product, and
- FRAGRANCE is the odour of a perfume or cosmetic.

Here the word “SMELL” is often not used as it has a negative connotation when it is considered to be a “mal-odour” - the word “taint” or the phrase “off-odour” is rather used then. One almost naturally talks about the "sense of smell" though!

According to Ford (1991), the following factors are essential for odour to register:
1. The substance needs to be VOLATILE enough to reach the regio olfactoria.
2. The substance needs to be partially SOLUBLE in the mucus covering of receptors.
3. A minimum NUMBER of odorous molecules need to be present.
4. These molecules need to be in CONTACT with receptors for a MINIMUM period of time.

SENSE OF TASTE - BASIC TASTE SENSATIONS

TASTE is the sense by which certain properties are perceived through taste buds on the tongue and hard palate (Jellinek, 1985).

There are FOUR basic tastes, viz., SALTY, SWEET, SOUR, BITTER. Sometimes “OTHER” is also permitted (Halpern, 1990) and, recently, “UMAMI” or “AMINO ACID” has tentatively been added as a fifth basic taste (O’Mahoney, 1990).

BASIC TASTES:
1. SWEET: taste on the tongue associated with sugars (tip of tongue is sensitive).
2. SOUR: taste on the tongue associated with acids (side edges of tongue are sensitive).
3. SALTY: taste on the tongue associated with sodium ions (tip and edges of tongue are sensitive).
4. BITTER: taste on the tongue associated with bitter agents such as caffeine, quinine, etc. (papillae at back of tongue are sensitive).

O’Mahony (1990) describes what is meant by the term “UMAMI TASTE”. A special feature of Japanese cooking is the use of broths, rather than spices, for seasoning. Three of these broths have primary importance in the emergence of the umami taste concept and these are:
1. KOMBU, made from the seaweed Laminiara japonica or sea tangle;
2. KATSUOBUSHI, made from dried flakes of the bonito fish; and
3. SHIITAKE, made from the shiitake or black mushroom (Lentinus edodes).

The active ingredients in these broths are:
1. Kombu = MSG (mono-sodium glutamate) - broth often used to cook rice in;
2. Katsuobushi = histidine salt of inosinic acid [nowadays the sodium salt of the appropriate isomer, IMP (disodium-5'-inosinate) is produced commercially]; and
3. Shiitake = another ribonucleotide, GMP (disodium-5'-guanylate).

This is why “umami taste” is being referred to as “AMINO ACID” in literature.

**Sense of touch - TACTILE SENSE**

All five the senses are complex, but recent literature abounds with information, differing terminologies and speculation regarding the finer details of the fourth sense, viz. the sense of touch.

In Table 1, Murphy & Gilmore (1990) describe sensory functioning as follows:

The CHEMICAL SENSES (taste, smell and trigeminal sensitivity) play important roles in preparing the body for food and signalling information about its nature and palatability. Although the chemical senses function in concert in the perception of food flavour, each makes a unique and independent contribution to that perception.

1. The SENSE OF TASTE alerts the brain to the presence of sweet, sour, bitter and salty substances in the oral cavity.
2. The SENSE OF SMELL processes the volatiles which produce the subtleties and complexities of food flavours. Often one cannot identify the food or beverage when the nostrils are blocked before ingestion.
3. The TRIGEMINAL SENSE provides the brain with information about other sensations in the oral and nasal cavities: warmth, cold, irritation, pungency. The heat of hot peppers, the coolness of menthol and the bite of horseradish are signalled by the trigeminal nerve.

In Table 1, Meilgaard et al. (1987) divide the sense of TOUCH into two parts, viz.
1. “SOMESTHESIS” (TACTILE SENSE, SKINFEEL) and
2. “KINAESTHESIS” [DEEP PRESSURE SENSE or proprioception which Webster (1979) defines as “the reception of stimuli produced within the organism”] both of which sense variations in physical pressure. The surface nerve ends in the skin are responsible for the SOMESTHETIC SENSATIONS we call TOUCH, PRESSURE, HEAT, COLD, ITCHING and TICKLING, whereas DEEP PRESSURE, KINAESTHESIS, is felt through NERVE FIBRES in MUSCLES, TENDONS and JOINTS whose main purpose is to SENSE the TENSION and RELAXATION of MUSCLES (e.g. the muscles of the hand, face, lips, jaw, tongue). Due to their SURFACE SENSITIVITY, very small force differences are detectable by these organs, e.g. particle size differences as well as thermal and chemical differences due to HAND AND ORAL MANIPULATION of products.

**Sense of hearing**

HEARING is considered to be the 5th sense which will be described briefly in this paper. It is seldom discussed in detail, but more physiological details might be found in literature, e.g. Meilgaard et al., 1987; Ford, 1991).

The following snippets of information may prove interesting: SOUND is the perception by humans of VIBRATIONS in a physical medium (AIR). The stimulus is the physical movement of sound waves in the air. The receptors are the ear drums (Ford, 1991).

Meilgaard et al. (1987) point out that the noise produced during mastication or handling of fabrics is a minor but not negligible sensory attribute. The pitch and loudness of the sound contribute towards the overall sensory impression. The duration or persistence of sound from a product often suggests other properties:

- **PITCH** = frequency (wavelength) of the sound;
- **LOUDNESS** = intensity of sound; and
- **PERSISTENCE** = endurance of sound over time.

The SOUND of food when it is being eaten is often an important aspect in determining quality (Ford, 1991), e.g.:

1. **POSITIVE** aspects:
   - snap, crackle and pop;
   - fizz of champagne or beer;
   - crispiness of lettuce or celery;
   - tapping a melon for quality.

2. **NEGATIVE** aspects:
   - noisy environment may distract or mask product sounds.
   - chewing bubble gum or crisp apples with open mouth in another person’s ear.
More detailed discussions regarding the physiology and functioning of the sense organs may be found elsewhere (e.g. Meilgaard et al., 1987; Jellinek, 1985, Charley, 1982).

**Flavour definitions**

FLAVOUR is the complex effect of:

1.3.1.1 olfactory sensations (aroma by mouth)
1.3.1.2 basic taste sensations (soluble substances in the mouth)
and
1.3.1.3 mouthfeel sensations

which are stimulated by a foodstuff/substance being present in the mouth (Charley, 1982).

[This may easily be remembered by the initials "T.O.M." for "Taste, Odour and Mouthfeel!" The natural sequence varies as odour is usually evaluated first!]

[MOUTHFEEL SENSATIONS are the sensations detected in the mouth by the tactile nerves.

Types: thermal (hot, cold) chemical (cool, warm, bite, astringent, prickle, burn)].

JELLINEK (1985) points out that two FLAVOUR definitions are found in literature, viz.

1. FLAVOUR includes the FOUR BASIC TASTES and the AROMA perceived through tasting;
2. FLAVOUR is the TOTAL IMPRESSION of taste, odour, tactile, kinaesthetic, temperature and pain sensations perceived through tasting.

This latter definition is similar to the one above and is preferred as it is more complete/all encompassing.

To confuse matters further, MEILGAARD et al. (1987) defines FLAVOUR as follows, using slightly different terminology, but when one concentrates on what exactly is being said, one realizes it is all basically the same:

1. The AROMATICS, i.e., olfactory sensations caused by volatile substances released from a product in the mouth via the posterior nares;
2. The TASTES, i.e., gustatory sensations (salty, sweet, sour, bitter) caused by soluble substances in the mouth; and
3. The CHEMICAL FEELING FACTORS, which stimulate nerve ends in the soft membranes of the buccal and nasal cavities (astringency, spice heat, cooling, bite, metallic flavour, umami taste).

**Texture**

TEXTURE is the sensory manifestation of the structure or inner make-up of foods in terms of feel and resistance to applied forces, or, as Szczesniak puts it, texture is the COMPOSITE OF THE STRUCTURAL ELEMENTS OF FOOD AND THE MANNER IN WHICH IT Registers WITH THE PHYSIOLOGICAL SENSES (Szczesniak, 1963). The COMPONENTS OF TEXTURE are shown in Tables 2 & 3, to illustrate how complex an issue texture is.

1. FEEL (tactile sense or sense of touch) is the use of tactile nerves on the surface of soft tissues in the mouth.
   1.1 Mechanical properties/characteristics (Table 2, 5 primary parameters; 3 additional secondary parameters) (Szczesniak, 1963);
   1.2 Geometrical properties or physical structure or particle size, shape & orientation (chalky, gritty, fibrous, grainy); and
   1.3 Other characteristics, viz., moisture (juiciness) & fat (greasy, oily) properties.
2. RESISTANCE TO APPLIED FORCES (kinaesthetics): e.g., hardness, chewiness, cohesiveness, viscosity, elasticity, adhesiveness, springiness, fracturability.

SOME PRACTICAL ASPECTS: TOUCH - TEXTURE/KINAESTHETIC (Also see Table 7)

Texture for solids or semi-solids
Viscosity for homogeneous Newtonian liquids
Consistency for non-homogeneous non-Newtonian liquids and semi-solids (Meilgaard et al., 1987)

Note: Instrumental methods only measure ONE aspect of "texture".

Ford (1991) has the following additional information/explanation:

1. FINGER FEEL
   1.1 Firmness/Softness - indicates the eating quality of some food products, e.g.,
   1. ripeness level of fruit such as avocado and mango
   2. crumb texture of bread
   3. crispiness of cracker biscuit
   4. fish texture
   1.2 Juiciness - e.g. thumbnail test for corn and squeezing meat between the fingers to determine initial juiciness for cooked meat.
2. MOUTHFEEL
   2.1 LIQUIDS:
   2.1.1 Viscosity - thin to viscous, e.g. sugar syrups
   2.1.2 Consistency - thin to thick, e.g. tomato paste/puree
2.2 SOLIDS:
Classification of textural characteristics - same as Table 2, hardness, brittleness, chewiness, moistness, oiliness/greasiness.
(As described above.)

Sensory interaction

As has been indicated previously, WHEN EATING OR TASTING FOOD, there is a continuous relationship between the senses. Unless steps are taken to separate the individual senses or stimuli, interactions may occur.

It is not known whether these interactions occur at the receptor site or the brain. However, the latter option would appear to be more likely (Ford, 1991).

Interaction between senses:

This is the ability of a response from one modality to influence or affect the response from another.

There are two aspects to this:
1. POSITIVE interactions giving clues to possible identity, e.g. red jam being strawberry flavoured.

2. NEGATIVE if clues are not correct, this may lead to confusion and a wrong judgement, e.g. red jam with pineapple flavour.

Taste-odour sensory interaction:

The receptors for these two senses are very close, indicating that interactions between these senses are highly likely and these may be important in classifying a particular taste. However, in controlled experiments to determine the actual taste of substances, it may be necessary to taste the food using nose clips. Intensification resulting in enhancement of flavours, e.g. salt and MSG on food, improves the natural flavours. Similar situations may exist for all other stimuli.

Summary

Interaction must be considered when designing sensory panels; if only one sense or stimulus is to be evaluated, then all other must be masked. However, if interactions are required then ensure this can be achieved by means of sample preparation.
The APPLICATION of this BACKGROUND INFORMATION ON THE SENSES AND RELATED MATTERS (TEXTURE AND FLAVOUR) is especially important in DESCRIPTIVE TESTS.

USES AND APPLICATION OF SENSORY ANALYSIS/EVALUATION

The bottom line

Common uses of sensory analysis

According to the Sensory Evaluation Division of the Institute of Food Technologists (SED, IFT, 1981b), the most common uses of sensory evaluation/analysis are:

1. panellist selection & training
2. correlation of sensory with chemical and physical measurements/supporting instrumental measurements
3. product grading or rating
4. new product development - will the consumer like the new product?
5. product matching
6. product improvement/product reformulation - will the new ingredient or the new formula change the product?
7. process change
8. cost reduction &/or selection of a new source of supply
9. quality control/quality assurance
9.1 - monitor batch-to-batch variability
9.2 - determine shelf-life of the product
10. storage stability
11. consumer acceptance &/or opinions
12. consumer preference.
Consider the following two examples:

1. In an advertisement relating to “lean burgers” and encapsulated salt, where the claim is made that this product helps to retain “natural texture, taste and color (Balchem, 1991). In relation to texture, it provides natural, juicy texture by eliminating protein extraction from ground meat and it does not interfere with hydrocolloid systems. Encapsulated salt enhances flavour and extends shelf-life by preventing rancidity and it stabilizes the natural meat colour as it prevents reaction with myoglobins.

2. A fat replacer called Stellar™ (Staley, 1991) is an ingredient considered to be suitable for pastries, snack cakes, frostings and fillings, cheese products, margarine, meat products, salad dressings and a variety of other products. It is a modified food starch ingredient derived from maize developed and to be marketed (1992) by and is reported to enable one to reduce the fat content of such foods such as margarines, cheese spreads, baked goods, while maintaining the texture, mouthfeel stability and visual qualities of full-fat products.

Such claims much surely be based upon definite, concrete sensory evaluation tests to substantiate the food science experimental results. If sensory analysis/evaluation is not done (properly), then a disaster will happen!

Two types of panels

1. Trained - analytical, trained.
2. Consumer - affective, untrained.

Consumer panels (via questionnaires, in-house testing or interviews) measure consumer reactions to a particular product in terms of:

1. acceptance/preference
2. difference/degree of difference between samples.

Each panel type has its own specific goals and requirements for training.

Project goals and nature of the product determines type of panel used:

1. Basic research
   - trained
   - consumer
2. New product development
   - bench top
   - trained
   - consumer
3. Product optimization
   - trained
4. Quality Control/Quality Assurance
   - trained

Types of tests

Sensory analysis is done by choosing the most appropriate test method from the following types of tests (SED, IFT, 1981a & b). See Tables 4, 5 & 6. Note that sensory analysis methods are classified as follows:

1. ANALYTICAL TESTS
   1.1 DISCRIMINATIVE TESTS
   1.2 DESCRIPTIVE TESTS
2. AFFECTIVE TESTS

Some attention will be paid to DESCRIPTIVE ANALYSIS, as this is the more unusual area of Sensory Analysis and one which is currently receiving much international attention.

Descriptive analysis or tests

Definition

This is the detection and description of the QUALITATIVE and QUANTITATIVE (and temporal) aspects of a product’s aroma, flavour, texture, appearance and sound by a group of 8-15 highly trained subjects (Table 4, Sub-section 1.2.2).

Those perceived sensory parameters which define the product are referred to by various terms such as ATTRIBUTES, CHARACTERISTICS, CHARACTER NOTES, DESCRIPTORS, or TERMINOLOGY (Meilgaard et al., 1987). These qualitative factors include terms which define the SENSORY PROFILE, PICTURE, SPECTRUM or THUMBPRINT of the sample. The selection of sensory attributes and the corresponding definition of these attributes should be related to the real chemical and physical properties of a product which can be perceived. Adherence to an UNDERSTANDING OF THE ACTUAL RHEOLOGY OR CHEMISTRY of a product makes the descriptive data easier to interpret and more useful for decision making. Please refer to Table 7.

Components of descriptive analysis (Meilgaard et al., 1987) (Please refer to Table 7.)

1. QUALITATIVE ASPECT - the characteristics or terms needed to describe the product comprehensively.
2. INTENSITY - quantitative aspect.
3. TEMPORAL - order of appearance - time aspect. (The changes in character or strength over time.)
4. OVERALL IMPRESSION - The integrated aspect or the whole picture/spectrum.
Uses and fields of application of descriptive analysis testing

DESCRIPTIVE ANALYSIS provides a sensory spectrum to document a product’s sensory properties (Meilgaard et al., 1987).

One uses descriptive tests to obtain detailed descriptions of the aroma, flavour, and oral texture of foods and beverages, skinfoel of personal care products, handleel of fabrics and paper products, and the appearance and sound of any product (Table 3). These sensory pictures are used in research and development, and in manufacturing, to:

1. Define sensory properties of a target product for new product development;
2. Define the characteristics/specifications for a control or standard for QA/QC and R&D applications;
(defines product flavour/texture = thumbprint or profile or picture or spectrum.)

Table 4: Classification of sensory evaluation methods and panels (SED, IFT, 1981b)

<table>
<thead>
<tr>
<th>Classification of methods by functions</th>
<th>Appropriate methods</th>
<th>Type and number of panelists</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ANALYTICAL TESTS: (trained judges)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluates differences or similarity, quality and/or quantity of sensory characteristics of a product</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 DISCRIMINATIVE TESTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.1 Difference tests:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measures simply whether samples are different</td>
<td>1.1.1.1. Paired-comparison</td>
<td>1. Screened for interest, ability to discriminate differences and reproduce results</td>
</tr>
<tr>
<td></td>
<td>1.1.1.2. Duo-trio</td>
<td>2. Trained to function as a human analytical instrument</td>
</tr>
<tr>
<td></td>
<td>1.1.1.3. Triangle</td>
<td>3. Normal sensory acuity</td>
</tr>
<tr>
<td></td>
<td>1.1.1.4. Ranking</td>
<td>4. Periodic requalification</td>
</tr>
<tr>
<td></td>
<td>1.1.1.5 Rating</td>
<td>5. Panel size depends on product variability and judgement reproducibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. No recommended “magic number” - a number often used is 10; a recommended minimum number is generally 5, since fewer could represent too much dependence upon one individual’s responses</td>
</tr>
<tr>
<td>1.1.2 Sensitivity tests:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measures ability of individuals to detect sensory characteristics</td>
<td>1.1.6. Threshold</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.1.7. Dilution</td>
<td></td>
</tr>
<tr>
<td>1.2 DESCRIPTIVE TESTS:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measures qualitative and/or quantitative characteristics</td>
<td>1.2.1. Attribute rating</td>
<td></td>
</tr>
<tr>
<td>(Scales = use of numbers to indicate the degree/amount/strength of attributes/characteristics)</td>
<td>1.2.1.1 Category scaling verbal and linear (structured/unstructured)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2.1.2 Ratio scaling (magnitude estimation)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2.2 Descriptive analysis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2.2.1 Flavour profile</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2.2.2 Texture profile</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2.2.3 Quantitative descriptive analysis</td>
<td></td>
</tr>
<tr>
<td>2. AFFECTIVE TESTS (untrained judges, consumers):</td>
<td>1. Randomly selected</td>
<td></td>
</tr>
<tr>
<td>Evaluates preferences and/or acceptance and/or opinions of the product</td>
<td>2. Untrained</td>
<td></td>
</tr>
<tr>
<td>(Often evaluates the overall character of the food)</td>
<td>2.2 Paired-preference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.2.2 Ranking</td>
<td>3. Representative of target population</td>
</tr>
<tr>
<td></td>
<td>2.2.2.1 Hedonic rating scale (verbal or facial)</td>
<td>4. Consumers of test product</td>
</tr>
<tr>
<td></td>
<td>2.2.2.2 Food action rating scale</td>
<td>5. No recommended “magic number” - minimum is generally 24 panelists, which is sometimes considered rough product screening: 50-1000 panelists usually considered adequate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: Time-intensity and Spectrum Descriptive work is not included in this table.
3. Document a product's attributes before a consumer test to help in the selection of attributes to be included in the consumer questionnaire and to help in the explanation of the results of the consumer test;

4. Track a product's sensory changes over time/storage with respect to understanding shelflife, packaging, etc.; &/or

5. Map a product's perceived attributes for the purpose of relating them to instrumental, chemical or physical properties.

6. APPLIED RESEARCH IN FLAVOUR:
   Ingredient variables and combinations
   - (soft drinks and salad dressings)
   Ingredient X processing variables
   - (coffee, cereals, chocolate, spaghetti sauce)
   Shelf-life and Q.A./Q.C.
   - (raw materials, in-process, finished products)
   REMEMBER: GIGO! (Garbage in, garbage out!)

7. BASIC RESEARCH IN FLAVOUR:
   Environmental variables, effects on raw materials
   - (Meat, fish, peanuts, grapes/wine, catfish)
   Processing variables
   - (Roasting, cooking, fermentation - e.g., peanuts, WOF)
   Storage variables
   - (Freezing, refrigeration, packaging, environmental conditions, e.g., Warmed-over flavours (WOF’s), peanuts.)
Table 7:  The components of a number of different descriptive spectra are given below (a number of examples of each are shown in parentheses) (Meilgaard et al., 1987)

<table>
<thead>
<tr>
<th>1. CHARACTERISTICS - THE QUALITATIVE ASPECT:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Appearance characteristics</td>
</tr>
<tr>
<td>1.1 Colour (hue, chroma, uniformity, depth)</td>
</tr>
<tr>
<td>1.2 Surface texture (shine, smoothness/roughness)</td>
</tr>
<tr>
<td>1.3 Size and shape (dimensions and geometry)</td>
</tr>
<tr>
<td>1.4 Interactions among pieces or particles (stickiness, agglomeration, loose particles)</td>
</tr>
<tr>
<td>2. Aroma characteristics</td>
</tr>
<tr>
<td>2.1 Olfactory sensations (vanilla, fruity, floral, skunky)</td>
</tr>
<tr>
<td>2.2 Nasal feeling factors (cool, pungent)</td>
</tr>
<tr>
<td>3. Flavour characteristics</td>
</tr>
<tr>
<td>3.1 Olfactory sensations (vanilla, fruity, floral, chocolate, skunky, rancid)</td>
</tr>
<tr>
<td>3.2 Taste sensations (salty, sweet, sour, bitter)</td>
</tr>
<tr>
<td>3.3 Oral feeling factors (heat, cool, burn, astringent, metallic)</td>
</tr>
<tr>
<td>4. INTENSITY - THE QUANTITATIVE ASPECT:</td>
</tr>
<tr>
<td>4.1 Mechanical parameters, reaction of the product to stress (hardness, viscosity, deformation/fractureability)</td>
</tr>
<tr>
<td>4.2 Geometrical properties, i.e., size, shape and orientation of particles in the product (gritty, grainy, flaky, stringy)</td>
</tr>
<tr>
<td>4.3 Fat/moisture properties, i.e., presence, release and absorption of fat, oil or water (oily, greasy, juicy, moist, wet)</td>
</tr>
<tr>
<td>5. Skinfeel characteristics</td>
</tr>
<tr>
<td>5.1 Mechanical parameters, reaction of the product to stress (thickness, ease to spread, slipperiness, denseness)</td>
</tr>
<tr>
<td>5.2 Geometrical parameters, i.e., size, shape and orientation of particles in product or on skin after use (gritty, foamy, flaky)</td>
</tr>
<tr>
<td>5.3 Fat/moisture parameters, i.e., presence and absorption of fat, oil or water (greasy, oily, dry, wet)</td>
</tr>
<tr>
<td>5.4 Appearance parameters, visual changes during product use (gloss, whitening, peaking)</td>
</tr>
<tr>
<td>6. Texture/handfeel of woven and nonwoven fabrics</td>
</tr>
<tr>
<td>6.1 Mechanical properties, reaction to stress (stiffness, force to compress or stretch, resilience)</td>
</tr>
<tr>
<td>6.2 Geometrical properties, i.e., size, shape and orientation of particles (gritty, bumpy, grainy, ribbed, fuzzy)</td>
</tr>
<tr>
<td>6.3 Moisture properties, presence and absorption of moisture (dry, wet, oily, absorbent)</td>
</tr>
</tbody>
</table>

VALIDITY AND RELIABILITY OF DESCRIPTIVE ANALYSIS TESTING (Meilgaard et al., 1987):

Again, the keys to VALIDITY AND RELIABILITY of descriptive analysis testing are:

1. Terms based on a thorough understanding of the technical and physiological principles of flavour or texture or appearance.
2. Thorough training of all panellists to fully understand the terms in the same way and to apply them in the same way (Meilgaard et al., 1987).

2. INTENSITY - THE QUANTITATIVE ASPECT OF DESCRIPTIVE ANALYSIS

1. The intensity or quantitative aspect of a descriptive analysis expresses the degree to which each of the characteristics (terms, qualitative components) are present. This is expressed by the assignment of some value along a measurement scale.
2. As with the validity and reliability of terminology, the validity and reliability of intensity measurements are highly dependent upon:
   2.1. The selection of a scaling technique which is broad enough to encompass the full range of parameter intensities and which has enough discrete points to pick up all the small differences in intensity between samples
   2.2. The thorough training of the panellists to use the scale in a similar way across all samples and across time

Three types of scales are in common use in descriptive analysis (Table 4):

1. Category scales
2. Line scales
3. Magnitude estimation (ME) scales.

3. ORDER OF APPEARANCE - THE TIME ASPECT (Meilgaard, 1987)

By controlling the manipulation (one chew, one manual squeeze) the subject induces the manifestation of only a limited number of attributes (hardness, denseness, deformation) at a time. Included as part of the treatment of the order of appearance of attributes is aftertaste or afterfeel, which includes those attributes that can still be perceived after the product or sample has been used or consumed. A complete picture of a product requires that all characteristics which are perceived after the product’s use should be individually mentioned and rated for intensity. Attributes described and rated for aftertaste or afterfeel do not necessarily imply a defect or negative note. For example, the cool aftertaste of a mouthwash or breath mint is a necessary and desirable property. On the other hand, a metallic aftertaste of a cola beverage may indicate a packaging contamination or a problem with a particular sweetener.

4. OVERALL IMPRESSION - THE INTEGRATED ASPECT

4.1 Total Intensity of Aroma or Flavour - a measure of the overall impact (intensity) of all the aroma components (perceived volatiles) or a measure of the overall flavour impact, which includes the aromatics, tastes and feeling factors contributing to the flavour.
4.2 Balance/Blend (Amplitude) - a well-trained panel is often asked to assess the degree to which various flavour or aroma characteristics fit together in the product. Evaluation of balance or blend (called ‘amplitude’ in the Flavour Profile Method) is difficult, even for a highly trained panel.
NEWER DEVELOPMENTS

Qualitative research

Unfortunately, seeing that Sensory Science is still a young science, there is still much confusion in terminology, e.g., "QUALITATIVE RESEARCH" - which is not to be confused with the corresponding aspect of Descriptive Analysis (Table 4, Section 1.2).

Chambers IV and Smith (1990) refer to the United States as being a nation of self-reported dieters, yet its people chronically overeat. Consumers want fruits and vegetables that are pure and natural, yet they also want low cost and only will buy foods that look perfect. Purchasers demand quality, yet they buy convenience. There appears to be a LARGE DIFFERENCE between WHAT CONSUMERS SAY, THINK, and ACTUALLY DO. Chay (1989) asks “How do you unlock the consumer’s mind? It is clearly evident that there is an enormous gap between attitudes and behaviour.” For the sensory professional this presents tremendous problems because response to product attributes is linked to expectations and biases.

QUALITATIVE RESEARCH answers the questions WHAT and WHY but not HOW MUCH or HOW OFTEN [Chambers IV and Smith (1990)]. It is concerned with describing and understanding products and ideas rather than measuring them. Quantitative research methods provide the measure of intensity or amount, as pointed out previously.

Neither qualitative nor quantitative research alone can provide all of the information a research project needs [Chambers IV and Smith (1990)]. QUALITATIVE TESTING usually needs to precede QUANTITATIVE TESTING to help ESTABLISH CRITERIA for data collection and to follow quantitative testing TO AID IN THE EXPLANATION of the quantitative data. Using both general classes of methods in conjunction with each other enhances and reinforces the use and validity of both methods.

DEFINITION [Chambers IV and Smith (1990)]:
QUALITATIVE RESEARCH provides detailed information about people’s attitudes, opinions, perceptions, behaviours, habits and practices. It is vocabularies, meanings, behaviours - not intensities or frequencies. All of these factors drive consumer behaviour and ultimately, product selection and use. Quantitative and qualitative research go hand-in-hand.

Note the following distinction:
QUALITATIVE RESEARCH is a GROUP OF METHODS; it is not marketing research, although the methods typically are used for that segment of testing. Qualitative methods are METHODS; they can be applied to many types of research including sensory research and product development.

Table 7 cont.: The components of a number of different descriptive spectra are given below (a number of examples of each are shown in parantheses) (Meilgaard et al., 1987)

<table>
<thead>
<tr>
<th>AROMATICS</th>
<th>DEFINITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooked Beef Lean:</td>
<td>the aromatics associated with cooked beef muscle meat.</td>
</tr>
<tr>
<td>Cooked Beef Fat:</td>
<td>the aromatic associated with cooked beef fat.</td>
</tr>
<tr>
<td>Browned:</td>
<td>the aromatic associated with the outside of grilled or broiled beef (seared but not blackened/burnt). (Maillard Reaction)</td>
</tr>
<tr>
<td>Serum/Bloody:</td>
<td>the aromatic associated with raw beef lean.</td>
</tr>
<tr>
<td>Grainy/Cowy:</td>
<td>the aromatic associated with cow meat and/or beef in which grain/feed character is detectable.</td>
</tr>
<tr>
<td>Cardboard:</td>
<td>the aromatic associated with slightly stale beef (refrigerated for a few days only) and associated with wet cardboard and stale oils and fats.</td>
</tr>
<tr>
<td>Oxidized/Rancid/Painty:</td>
<td>the aromatic associated with rancid oil and fat (distinctly like linseed oil).</td>
</tr>
<tr>
<td>Fishy:</td>
<td>the aromatic associated with some rancid fats and oils (similar to old fish).</td>
</tr>
</tbody>
</table>

Table 8: BEEF FLAVOUR DESCRIPTORS (Civille, 1988, in Miller, 1990)
THERE ARE GENERALLY THREE COMMON TYPES OF QUALITATIVE RESEARCH RECOGNISED AT PRESENT [Chambers IV and Smith (1990)];

1. Focus Groups,
2. Focus Panels,
3. In-depth or one-on-one interviews are the common types of qualitative research.

1. FOCUS GROUPS
A focus group usually consists of 8 to 10 respondents, recruited according to predefined specifications. The respondents engage in a discussion led by a qualified group moderator (Wu, 1989). The moderator (1) directs the flow of the discussion; (2) recognises important points and encourages the group to explore and elaborate on them; (3) observes the nonverbal communication among respondents, between respondents and moderator and between respondents and the subject matter; (4) creates an atmosphere that allows respondents to relax and lower some of their defences; (5) synthesises the understanding gained about the objectives and (6) tests ideas generated by the information gained (Gorden & Langmaid, 1988).

The group discussion often is observed by researchers and other interested individuals in an adjacent room or through a video-conference. Observers of the focus groups later may constitute a focus group themselves, as a formal de-briefing is held using qualitative methods to ensure that the observers have a common experience for making future decisions.

Focus groups are TAPEd for a permanent record. AUDIO TAPES are far easier to transcribe than video tapes, but video tapes are needed if action is involved or BODY LANGUAGE is likely to be important. Often a combination of audio and video tapes are best. A TRANSCRIPTION of the tapes is made to provide detail and viewing the actual tapes may be an important step when a critical issue is what the respondents do. In reality, many people involved with the project simply read the report written by the MODERATOR THAT SUMMARISES and links each group's discussion with that of other groups in the study.

Properly structured focus groups can be used to obtain almost any kind of qualitative information from almost any type of respondents (Templeton, 1987). It is the most VERSATILE OF QUALITATIVE RESEARCH METHODS and is used more often than all other qualitative methods. As a matter of interest, in the latest available Food Technology (1992, 46(7):38) they refer to work done recently by the Office of Scientific Public Affairs entitled “IFT Focus Groups find consumers favor biotechnology and increased R&D funding.” One finding was that they found that the production of meat with lower fat content was viewed as a benefit of biotechnology by 91 % of the participants and 88 % of the were “likely” or “very likely” to buy these meat products.

2. FOCUS PANELS
Typically, respondents for focus groups are consumers who participate infrequently in consumer research and have not discussed the topic previously for other research. Alternatively, FOCUS PANELS are focus groups that return ONE OR MORE TIMES to explore areas that have been discussed previously and to have follow-up discussions (Bellenger et al., 1976). For example, a focus panel may discuss a concept, take the product home to use and return to discuss the product's attributes. Other USES of focus panels include iterative testing and discussion of prototypes and competitors or long-term testing of product consumption and use.

3. IN-DEPTH INTERVIEWS
Some ideas cannot be explored most effectively in a group situation. Respondents may feel uncomfortable discussing certain subjects in group settings, such as flatulence production by different food products, or simply because one needs more information (e.g., more detailed descriptions of items hard to describe in words).

Typically, in a focus group each respondent has about 5 to 8 minutes of “talking time”; a one-to-one interview may provide 45 minutes of “talking time”, (Seymour, 1988). A general outline of questions is followed, but ample time is provided to probe the respondent's answers and reasons. As with group situations, the original questions are carefully established to be sure the objectives of the study will be met.

Free choice profiling (FCP), principle component analysis (PCA)

More mention is being made of “free choice profiling” and its corresponding “Procrustes” statistical analysis method (Oreskovich, Klein & Sutherland, 1990). FCP is useful, like qualitative research, to find the correct terminology to use for quantitative work. The statistics is sometimes considered to be manipulative (“made to fit”)! [“Procrustes” refers to a giant of the Greek city, Eleusis, who forced travellers to fit one of two unequally long beds by stretching or their bodies or cutting off their legs (Webster, 1979).]

Response surface analysis (Meilgaard 1987 & Zondagh, 1984)
The objective of a RSM experiment is to develop a regression equation that predicts the value of a response variable (called the dependent variable) based on the controlled values of the experimental factors (called the independent variables). All the factors in a RSM experiment must be quantitative. The prediction equation can be depicted graphically in what is called a “response surface” or contour plot. These are very easy to in-
interpret as the predicted value of the particular variable may be read off without having to calculate the response.

**Multivariate analysis with MANOVA** (multivariate analysis of variance).

PRINCIPLE COMPONENT ANALYSIS (PCA) and FACTOR ANALYSIS are multivariate techniques that can be used to summarize a set of data containing many responses by a small number of “derived responses” (Meilgaard et al., 1987).

**A few trends in sensory science:**

Words like “chemosensation” and “somatosensory sensation” (e.g., irritation by capsaicin) (Beauchamp, 1990) are being found more and more in literature.

**HOW MIGHT YOU BENEFIT FROM SENSORY ANALYSIS?**

The four WHAT’S should be asked and answered at the beginning and end of the sensory analysis project:
1. WHAT WAS THE OBJECTIVE?
2. WHAT WAS DONE? (WERE THE TESTS DONE CORRECTLY?)
3. WHAT WERE THE RESULTS?
4. WHAT CAN BE CONCLUDED?

**Role of sensory evaluation**

**Technical**
1. Conduct sound sensory experiments with control of test variables:
   - preparation and presentation of samples
   - the test environment: noise, odour, lighting
   - selection and training of subjects
   - data analysis and interpretation
2. Develop effective sensory methods to measure specific responses to a sensory attribute using proper terminology and scaling.
3. Study new concepts and approaches to sensory methodology, sensory subjects, sensory facilities to maintain a quality testing program.

**Business**
1. To provide valid and reliable product information for making sound business decisions in research and development, marketing/research and manufacturing/quality assurance.
2. To serve as a sensory consultant in the company for:
   - product reviews
   - benchtop product screening
   - product sensory information prior to consumer tests, quality control specifications, advertising, etc.
   - update on sensory literature relevant to company products and projects.

**Meat Industry Centre, Irene Animal Production Institute (IDPI)**

The Meat Quality Section of the Meat Industry Centre (MIC) of the Irene Animal Production Institute (IDPI) is involved with the SENSORY ANALYSIS or SENSORY EVALUATION of mainly meat and meat products (all species) as well as research relating to their nutritional value. A trained sensory panel (ASTM Committee E-18, 1968; Lamord, 1977; Cross et al. 1978; Johnson & Civille, 1986) from the staff of the Meat Industry Centre usually do the sensory analyses. The Section initiates its own research as well as doing routine analytical evaluations (service laboratory work) for other researchers in meat production, meat biochemistry, carcass evaluation, meat technology, meat microbiology, animal nutrition, poultry science and meat companies from the meat industry (confidential contract work). Therefore, Meat Quality is in service of the entire meat (and food) industry, broadly speaking, both academically and in a practical way.

Sensory work/projects done at the MIC of the IAPI include the following:
- pork spare ribs,
- Boer goat, Angora goat versus sheep
- boar taint (“androstenone” & skatole) identification &
- pork “Swine Sex Odours", plus bacon, ham & M. longisimus lumborum chop quality
- meat products, e.g., viennas, frankfurters, bacon, ham, meat loaves (e.g., pickle and pimento loaves), pastrami, cabanossi, species sausages, boerewors, etc.
- waterfowl
- cooking all 15 the cuts in a beef carcass (moist heat cuts, viz., silverside (M. biceps femoris), thick flank, chuck, brisket, neck, shoulder, thin flank and shins and dry heat cuts, viz., prime rib, wing rib, silverside (M. semitendinosus), rump, topside and fillet) and the seven veal cuts.

Under the AGRICULTURAL RESEARCH COUNCIL (ARC) permission has been granted to the Section to work in a much wider field and it is therefore possible to do work on apples, crocodiles, giraffe, poultry, including ostrich, etc. This would all go together with the necessary literature reviews and report
writing as would be the case for a research project (SED, IFT, 1981a).

CONCLUSION

Keeping in mind the GLOBAL ECONOMY (Ganguly, 1991, Appendix 1) and Food Shoppers’ Changing Attitudes (Chou, 1992, Appendix 2) and since compromised nutritional status is a problem for significant numbers of elderly people where dietary selection may be particularly important for the health and well-being of the elderly (Murphy & Gilmore, 1990; Galvin & Waldrop Jr, 1990), the full utilization of SENSORY SCIENCE and SENSORY ANALYSIS would be in your best interests. Do not hesitate to ask for our advice. You might find the Peryam and Kroll advert (1991, Appendix 3) interesting!

Chambers IV (1990) concludes his paper as follows: Because the food business is dynamic and constantly changing, sensory evaluation must be a dynamic, changing science and technology as well. Sensory scientists must continue to assist in the development of products by testing those products, the people who may use those products and the methods used for testing people and products. And sensory methods must continue to be adapted or developed to help us understand what products will be available in the coming years. The Sensory Evaluation Section of the MIC strives to do just this.

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APPENDIX 1


Ganguly (1991) also points out that technological, marketing and commercial changes facing the global food industry are formidable, yet taste and appearance will continue to be pre-eminent desirables. He referred to the increasing demand for products to fit “lifestyles” and “lifestages”. This began with slimming products but is now spreading to include sports activity foods and foods suitable for “older consumers”. The most controversial development in this area is the so-called “physiological functional foods” which claim to be medically beneficial, regulating bodily functions in a way that helps protect against serious disease such as hypertension, diabetes, cancer, osteoporosis and heart disease. Japan is currently (1991) the leader for such products.

“The discipline of food technology will have to reorient significantly to train managers and leaders to be relevant to the industry’s future needs. Exploiting the roles of quality, biotechnology, preservation, health, nutrition, and environment in a positive, responsible, and comprehensive manner will determine whether our industry can successfully cross global
barriers and conquer new horizons. Consumer concern, advances in modern science and technology, an developing sustainable and reassuring legislation will be the key to this transition” (Ganguly, 1991).

SENSORY ANALYSIS HAS AN IMPORTANT PART TO PLAY IN THIS ENDEAVOUR TO CROSS GLOBAL BARRIERS (even across-African barriers) AND TO CONQUER NEW HORIZONS (including new horizons to be found right across the African continent).

APPENDIX 2


‘TRENDS - CONSUMER ATTITUDES AND THE SUPERMARKET, 1991.” This study is published annually by the Food Marketing Institute (FMI) in the USA & reveals changing consumer priorities. The 1991 survey is the twentieth one. This survey is conducted for Food Marketing Institute by Opinion Research Corporation, Washington, DC, 1991.

Shoppers in 1991 were more concerned about economizing and less concerned about food safety issues and reducing fat, cholesterol, and calories in their diet than were shoppers in 1990.

1. Increased emphasis on price - due to a combination of a significant rise in average grocery bills for the first time since 1986 and a recession. Shoppers were more apt to buy products on special, buy store or lower-priced brands, and stock up on bargains. More than half those surveyed used more coupons, did more with leftovers and bought fewer luxury or gourmet items.

2. Consumer activism increasing - 84% refused to buy products that cost too much, compared to 72 % in 1984.

3. Nutrition concerns levelling off - taste is ranked as the factor of greatest importance to shoppers, followed by nutrition, product safety (especially pesticide and herbicide residues as a "potential health hazard") and price.

Shopper concerns about fat, salt, cholesterol and calories peaked in 1990 & have dropped markedly for the first time since 1984. Over the past 8 years concerns about preservatives, nutritional value and chemical additives also declined.

Some individuals may be aware now that individual risk factors need to be considered before adopting stricter dietary limitations.

On the other hand, some may have hoisted the white flag & decided to eat what they wanted because they were tired of vacillating admonitions on what's healthy and what's not. Others may be preoccupied with making ends meet so that watching fat & calories is not a priority concern or they may feel entitled to a treat.

APPENDIX 3

Food Technology 45, 42: Peryam and Kroll advert - 1991:

A TWO-MINUTE SEMINAR ON SENSORY RESEARCH - BEVERLEY KROLL

Choosing the sensory research firm that best meets your needs is more difficult than it sounds. It’s not easy to step back from an important project to give objective consideration to vendor capabilities. Certain factors, however, are critical:

1. The firm should have the confidence to question criteria and methodology as well as to implement your protocol. When they think you are wrong, they should have the expertise to suggest changes that meet the real objectives within budget and time constraints.

2. Consistent and accurate sensory research results require the right laboratory and equipment. Comprehensive operations are not always essential, but smart clients want the flexibility to expand parameters or add components like Research Guidance and Crisis Response tests. Facilities should exceed basic requirements to allow for enhancements.

3. A consumer sensory research firm is only as good as its access to consumers, especially since specialty population research is becoming more common. The research firm should be able to meet exacting market specifications easily and quickly. The quality of your study can’t be sacrificed to the limitations of available panellists.

4. Without quality reporting, even good research is not effective. The research supplier should have comprehensive computer functions backed by statistical expertise to analyze the large volumes of raw data on a timely basis. The firm should be able to prepare a variety of reports, ranging from quick top line summaries to comprehensive analysis that present all findings and discuss nuances.

6323 North Avondale Avenue
Chicago, Illinois 60631
&
4175 East La Palms
Anaheim, California 92807.
APPENDIX 4:

Fig. 1: Quantitative Descriptive Analysis (QDA) "spider's web" for three types of berries (Stone et al., 1974; Stone, 1990)
INTRODUCTION

The word “protein,” derived from the Greek “πρωτειν” which means “I occupy first place,” was originally and accurately suggested by the Swedish chemist, baron J’s Jakob Berzelius, during the 19th Century. Indeed, proteins are the fundamental components of living matter. No form of life devoid of protein, is known. Viruses, considered by some as the borderline between the living and the inanimate, are made up of protein.

From the biological standpoint, the function of proteins is as diverse and complex as their chemical structure. Among others, proteins are needed for structural purposes and contractility of living beings. In addition, they are intimately related to the mechanisms of transfer, storage and release of energy. Blood proteins are an example of those engaged in transport processes. Several hormones are peptides made up of a few amino acids whilst others, such as insulin, are considered proteins. A fascinating function of certain proteins, known as enzymes, is to act as biological catalysts. All enzymes known are proteinaceous substances.

Nucleic acids, biological compounds on which the genetic code, inheritance and the expression of life are based, depend on the presence and function of proteins (enzymes). Their own synthesis, the transfer, processing and storage of the vital information they contain would not be possible in the absence of such enzymes. The foregoing clearly illustrates the importance of proteins within the context of life and living beings.

Not surprisingly, proteins constitute an extremely important type of nutrient which must be present (as such, or in the form of amino acids) in the diet of many higher forms of life. Indeed, from the standpoint of nutrition, proteins have been the object of numerous studies. The early work of Osborne and Mendel at the onset of the 20th Century, and later on, the findings of W.C. Rose, were instrumental in establishing the concept of biological value of proteins, and the indispensable or essential character of certain amino acids in the nutrition of animals. These concepts, continuously strengthened and enriched through the present time, account for innumerable advances in the health and agricultural sciences.

FOOD SUPPLY

During the past few decades, the supply of food for a growing human population, now approximating 6 000 million, has occupied a great deal of attention internationally, in the political, economical and sociological spheres. Of great concern is the situation in countries under development, which comprise the bulk of the world's population. Fertility index (offspring/woman) and thus the rate of population expansion are generally far greater in developing countries than in the industrialized world. Recent estimates indicate that, if the rate of population expansion is maintained, ca 90 % of all human beings will inhabit the Third World in two more decades.

Many developing nations are also characterized by one or more of the following: uneven distribution of wealth, low indices of sanitation, health, education, technology, and industrialization; increasingly inadequate food production capabilities; poorly managed economies, environments and natural resources; a very large portion of the inhabitants are children under 15 years of age; malnutrition affecting most of the population.

A number of monumental tasks must be completed by the beginning of the 21st Century. Amongst them:

- Nearly 700 million jobs must be created in countries under development, or 35 times as many as those needed in industrialized nations!
- The world's supply of food must be substantially improved.
The degree of difficulty of either of the above is as great as their importance. The longer it takes for solutions to be reached, the harder these will be to come by, and the more serious the consequences.

Concentrating on the supply of food, inadequate energy intake appears to be a very common deficiency in countries under development. Perhaps the most serious one, however, is a deficient ingestion of high biological value protein which, during the embryonic stages and later on during perinatal age, may seriously impair physical growth and the development of the nervous system.

At present, the need for high quality food protein greatly exceeds the world’s supply. Several factors perpetuate this situation:

The production of traditional sources (meat, milk and eggs) may be a lengthy, capital intensive process. Meat, milk and eggs are often unaffordable to the most undernourished/marginal groups. Population grows at a faster pace than do traditional food protein resources.

The mean per capita consumption of meat in the world from 1970 to 1988, for instance, has grown approximately 18 percent. During the same period, the population of the world increased by a factor of approximately 32 percent. If these data are viewed from the perspective of developed vs. developing countries, the increase in mean annual per capita consumption in the former was of the order of magnitude of 13.6 kg (to 79.7 kg) vs 5.6 kg (to 15.6 kg) in the latter.

One truly outstanding case is China, where meat consumption (in million metric tons) has grown from 7.8 in 1970 to 22.4 in 1988. This, on a per capita, per annum basis, represents a jump from 9.4 to 20.9 kg or +223 percent. Annual population growth, during the same period, was ca 1.6 percent. In any case, an annual per capita consumption of meat such as that found in countries under development (15.6 kg), or even China’s, may be considered low.

A very serious, related issue is that certain food staples may be used either as food or as feed. Simply stated, the alternatives are to use the indirect route (i.e., converting feed protein to animal protein); or, for humans to consume protein directly, thus by-passing the animal.

PROTEIN RESOURCES

From the standpoint of efficiency, the indirect route is time consuming and costly. To illustrate the point, a chicken must ingest ca 4 kilograms of feed protein, during 7 or 8 weeks, before it produces one kilogram of food protein. In the case of pork, the feeding period is of the order of 180 days and the conversion ratio of feed/food protein ca 9:1. Beef protein takes up to one year with a feed/food protein conversion ratio of up to 20:1.

The concept of transforming feed protein to food protein faces other constraints. In order to obtain one metric ton of edible pork protein, it is necessary to manufacture, mobilize and store, some 40 MT of feed containing a large proportion of grain and oilseeds. In the case of beef, approximately 100 MT of food results in one metric ton of protein for human consumption. The foregoing is particularly important in countries which must disburse large amounts of foreign exchange for the import of feed ingredients, whether permanently or due to unexpected circumstances such as an unexpected crop failure.

Considering the conversion of feed protein to food protein, it is interesting to consider production and utilization of alternate, renewable food protein sources on a broader perspective, taking not only availability into consideration but also their nutritional, sensorial, logistical, and economical aspects.

PROTEIN POLICY

Briefly, this could be stated as a protein policy that would allow the manufacture of traditional foods by combining available, edible protein ingredients in such a manner that:

The protein and essential amino acid needs of the population be met successfully in the most economical fashion; whilst,

The sensorial characteristics of the traditional foods in question remain without alteration, strictly adhering to those which consumers prefer, expect and, ultimately, demand.

At present, most of the protein produced in the world is of vegetable origin, much of which is utilized as feed. Nearly half the protein derived from cereals, and only one tenth of that from oilseeds is for human consumption. It would therefore seem reasonable to assume that vegetable protein presently available could alleviate the protein deficiency observed in many parts of the world.

The recommended protein intake proposed by FAO/WHO is 800 mg/kg body weight in the case of adult human beings. Satisfying the protein requirement of adult weighing 70 kg, using cereals alone, would require a daily ingestion of 470 g wheat, or about 620 g corn (maize), or some 700 g rice. The feasibility of the foregoing would be greatly improved if protein from these sources could be available in a highly purified form (>90% protein).
Although it is possible to obtain ca 620 kg corn protein per hectare cultivated land, extracting protein in a highly purified form from this cereal may encounter yield related difficulties, since corn contains only 9 % protein. Other cereals would exhibit the same limitation, plus that represented by the poor biological value of the protein they contain. In addition, during the past decades, the world's grain production has marginally exceeded consumption thereof.

Albeit cultivated at a considerably smaller scale, oilseeds contain higher protein levels than cereals. However, their yield of protein per hectare, in many cases, is below that indicated for corn. Furthermore, as is true in the case of cereals, the protein from most oilseeds is deficient in one or more amino acids essential to human nutrition.

**ISOLATED SOY PROTEINS**

Soybeans, which contain ca 35 % protein, represent almost one half the tonnage of all oilseeds produced in the world. About two thirds of all protein derived from oilseeds is soy protein. Currently, isolated soy protein may be produced on a large scale, at low cost and with a modest capital expenditure. Indeed, isolated soy protein constitutes a very interesting case as a unique, established world protein resource with a history of consumption by human beings.

Nutritionally, isolated soy protein is highly digestible. Its essential amino acid composition is such that, as sole protein source, it may meet protein and amino acid requirements of humans when fed at the recommended minimum levels of ingestion. Indeed, there are isolated soy proteins which meet or exceed the amino acid requirement suggested for children and adults by the FAO/WHO/UNU. Clinically controlled studies indicate that the nutritional value of isolated soy protein is comparable to that of egg, milk and meat protein, for humans.

From the agricultural perspective, it is possible to obtain a yield of over 725 kg soy protein/ha cultivated land. By comparison, the figure for the highest yielding of all meat sources, that of poultry, is of the order of 200 kg protein/ha. Economically speaking, isolated soy protein is efficiently produced from current resources, and is only marginally affected by constraints frequently found in many countries around the world such as limited arable land, scarcity of labour or high cost of fuel energy. For food production purposes, one metric ton of isolated soy protein is equivalent to four metric tons of lean meat.

**CONSUMER DEMANDS**

Traditional proteinaceous foods are quite varied. In many cases, their characteristics have been defined for centuries thus constituting veritable cultural entities. At present, the technology to manufacture isolated soy proteins with defined functional characteristics, and the methodology to incorporate them into traditional foods without affecting sensorial characteristics thereof, whilst simultaneously delivering significant economical value, is a reality.

Within a world hungry for protein, isolated soy proteins constitute an outstanding building block for the production and development of food for human consumption. Furthermore, they represent a challenging field of endeavour for those confronted with the task of providing wholesome, nutritious, economically sound food products, traditional or novel, which will fully satisfy or exceed consumer preferences and high quality expectations.

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Sensory analysis of *M. longissimus lumborum* from lambs fed either maize or sorghum silage diets

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**INTRODUCTION**

Alternative dietary materials such as silage for weaner lambs were investigated in the Highveld Region of the Transvaal (RSA), as this an area characterised by a lack of natural winter grazing. This could lead to more effective use of the autumn lambing season viewed as being more advantageous than the spring lambing season in the Highveld region due to better parasite control (Reyneke, 1967). Maize and grain sorghum crops are produced successfully in this region and both are suitable for silage production (Agricultural Development Programme, 1986). However, limited information concerning the feeding of weaner lambs on maize or sorghum silage is available in the literature (Boshoff *et al.*, 1980). According to Paul *et al.* (1981), many researchers have reported results on the effect of nutrition on the carcass classification of lambs, but only a few have worked on the effect of the diet on both the eating quality of the meat and its cooking losses. Some researchers have found that the eating quality of lambs is affected by the diet and that foreign odours and foreign flavours (generally referred to as "taints") in particular, may occur (Cramer *et al.*, 1967). Field *et al.* (1978) found that high levels of maize silage only caused an increase in the flavour intensity and that the flavour became more moderate as the maize silage level was decreased and the maize levels increased.

Considering the availability of maize and sorghum in the Highveld region and the resultant potential for silage production, as well as the limited information available on the effect of the various silage diets on the eating quality of lamb, this study was conducted to determine the effect of various types of silage on the selected sensory quality characteristics and cooking losses of lamb.

**AIM**

The aim of this research was to assess the eating quality and cooking losses of *M. longissimus lumborum* cuts obtained from lambs fed on one of four types of silage or the control diet, to determine whether or not significant differences occurred.

**MATERIALS**

**Lambs**

South African Mutton Merino weaner lambs (wethers, starting mass approximately 20 kg) were randomly divided into five groups according to the dietary treatments. The groups of lambs were put onto the diets under the same circumstances, until a finishing average slaughter mass of 45 kg was reached. After a fasting period of 18 hours the lambs were slaughtered according to normal slaughtering procedures (not electrically stimulated), the carcasses cooled and aged for 5 days at 2 °C before being cut up. The left and right *M. longissimus lumborum* cuts (loins) were taken from four lambs per group. After receipt, the two (left and right) loins cut of each lamb were vacuum packed, labelled and frozen at −70 °C.

**Diets**

The following diets were implemented:

<table>
<thead>
<tr>
<th>Diet</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (S)</td>
<td>Non-bird-resistant grain sorghum silage + concentrate</td>
</tr>
<tr>
<td>2 (M)</td>
<td>Maize silage + concentrate</td>
</tr>
<tr>
<td>3 (B)</td>
<td>Bird-resistant grain sorghum silage + concentrate</td>
</tr>
</tbody>
</table>

14 October 1992, ADSRI, Irene, South Africa

2nd Revised Printing 11 November 2014
The left loin of each lamb was minced for the detection of possible foreign odours and foreign flavours. As foreign odours and flavour could be present in the fat (Sink & Caporaso, 1977), the fat was removed from the bone with the meat and minced together, using a Kenwood mincer. Each sample was individually prepared and the mill was washed thoroughly in between samples. Individual samples of 500 g were stored overnight in plastic bags, clearly coded and labelled.

Cooking methods

Stewing (left loins, minced)

For each evaluation session the five minced loin samples were stewed simultaneously for 45 minutes in separate 2-litre saucepans fitted with hollow lids. For every 100 g of mince an amount of 25 ml boiling distilled water was added. To retain volatile odours and flavours the samples were stewed slowly in closed saucepans and only stirred occasionally to keep the mince loose. The samples were served directly from the saucepans for effective evaluation of foreign odours.

Oven-roasting (right loins, whole)

The individual bone-in right loin cuts were roasted, uncovered, on a rack in a roasting pan with the fat layer uppermost in an oven (Defy 420D), at 160 °C until an internal endpoint temperature of 70 °C was reached (Electronic Ama-Digit ET thermometer). Each roasted loin cut was then removed from the oven, the relevant masses determined, the 10-minute standing period allowed before the M. longissimus lumborum was removed from the bone. Because the typical lamb aroma and flavour is also associated with the fat, the subcutaneous fat was retained for evaluation by the sensory panel.

Sampling for sensory evaluation

Left loin, minced

In order to ensure that the sensory panel room remained relatively free from food odours, the minced samples were served in the 2-litre saucepans with hollow lids on two prepared tables on an adjoining verandah in front of the sensory panel room. The lid of each sample was lifted by the sensory panel leader so that the steam could escape (as a precaution against scalding) before the panel members were allowed to move closer to smell. The sensory panel evaluated every sample for the presence of foreign odours by deeply inhaling the vapours and specifically also smelling the vapours which had collected in the hollow of the lid, and noting their conclusions on the score sheets. Then 15 ml of each sample was served into lukewarm, coded, porcelain bowls and served in the random order indicated on the evaluation forms to the sensory panel in the sensory panel cubicles, for evaluation of the presence or absence of foreign flavours.

Right loin, whole

Six 5 mm-thick slices were subsequently cut from the caudal halves of each oven-roasted sample, placed on lukewarm, coded, white porcelain bowls, covered with aluminium foil to prevent loss of aroma, drying and cooling and served warm to the sensory panel members. This meant that each panellist received five bowls on a white plate per session.

Serving

Four evaluation sessions were conducted with two 5-sample series of five mince samples followed by the five oven-roasted samples per session.

Sensory evaluation

Permanent staff from the Department of Home Economics and Dietetics, PU for CHE, Potchefstroom, were screened and trained according to procedures outlined by the AMSA (1978) and Cross et al. (1978). The eating quality characteristics of the lamb samples were thus evaluated by the 6-member trained, analytical sensory panel using a category scaling test with a 1-8 point Likert-type measuring scale. The sensory quality attributes evaluated were tenderness, juiciness, flavour and the presence of foreign odour and foreign flavours. A value of 1 always indicated the minimum (negative) and 8 the maximum (positive) presence of a characteristic, except in the case of foreign odour and flavour, where 8 indicated the absence of any taints. The criteria for sensory evaluation, as well as accompanying explanations, were presented to the sensory panel members during every session together with the evalua-
tion form so that there could be no uncertainty regarding the meaning of the values allocated.

Shear force resistance

Shear force samples were obtained from the thoracic half of the right side M. longissimus lumborum. A Warner-Bratzler shearing device was used to determine the shear force required to cut through a 12.5 mm diameter cylindrical core of cooked meat cooled overnight (15 °C), perpendicular to the grain of the meat. Ten measurements were carried out on each sample and from these values the mean shear force resistance (kg force) per sample was calculated. The higher the reading obtained, the greater the shear force required to cut through the meat and therefore the tougher the meat.

Statistical analyses

Testing differences between the means of dietary treatments, one-way analyses of variance were done on the sensory and cooking loss data. This was followed by multiple comparisons between dietary means using the Tukey-method (Steel & Torrie, 1980) which controls the experiment-wise error rate (in contrast with the least significant difference (LSD)-method, which only controls the comparison-wise error rate). The procedure GLM of SAS (SAS Institute Inc., 1985) was used in these computations.

RESULTS AND DISCUSSION

The means, their standard deviations and the P-values obtained from the one-way ANOVA's with diet as factor and Tukey's multiple comparisons, for the various sensory quality characteristics, total cooking losses (%) and shear force resistance measurements, are given in Tables 1 and 2.

From Table 1 (50 % silage) and Table 2 (70 % silage) it is clear that no statistically significant differences (P<0.05) occurred for any of the sensory quality characteristics or cooking losses. The results also indicate no foreign odour or foreign flavour due to maize silage or any of the other silage types. This is in contrast to the report by Field et al. (1983) referring to research done by Locker & Moore, who found a pork taint in lamb's meat due to maize silage.

In contrast to the sensory tenderness results, the shear force resistance evaluation (Table 1) showed a significant diet effect (P=0.0004), with the mean of loin muscles obtained from Diet 3 being significantly different (less tender) from those of the other diets. This could be due to the smaller variations and more replications in the case of shear evaluations. Note, however, that a shear force mean of 2.16 kg (Diet 3) indicates very tender meat in any case and is therefore not of practical significance. The shear force resistance evaluation in Table 2 indicates that the mean of loin muscles obtained from Diet 2 differed significantly (more tender) from those of Diets 1, 3 and 5. These values also, however, indicate that all the samples were very tender.

ADDITIONAL ANALYSES

A two-way ANOVA was also performed on the data, with silage level and diet as factors (control diet excluded). No statistically significant effects were found for any of the sensory quality characteristics, total cooking losses (%) and shear force resistance measurements, are given in Tables 1 and 2.

From Table 1 (50 % silage) and Table 2 (70 % silage) it is clear that no statistically significant differences (P<0.05) occurred for any of the sensory quality characteristics or cooking losses. The results also indicate no foreign odour or foreign flavour due to maize silage or any of the other silage types. This is in contrast to the report by Field et al. (1983) referring to research done by Locker & Moore, who found a pork taint in lamb's meat due to maize silage.

In contrast to the sensory tenderness results, the shear force resistance evaluation (Table 1) showed a significant diet effect (P=0.0004), with the mean of loin muscles obtained from Diet 3 being significantly different (less tender) from those of the other diets. This could be due to the smaller variations and more replications in the case of shear evaluations. Note, however, that a shear force mean of 2.16 kg (Diet 3) indicates very tender meat in any case and is therefore not of practical significance. The shear force resistance evaluation in Table 2 indicates that the mean of loin muscles obtained from Diet 2 differed significantly (more tender) from those of Diets 1, 3 and 5. These values also, however, indicate that all the samples were very tender.

A two-way ANOVA was also performed on the data, with silage level and diet as factors (control diet excluded). No statistically significant effects were found for any of the sensory quality characteristics, total cooking losses (%) and shear force resistance measurements, are given in Tables 1 and 2.
Table 2: Mean values, standard deviations and one-way ANOVA levels of significance for the sensory quality characteristics, cooking losses and shear force resistance of lamb *M. longissimus lumborum*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>P-value</th>
<th>Diet and level administered (70 % silage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign odour</td>
<td>0.5237</td>
<td>7.92 ± 0.28#</td>
</tr>
<tr>
<td>Foreign flavour</td>
<td>0.6680</td>
<td>7.96 ± 0.20</td>
</tr>
<tr>
<td>Tenderness</td>
<td>0.2981</td>
<td>7.42 ± 0.58</td>
</tr>
<tr>
<td>Juiciness</td>
<td>0.8426</td>
<td>7.38 ± 0.49</td>
</tr>
<tr>
<td>Flavour</td>
<td>0.5549</td>
<td>7.33 ± 0.56</td>
</tr>
<tr>
<td>Cooking losses:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total, %</td>
<td>0.1731</td>
<td>17.08 ± 3.70</td>
</tr>
<tr>
<td>Drip, %</td>
<td>0.1367</td>
<td>6.21 ± 2.14</td>
</tr>
<tr>
<td>Evaporation, %</td>
<td>0.2797</td>
<td>10.88 ± 1.69</td>
</tr>
<tr>
<td>Shear force:</td>
<td>0.0014**</td>
<td>1.93 ± 0.40*</td>
</tr>
</tbody>
</table>

# Standard deviation. A score of six for sensory characteristics was considered to be most positive response
** Means in the same row with different superscripts differ significantly at 5 % level, applying Tukey's multiple comparisons
** P<0.01

Characteristics as far as diet is concerned. Although a few statistically significant effects were obtained concerning level and interaction effects, none of these exceptions turned out to be practically significant.

Comparison of the data obtained from the twolevels within each diet using t-tests, showed that no statistically significant differences occurred between the levels concerning the means for any of the sensory quality characteristics or cooking losses.

CONCLUSION

As no statistically significant differences were found for any of the sensory quality characteristics, there is no reason to assume that the eating quality of the eating quality of the loins differs. Generally speaking, the *M. longissimus lumborum* cuts obtained from lambs fed on concentrate plus the different silage diets (both levels) and the loin cuts from lambs fed on the control diet (equal proportions of maize meal and milled hay), were considered to be of high eating quality by the trained sensory panel. Using the terminology on the score sheet, all these samples were assessed as being very tender, very juicy, with a taint-free, typical lamb odour and flavour.

One may thus be safe in concluding that these silage diets and their levels of administration (50 % and 70 %) may be recommended for the feeding of weaners, as they do not cause significant sensory defects in the loin cuts. Further research may possibly be directed at leg cuts, using a moist heat cooking method, to determine whether or not these findings may be generalized for the whole carcass. It is also strongly recommended that sensory analysis of meat should be a standard procedure included in research of this nature.

ACKNOWLEDGEMENTS

The authors wish to acknowledge co-operation and assistance of the Animal Science Section, Highveld Region of the Department of Agricultural Development, Potchefstroom, RSA.

Sincere appreciation is also expressed to Mrs Jennie Illsley, Meat Industry Centre, Irene Animal Production Institute, for her valuable expertise in the preparation of the graphics for this poster presentation.

REFERENCES

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The influence of experimental feeding conditions on growth performance of cattle

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INTRODUCTION

In the feedlot and related intensive livestock industry, feed efficiency (as measured by feed conversion ratio (FCR)) is of major economic importance. Consequently, it should always be evaluated in any growth experiment. In order to keep the costs down and minimize the animal numbers, animals are fed individually in single pens (1 x 2 m) at the Irene Animal Production Institute (IAPI) and many other research institutes. In this way the feed intake of each animal is representative of that of a whole pen of animals. However, the question is often raised as to the effect of these restricted conditions on the growth response of the animal. Furthermore, it is questionable whether results obtained under these circumstances are valid for commercial conditions in which animals have more freedom of movement, yet have to compete for their food. Similarly, Phase-C growth results are queried, as animals on Phase-C have freedom of movement but no competition for food.

AIM

A trial was conducted to compare the effect of different methods of feeding and housing on the growth performance of experimental animals.

METHODS

Thirty Hereford steers (approx. 12 months old) were randomly divided into 3 groups so that the average mass of the 3 groups was similar. The 3 groups were then randomly allocated to the following treatments:

1. Ten individual pens (1 x 2 m), with individual water and food supply (1m feeding space/animal) each housing a single animal. The animals were allowed out on a daily basis between 08:00 and 09:00.

2. Ten animals to a pen (14 x 6 m) with free access to food and water. The feed was supplied in a trough 6 m wide (feeding space: 0.6 m/animal).

3. Phase-C feeding facilities at IAPI: one pen (20 x 8 m) equipped with 10 individual feeding troughs (0.6 m/animal), each with an electronically controlled access.

A commercial cattle finishing diet (meal form) was supplied to all treatments on an ad lib. basis.

Diet composition:

<table>
<thead>
<tr>
<th>Component</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>12.0</td>
</tr>
<tr>
<td>Fibre</td>
<td>12.5</td>
</tr>
<tr>
<td>Metabolisable energy</td>
<td>11.72 MJ/kg</td>
</tr>
</tbody>
</table>

Growth evaluation

Each animal was weighed at commencement of the trial, after a 14 day dietary adaptation period and on a weekly basis thereafter until slaughter at 70 days on trial. The animals of the Phase-C group were adapted to the self-feeders for an additional 7 days and consequently had a growth period of only 63 days. Weekly feed intakes were determined and used to calculated the total dry matter intake and the FCR of the animals. The animals were slaughtered at the IAPI abattoir and their carcasses classified according to fat cover and conformation.

RESULTS

The average daily gain (ADG), dry matter feed intakes and FCR of the three feeding regimes did not differ significantly (P>0.05) from each other. Since carcass mass and classifica-
tion of the three treatments did not differ significantly, the possible influence of these variables on FCR was nullified.

CONCLUSION

Feeding regime, in terms of method of feed supply and housing of animals, had no significant effect on the growth performance of cattle under intensive feeding conditions. Growth results obtained from experiments where Phase-C self feeders or individual pen-feeding are used, can therefore be applied with confidence to commercial group feeding situations.

Table 1: Performance means for growth and carcass data of three feeding regimes.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Individual feeding (I) (1 animal/pen)</th>
<th>Phase-C individual feeding (C)</th>
<th>Group feeding (G)</th>
</tr>
</thead>
<tbody>
<tr>
<td>End mass (kg)</td>
<td>367</td>
<td>361</td>
<td>366</td>
</tr>
<tr>
<td>Carcass mass (warm) (kg)</td>
<td>216</td>
<td>213</td>
<td>216</td>
</tr>
<tr>
<td>Fat code</td>
<td>3+</td>
<td>4-</td>
<td>4-</td>
</tr>
<tr>
<td>Conformation</td>
<td>4</td>
<td>4+</td>
<td>4+</td>
</tr>
<tr>
<td>Feed intake*(kg/day)</td>
<td>10,06</td>
<td>10,17</td>
<td>9,94</td>
</tr>
<tr>
<td>ADG* (kg/day)</td>
<td>1,84</td>
<td>1,81</td>
<td>1,76</td>
</tr>
<tr>
<td>FCR* (kg/kg)</td>
<td>5,49</td>
<td>5,64</td>
<td>5,69</td>
</tr>
</tbody>
</table>

* Trial commenced after 14 days of adaptation for groups I and G. Group C was adapted to the self feeders for a further 7 days. Average daily gain (ADG), feed conversion ratio (FCR) and feed intake for I & G was calculated over 70 days and over 63 days for C.


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Evaluation of the quality characteristics of *Mm. longissimus thoracis et lumborum* from South African Mutton Merino cross Merino lambs on ten different dietary regimes

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INTRODUCTION

Acceptability of red meats (pork, lamb or mutton and beef) is generally determined by their flavour. Genetics and environment influence meat flavour. Species is the most important genetic factor, and feed source is the most important environmental factor (Melton, 1990).

According to Ashes & Rich (1987) diet plays a very important role in the meat production of sheep. Many flavours are transferred to the meat and many substances that are produced during the digestive process or are contained in the diet can react during the cooking process to produce undesirable flavours and odours. Park, Ford & Ratcliff (1978) detected a “sweet” and “oily” odour and flavour in cooked lamb meat, where the lambs were fed a protected sunflower seed-casein supplement. In general, sheep fed on concentrate diets are more likely to have meat with a more bland taste than that from pasture fed animals (Ashes & Rich, 1987). Any feed that influences the concentration of the flavour precursors or deposits unique components in the fat will affect the cooked meat flavour, with the extent of the influence being dependent on the animal species (Melton, 1990).

AIM

The aim was to determine which dietary regime(s), if any, is/are superior, in terms of selected quality characteristics (odour of fat and meat, initial and sustained juiciness, tenderness, flavour and residue), cooking losses and shear force resistance measurements of oven-roasted lamb *Mm. longissimus thoracis et lumborum* cuts obtained from SA Mutton Merino X Merino crosses.

MATERIALS AND METHODS

Lambs and *Mm. longissimus thoracis et lumborum* cuts: A total of 80, four month old, South African Mutton Merino cross Merino lambs were randomly allocated to the ten respective diets, as summarised in Table 1. There were therefore eight lambs per dietary regime. The lambs were slaughtered at an age of eight to nine months, when they reached a live mass of ca 42 kg. The lambs were weighed and slaughtered at the Meat Science Centre of the Animal and Dairy Science Research Institute, Irene. The carcasses were electrically stimulated at 800 V for 120 seconds, immediately after bleeding. The dressed carcasses were then chilled for a total of 24 hours at a temperature of 0-5 °C and reweighed. The carcasses were then graded, halved and subdivided. The right *Mm. longissimus thoracis et lumborum* cuts used in this study, were weighed. Each cut was then labelled with computer generated labels bearing the following information: code number, name of cut, mass, date slaughtered and date to be frozen. Sharp bones were covered with “bone guard” to prevent puncturing of the packaging. Each cut was individually wrapped and vacuum-packaged using “Cryovac Barrier Bags (BB1)” supplied by Darex Africa (Pty) Ltd.

The whole cuts for sensory analysis were left at a temperature of 0-5 °C for seven days to mature and were frozen and stored at -20 °C until further testing.
Oven-roasting and sensory analysis:
The required meat cuts were thawed slowly to prevent excessive thawing losses, according to a standardised procedure (for 24 hours in a coldroom at a temperature of 5-7 °C) prior to cooking and further preparation for sensory analysis.

The thoracic and lumbar parts of the cuts were oven-roasted (dry heat cooking method) separately, at 160 °C, on a rack, as this has been found to be the most suitable method for these cuts (Van Rensburg, 1990). An internal cooking temperature of 75 °C is the most acceptable for sensory analysis of lamb. Each cut was cooked in an AEG oven model B 880 D, following basic AMSA (1978) guidelines, for cooking loss determinations.

The cooking data collected included: mass of raw sample in grams, cooking time in minutes, internal endpoint temperature (°C), drip loss (in ml), drip’s fat and stock volume (in ml). After cooking, a standing period of ten minutes was allowed before weighing for total cooking loss calculations.

After weighing, the fat layer was removed and cut into 1 cm x 1 cm squares. Each square was placed in a 50 ml beaker, covered with a coded aluminium foil square, placed into a warming oven at approximately 100 °C and left there (approximately 5 - 10 minutes) until the sensory panel members were ready to evaluate it for odour.

The M. longissimus lumborum was used for sensory analysis and the M. longissimus thoracis for Instron determinations (using the section of the muscle adjoining the lumbar area).

RESULTS AND DISCUSSION

Table 2 is a summary of the means obtained for the cooking loss and Instron shear force resistance data, whereas Table 3 gives the average scores for the sensory quality characteristics. Significant differences amongst the different dietary treatments are indicated with superscripts.

Discussion of cooking losses and shear force resistance results.

The total cooking loss percentages (Table 2) ranged from the lowest mean value of 15,55 % for loins obtained from lambs fed on the grain sorghum-cotton seed oilcake diet (Diet 2), to

---

Table 1: Composition of the ten different dietary regimes

<table>
<thead>
<tr>
<th>FEED COMPONENT</th>
<th>Dietary Treatment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>371,40</td>
<td>385,63</td>
</tr>
<tr>
<td>Grain sorghum</td>
<td></td>
<td>339,95</td>
<td>341,30</td>
<td>302,06</td>
<td>337,35</td>
<td>302,52</td>
<td>370,90</td>
<td>389,38</td>
<td>395,98</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Sunflower seed oilcake</td>
<td></td>
<td>50,00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cottonseed oilcake</td>
<td></td>
<td>-</td>
<td>50,00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Saponified cottonseed oilcake</td>
<td></td>
<td>-</td>
<td>90,00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Soya beans</td>
<td></td>
<td>-</td>
<td>-</td>
<td>50,00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lucerne</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>91,30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fish meal</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>25,53</td>
<td>-</td>
<td>-</td>
<td>22,00</td>
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</tr>
<tr>
<td>High urea</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8,54</td>
<td>-</td>
<td>-</td>
<td>77,93</td>
<td>-</td>
</tr>
<tr>
<td>Low urea</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,06</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Enargogis curvula</td>
<td></td>
<td>75,00</td>
<td>75,00</td>
<td>75,00</td>
<td>75,00</td>
<td>75,00</td>
<td>75,00</td>
<td>75,00</td>
<td>75,00</td>
<td>75,00</td>
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<tr>
<td>Molasses</td>
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<td>15,00</td>
<td>15,00</td>
<td>15,00</td>
<td>12,50</td>
<td>12,50</td>
<td>12,50</td>
<td>12,50</td>
<td>12,50</td>
<td>12,50</td>
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<tr>
<td>Urea</td>
<td></td>
<td>5,49</td>
<td>4,16</td>
<td>6,09</td>
<td>4,86</td>
<td>7,90</td>
<td>5,25</td>
<td>( )</td>
<td>( )</td>
<td>5,25</td>
<td>( )</td>
</tr>
<tr>
<td>NH₄Cl</td>
<td></td>
<td>5,00</td>
<td>5,00</td>
<td>5,00</td>
<td>5,00</td>
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<td>5,00</td>
<td>5,00</td>
<td>5,00</td>
<td>5,00</td>
<td>5,00</td>
</tr>
<tr>
<td>Ca(CH₃COO)₂ (slaked lime)</td>
<td></td>
<td>4,50</td>
<td>4,50</td>
<td>4,50</td>
<td>4,70</td>
<td>4,50</td>
<td>4,50</td>
<td>4,50</td>
<td>4,50</td>
<td>4,50</td>
<td>4,50</td>
</tr>
<tr>
<td>CaCO₃ (lime)</td>
<td></td>
<td>2,50</td>
<td>2,50</td>
<td>2,00</td>
<td>2,50</td>
<td>2,50</td>
<td>2,50</td>
<td>2,50</td>
<td>2,50</td>
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</tr>
<tr>
<td>Ca₃P₂O₇</td>
<td></td>
<td>-</td>
<td>-</td>
<td>3,00</td>
<td>-</td>
<td>-</td>
<td>3,04</td>
<td>-</td>
<td>-</td>
<td>3,00</td>
<td>-</td>
</tr>
<tr>
<td>NaCl (salt)</td>
<td></td>
<td>2,50</td>
<td>2,50</td>
<td>2,00</td>
<td>2,50</td>
<td>2,00</td>
<td>2,00</td>
<td>2,00</td>
<td>2,50</td>
<td>2,50</td>
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</tr>
<tr>
<td>Water</td>
<td></td>
<td>25,00</td>
<td>25,00</td>
<td>25,00</td>
<td>25,00</td>
<td>25,00</td>
<td>25,00</td>
<td>25,00</td>
<td>25,00</td>
<td>25,00</td>
<td>25,00</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>474,94</td>
<td>524,96</td>
<td>524,95</td>
<td>524,91</td>
<td>528,22</td>
<td>528,18</td>
<td>524,96</td>
<td>524,54</td>
<td>528,15</td>
<td>528,56</td>
</tr>
</tbody>
</table>
Table 2: Cooking losses and shear force resistance measurements of loins obtained from lambs fed on the ten different dietary treatments (according to the 95 % LSD multiple range tests)

<table>
<thead>
<tr>
<th>Measurements</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cooking loss %</td>
<td>16,97</td>
<td>15,55</td>
<td>18,80</td>
<td>17,97</td>
<td>18,59</td>
<td>20,93</td>
<td>18,31</td>
<td>20,93</td>
<td>21,68</td>
<td>17,50</td>
</tr>
<tr>
<td>Drip loss %</td>
<td>5,08</td>
<td>4,30</td>
<td>6,05</td>
<td>5,50</td>
<td>5,61</td>
<td>6,94</td>
<td>5,03</td>
<td>6,09</td>
<td>6,86</td>
<td>5,57</td>
</tr>
<tr>
<td>Evaporation loss %</td>
<td>11,90</td>
<td>11,25</td>
<td>12,75</td>
<td>12,48</td>
<td>12,98</td>
<td>13,99</td>
<td>13,26</td>
<td>14,82</td>
<td>14,91</td>
<td>11,92</td>
</tr>
<tr>
<td>Shear force resistance (Instron) N</td>
<td>62,37</td>
<td>43,70</td>
<td>50,13</td>
<td>48,60</td>
<td>62,20</td>
<td>37,53</td>
<td>49,10</td>
<td>50,17</td>
<td>55,17</td>
<td>51,43</td>
</tr>
</tbody>
</table>

**ab** = Means in the same row with different superscripts differ significantly (P<0.05)

Where:
- Diet 1 = grain sorghum + sunflower seed oilcake
- Diet 2 = grain sorghum + cottonseed oilcake
- Diet 3 = grain sorghum + saponified cottonseed oilcake
- Diet 4 = grain sorghum + soya beans
- Diet 5 = grain sorghum + lucerne
- Diet 6 = grain sorghum + fish meal
- Diet 7 = grain sorghum + high urea
- Diet 8 = grain sorghum + low urea
- Diet 9 = maize + fish meal
- Diet 10 = maize + high urea

Cooking losses are of considerable economic importance, because with higher cooking losses fewer servings will be obtained per kilogram of raw meat (Campbell, Penfield & Griswold, 1987). The average percentage total cooking losses for loins obtained from lambs fed on all ten diets was 18.72 %. This compares well with results reported by Schönfeldt (1989), who found an average percentage total cooking loss of 18.66 % for lamb loins.

The results in this study show that for Instron shear force resistance measurements, the lowest mean value (most tender) was 37.53 N of loins from lambs fed on the grain sorghum-fish meal diet (Diet 6), the highest value being 62.37 N from loins obtained from lambs fed on the maize-fish meal diet (Diet 9). From Table 2 it can be seen that meat obtained from lambs fed on the grain sorghum-fish meal diet (Diet 1), the grain sorghum-cottonseed oilcake diet (Diet 2), the grain sorghum-soya beans diet (Diet 4) and the maize-high urea diet (Diet 10) had the lowest percentages of total cooking loss (ranging from 15.55 % to 17.97 %), while the loins obtained from lambs fed on the grain sorghum-lucerne diet (Diet 5), the grain sorghum-fish meal diet (Diet 6), the grain sorghum-low urea diet (Diet 8) and the maize-fish meal diet (Diet 9) (ranging from 18.59 % to 21.68 %) had the highest percentages of total cooking loss.

Table 3: Sensory analysis results of loins obtained from lambs fed on the ten different dietary treatments (according to the 95 % LSD multiple range tests)

<table>
<thead>
<tr>
<th>Sensory analysis variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat odour</td>
<td>3,96</td>
<td>4,18</td>
<td>3.92</td>
<td>3,90</td>
<td>4,56</td>
<td>4,00</td>
<td>3,76</td>
<td>4,02</td>
<td>4,66</td>
<td>3,60</td>
</tr>
<tr>
<td>Meat odour</td>
<td>4,34</td>
<td>4,72</td>
<td>4,94</td>
<td>4,78</td>
<td>4,54</td>
<td>4,68</td>
<td>4,44</td>
<td>4,76</td>
<td>4,78</td>
<td>4,06</td>
</tr>
<tr>
<td>Initial juiciness</td>
<td>5,34</td>
<td>5,16</td>
<td>4,98</td>
<td>5,30</td>
<td>5,32</td>
<td>5,26</td>
<td>5,16</td>
<td>5,14</td>
<td>5,10</td>
<td>5,02</td>
</tr>
<tr>
<td>Sustained juiciness</td>
<td>4,98</td>
<td>4,58</td>
<td>4,60</td>
<td>4,82</td>
<td>4,90</td>
<td>4,68</td>
<td>4,52</td>
<td>4,46</td>
<td>4,72</td>
<td>4,78</td>
</tr>
<tr>
<td>Tenderness/ toughness</td>
<td>4,46</td>
<td>5,50</td>
<td>4,50</td>
<td>4,44</td>
<td>5,04</td>
<td>5,52</td>
<td>4,94</td>
<td>4,26</td>
<td>5,22</td>
<td>5,50</td>
</tr>
<tr>
<td>Flavour</td>
<td>4,44</td>
<td>4,74</td>
<td>4,52</td>
<td>4,28</td>
<td>4,64</td>
<td>4,58</td>
<td>4,18</td>
<td>4,26</td>
<td>4,24</td>
<td>4,18</td>
</tr>
<tr>
<td>Residue</td>
<td>3,94</td>
<td>4,64</td>
<td>3,78</td>
<td>3,96</td>
<td>4,30</td>
<td>4,50</td>
<td>4,14</td>
<td>3,48</td>
<td>4,30</td>
<td>4,48</td>
</tr>
</tbody>
</table>

**ab** = Means in the same row with different superscripts differ significantly (P<0.05)

Where:
- Diet 1 = grain sorghum + sunflower seed oilcake
- Diet 2 = grain sorghum + cottonseed oilcake
- Diet 3 = grain sorghum + saponified cottonseed oilcake
- Diet 4 = grain sorghum + soya beans
- Diet 5 = grain sorghum + lucerne
- Diet 6 = grain sorghum + fish meal
- Diet 7 = grain sorghum + high urea
- Diet 8 = grain sorghum + low urea
- Diet 9 = maize + fish meal
- Diet 10 = maize + high urea

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obtained from lambs fed on the grain sorghum-sunflower seed oilcake diet (Diet 1). The average Instron shear force resistance reading for the loins obtained from lambs fed on all ten diets is 51,04 N. Schönfeldt (1989) reports an average reading of 32,5 N for lamb loins.

**Discussion of sensory analysis results.**

For odour of fat, odour of meat, initial juiciness, sustained juiciness, tenderness/toughness and flavour, the sensory panel could have given a score ranging from one to seven with one being extremely unpleasant and seven being extremely pleasant. A score of four is neutral as well as any score ranging from 3,5 to 4,5. For all of the sensory quality characteristics measured on a scale of one to seven, none of the lowest scores were below the lowest neutral score of 3,5 (Table 3).

For odour of fat, loins from lambs fed on the grain sorghum-lucerne diet (Diet 5) and the maize-fish meal diet (Diet 9) received higher-than-neutral scores and can thus be considered as being good/acceptable/pleasant. The maize-high urea diet (Diet 10) had the lowest score (3,60).

For odour of meat, loins obtained from lambs fed on the grain sorghum-cotton seed oilcake diet (Diet 2), the grain sorghum-saponified cotton seed oilcake diet (Diet 3), the grain sorghum-soya beans diet (Diet 4), the grain sorghum-lucerne diet (Diet 5), the grain sorghum-fish meal diet (Diet 6), the grain sorghum-low urea diet (Diet 8) and the maize-fish meal diet (Diet 9) received higher-than-neutral scores and can thus be considered as pleasant.

For initial juiciness, loins obtained from lambs fed on all ten the diets had higher-than-neutral scores and can thus be considered as being juicy. The same trend is noted for sustained juiciness, except for the grain sorghum-low urea diet (Diet 8) where the score was 3,48.

For tenderness/toughness loins obtained from lambs fed on the grain sorghum-cotton seed oilcake diet (Diet 2), the grain sorghum-saponified cotton seed oilcake diet (Diet 3), the grain sorghum-lucerne diet (Diet 5), the grain sorghum-fish meal diet (Diet 6), the grain sorghum-high urea diet (Diet 7), the maize-fish meal diet (Diet 9) and the maize-high urea diet (Diet 10) had higher-than-neutral scores and can thus be considered as being tender. Although there were significant differences in tenderness of the loins obtained from lambs fed on the ten different diets, the loins obtained from lambs fed on all ten the diets can be considered to be tender. Loins obtained from lambs fed on the grain sorghum-fish meal diet (Diet 6) were the most tender and those obtained from lambs fed on the grain sorghum-low urea diet (Diet 8) the least tender.

For flavour, loins obtained from lambs fed on the grain sorghum-cotton seed oilcake diet (Diet 2), the grain sorghum-saponified cotton seed oilcake diet (Diet 3), the grain sorghum-lucerne diet (Diet 5) and the grain sorghum-fish meal diet (Diet 6) had higher than average scores and can thus be considered as pleasant. The acceptability of meat is generally determined by the flavour thereof, with feed source being the most important environmental factor (Melton, 1990). The flavour of lamb can be influenced by the diet that the lambs were on (Field, Williams & Miller, 1983). From the results obtained it can be seen that there were significant differences, although small, in the flavour of meat obtained from lambs fed on the ten different diets.

Loins from lambs fed on the grain sorghum-sunflower seed oilcake diet (Diet 1) resulted in loins with a low score on flavour. Field *et al.* (1983) also found that feeds with a protected sunflower seed supplement resulted in lamb meat with a oily aroma and flavour.

Loins from lambs fed on the grain sorghum-soya beans diet (Diet 4) had a relatively low score for flavour, but were still acceptable. Melton (1990) found that lamb chops obtained from lambs fed on a diet containing soya bean meal had a more intense, musty flavour than chops from lambs fed on a lucerne diet.

The fact that loins from lambs fed on the maize-high urea diet (Diet 10) received the lowest score for flavour is in accordance with the finding of Field *et al.* (1983) who reported that feeds with high levels of corn (maize) resulted in lamb meat with stronger tastes.

Loins from lambs fed on the grain sorghum-cotton seed oilcake diet (Diet 2) had the highest score for flavour, according to Melton (1990) the inclusion of cotton seeds into the diets of lambs produces meat with a bland flavour.

Loins obtained from lambs fed on the grain sorghum-lucerne diet (Diet 5) had a good score for flavour, although Park *et al.* (1975) reported that meat obtained from lambs fed on lucerne was less acceptable, with a foreign taste compared to meat obtained from lambs fed on grass.

Loins from lambs fed on the maize-fish meal diet (Diet 9) had an average score for flavour and those from the grain sorghum-fish meal diet (Diet 6) had a good score for flavour. This is in contradiction with McDonald, Edwards & Greenhalgh (1981) and Lategan & Louw (1974) who claim that a fishy taint can be tasted in meat from lambs fed on a fish meal-containing diet.
From Table 3 it can be concluded by taking the results of fat odour, meat odour and flavour in consideration, that the most pleasant meat was obtained from lambs fed on the grain sorghum-cotton seed oilcake diet (Diet 2), the grain sorghum-lucerne diet (Diet 5) and the maize-fish meal diet (Diet 9) and the least pleasant meat from lambs fed on the grain sorghum-sunflower seed oilcake diet (Diet 1), the grain sorghum-high urea diet (Diet 7) and the maize-high urea diet (Diet 10).

When flavour and tenderness are considered together, it would seem that the best meat for eating purposes, is obtained from lambs fed on the grain sorghum-cotton seed oilcake diet (Diet 2), the grain sorghum-lucerne diet (Diet 5) and the maize-fish meal diet (Diet 9) and the worst meat, for eating purposes, obtained from lambs fed on the grain sorghum-sunflower seed oilcake diet (Diet 1). This same trend is not applicable when juiciness is considered. In this case meat obtained from lambs fed on the grain sorghum-sunflower seed oilcake diet (Diet 1) was the most acceptable and meat obtained from lambs fed on the grain sorghum-low urea diet (Diet 8) the least accept-able.

The objective of the project was to determine which dietary regime(s), if any, is/are superior, in terms of cooking losses, shear force resistance measurements and selected sensory quality characteristics (odour of fat and meat, initial and sustained juiciness, tenderness, flavour and residue), of oven-roasted lamb *Mm. longissimus thoracis et lumborum* cuts.

To answer this question, a summary of the results from Tables 2 and 3 is presented in Table 4. For this purpose the “best” and “worst” results in Tables 2 and 3 are taken and all the scores that are not significantly different from these two are deemed to be equally “good” or “bad”.

From Table 4 it seems that loins obtained from lambs fed on Diet 2 are the best as far as % total cooking losses, shear force resistance, flavour and tenderness is concerned. Loins obtained from lambs fed on Diet 6 is also good as far as shear force resistance and tenderness is concerned and loins obtained from lambs fed on Diet 9 is good for flavour and tenderness. There is no constant trend as far as loins obtained from lambs fed on “worst” diets are concerned. Loins obtained from lambs fed on Diet 9 results in lamb with high levels of % total cooking losses, high shear force resistance but good flavour and good tenderness according to the sensory panel. Diet 1 is perhaps the least well-suited for lamb feeding because it leads

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Table 4: Summary of the best and worst diets (compiled from Tables 2 and 3)

<table>
<thead>
<tr>
<th>Objective measurement</th>
<th>From Table 2</th>
<th>Best diets</th>
<th>Worst diets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cooking loss %</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>Drip loss %</td>
<td>2 7</td>
<td>6 8 9</td>
<td></td>
</tr>
<tr>
<td>Evaporation loss %</td>
<td>1 2 3 4 10</td>
<td>6 7 8 9</td>
<td></td>
</tr>
<tr>
<td>Cooking losses</td>
<td>2</td>
<td>6 8 9</td>
<td></td>
</tr>
<tr>
<td>Shear force resistance (Instron) N</td>
<td>2 6 1 5 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensory analysis variables</td>
<td>Best diets</td>
<td>Worst diets</td>
<td></td>
</tr>
<tr>
<td>Fat odour</td>
<td>2 5 9</td>
<td>1 3 4 6 7 8 10</td>
<td></td>
</tr>
<tr>
<td>Meat odour</td>
<td>2 3 4 5 6 8 9</td>
<td>1 7 10</td>
<td></td>
</tr>
<tr>
<td>Flavour</td>
<td>1 2 3 4 5 6 8 9</td>
<td>1 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>Taste</td>
<td>2 5 9 1</td>
<td>7 10</td>
<td></td>
</tr>
<tr>
<td>Initial juiciness</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Sustained juiciness</td>
<td>1</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Juiciness</td>
<td>1</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Tenderness/toughness</td>
<td>2 5 6 7 9 10</td>
<td>1 3 4 8</td>
<td></td>
</tr>
<tr>
<td>Residue</td>
<td>2 5 6 7 9 10</td>
<td>1 3 4 8</td>
<td></td>
</tr>
<tr>
<td>Tenderness</td>
<td>2 5 6 7 9 10</td>
<td>1 3 4 8</td>
<td></td>
</tr>
</tbody>
</table>

Where:
- Diet 1 = grain sorghum + sunflower seed oilcake
- Diet 2 = grain sorghum + cottonseed oilcake
- Diet 3 = grain sorghum + saponified cottonseed oilcake
- Diet 4 = grain sorghum + soya beans
- Diet 5 = grain sorghum + lucerne
- Diet 6 = grain sorghum + fish meal
- Diet 7 = grain sorghum + high urea
- Diet 8 = grain sorghum + low urea
- Diet 9 = maize + fish meal
- Diet 10 = maize + high urea

Loins from lambs fed on the grain sorghum-high urea diet (Diet 7) had the lowest score for flavour. This diet had an urea content of approximately 1.6%. This finding is contradictory to the results of Bhattacharya & Khan (1973), where the meat obtained from lambs fed on the diet with 1.5% urea was preferred and found superior by their taste panel.

Residue was measured on a scale of one to six, with one being an excessive amount of residue and six being no residue. Thus any score ranging from three to four can be considered as being neutral. Loins obtained from lambs fed on the grain sorghum-cotton seed oilcake diet (Diet 2), the grain sorghum-lucerne diet (Diet 5), the grain sorghum-fish meal diet (Diet 6), the grain sorghum-high urea diet (Diet 7), the maize-fish meal diet (Diet 9) and the maize-high urea diet (Diet 10) had higher than average scores and this is positive. Generally a high score for residue was given for loins from lambs fed on the ten different diets by the sensory panel members. This means that only a small amount of residue was present. The average score for residue of loins for all ten the diets is 4.2. This compares well with the average residue score for lamb loins of 4.4 as found by Schönfeldt (1989).

**CONCLUSION**

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to lambs with high shear force resistance, poor flavour and relative toughness.

Although it is possible to point out that Diet 2 is possibly the best and Diet 1 the worst for raising lambs judged by objective evaluations and sensory panel evaluations, none of the diets resulted in lamb cuts that were unacceptable to the sensory panel.

**RECOMMENDATIONS**

It may be recommended that from a meat quality point of view, the ten dietary regimes are suitable for raising sheep to produce acceptable meat. Knowing that diet can alter lamb flavour is useful because it shows that diet can provide a means of making lamb flavour more acceptable to those who otherwise might object to it (Field et al., 1983).

Continued research on the different influences on the quality characteristics of meat obtained from animals fed on grain sorghum or maize as energy supplement with different sources of protein may be considered. Melton (1990) agrees that more research is needed on lamb meat obtained from lambs fed on different diets, combined with sensory analysis to assess what differences in meat flavour are caused by different diets.

This study can perhaps be used as a pilot study for future research. It would be of great value to compare maize and grain sorghum as energy sources in diets where maize and grain sorghum are combined with the same protein sources. In this study no comparison could be made, for example, between maize as energy source with lucerne as protein source and grain sorghum as energy source with lucerne as protein source. It is therefore recommended that maize and grain sorghum as energy sources in combination with the same protein sources be used as different dietary regimes and the meat quality characteristics thereof be evaluated in a possible future project. This should lead to clear-cut results.

**ACKNOWLEDGEMENTS**

Mr J. Meyer and Miss I. Osler are thanked very sincerely for their contribution of the meat samples. The conscientious work done by the sensory panel of the Meat Industry Centre is also greatly appreciated.

The paper presented by J.H.F. Meyer, I. Osler & D. Swart, entitled “Effect of protein source on growth and carcass quality characteristics in feedlot lambs” evaluates the animal nutrition aspects of this research project.

**REFERENCES**


Added value: A novel technique for the restructuring of meat products

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Irene Animal Production Institute, Private Bag X2, Irene, 1675 Republic of South Africa

INTRODUCTION

Meat restructuring technology permits the formation of products into any desired shape or size, resulting in accurate portion control, customer convenience, diversity and added value. The word restructuring, as used with regard to red meat and poultry products, refers to taking the raw material - the soft tissue, including lean, fat and connective tissue, and changing its form. Various technologies have been used before but this alginate/calcium lactate system represents a system of its own. This technique which does not involve the use of NaCl, has certain advantages. A continuous gel matrix is responsible for the binding of the meat pieces which consist of a blend of coarsely and finely comminuted meats. Alginates were used in the form of sodium alginate, but gel formation itself depends on the subsequent addition of calcium. During this process calcium is effectively bound to alginate (Mandigo, 1986). By employing this method quality trim and lower grades of meat can be upgraded to such an extent as to be supplied to the consumer in the form of a fresh product which is acceptable, at a reasonable price.

AIM

The main objective of this study was to demonstrate the enhancement in value of meat from various animal species which could be obtained by employing the alginate/calcium lactate system of restructuring.

MATERIALS AND METHODS

Technology

The study consisted of various treatments:

Beef:
- Treatment 1: HB2 = –CT –FAT –WATER
- Treatment 2: HB4 = –CT +FAT +WATER
- Treatment 3: HB6 = +CT +FAT +WATER
- Treatment 4: HB7 = +CT(M) +FAT +WATER
  (M=Mechanically tenderized)

Pork:
- Treatment 5: HV2 = +CT –FAT –WATER
- Treatment 6: HV3 = +CT –FAT +WATER

where:
- (CT=connective tissue)
- (“=”=removal of CT and fat or non-addition of water)

A batch of 5 kg was made and all the meat was minced through a kidney plate after the manual removal of fat and connective tissue. Eighty per cent of this mass was used as chunks and minced through a kidney plate and 20 % of the meat was minced through a 3 mm mincer plate and used for the matrix. Water can be added for extra moisture. The 80 % mass usually consists of better quality lean and the 20 % is made up of meat with more fat. This ratio ensures a final cooked product with a highly acceptable texture. All the meat and the water was mixed and the alginates were added, mixed and thereafter the encapsulated calcium lactate was added and mixed. The encapsulated calcium could still be seen as white specks within the product after mixing, but dissolved after being left overnight in a cooler at ca. 0 °C and also after the cooking process. Meat can also be tenderized without de-sinewing and this proved to be very successful. Organic acids may also be used for this purpose (Arganosa & Marriot, 1989).

Fat can also be included in the product, but this can have a negative influence on binding, and smearing may also occur.
Sensory evaluation

Pilot study for sensory evaluation

Panel training was done the day before the project began and during these sessions it was found that the use of the cow’s rump steak as a control was inappropriate. Treatment 1 [(-CT, -FAT & -WATER)] was then used as the control. To prove that this was a wise decision the researchers in the Meat Industry Centre were asked to evaluate a single set of rump steak versus Treatment 4 [(+CT(M), +FAT, +WATER)] samples.

Cooking and sensory evaluation procedures

The 4,5 mm thick steaklets were cooked in electric frying pans at ca. 160 °C for about 8 minutes, until an internal endpoint temperature of 70 °C was reached. Thawing and total cooking losses (%) were calculated. Each steaklet was cut into quarters, wrapped in coded foil squares and served warm on foil trays on pre-heated sandbaths. A trained sensory panel of 8 members and 2 reserves was used to evaluate 4 beef and 4 pork replications. Beef was evaluated during the first session and pork during the second session. There were 45 minutes between sessions. Details of the eight attributes evaluated (cohesiveness, moisture, initial tenderness, chewiness, flavour, fat content, connective tissue residue, general acceptability).

Table 1: Analysis of variance and 95 % least significant difference results (cooking-related and sensory characteristics) for cooked restructured beef (old cow) and pork analyzed separately

<table>
<thead>
<tr>
<th></th>
<th>Beef</th>
<th>Pork</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-Value Treatment</td>
<td>P-Value Treatment</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4</td>
<td>5  6</td>
</tr>
<tr>
<td>Cooking-related</td>
<td></td>
<td></td>
</tr>
<tr>
<td>characteristics:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw mass, g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0724 319.38*</td>
<td>0.0002*** 318.95*</td>
<td></td>
</tr>
<tr>
<td>Tot cook loss, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0292* 14.49%</td>
<td>0.0023** 14.31*</td>
<td></td>
</tr>
<tr>
<td>Tot thaw loss, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0006*** 1.34*</td>
<td>0.3391 2.51</td>
<td></td>
</tr>
<tr>
<td>Exudate, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0004*** 0.37*</td>
<td>0.8583 1.20</td>
<td></td>
</tr>
<tr>
<td>Sensory attributes:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>0.083 4.78*</td>
<td>0.6221 3.97</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.3594 4.97</td>
<td>1.000 5.84</td>
</tr>
<tr>
<td>Initial tenderness</td>
<td>0.0078** 3.97*</td>
<td>0.0078** 6.16</td>
</tr>
<tr>
<td>Chewiness</td>
<td>0.0176* 3.19*</td>
<td>0.7060 4.13</td>
</tr>
<tr>
<td>Flavour</td>
<td>0.9341 5.16</td>
<td>0.6767 6.19</td>
</tr>
<tr>
<td>Fat content</td>
<td>0.8802 5.22</td>
<td>0.7666 4.19</td>
</tr>
<tr>
<td>Connective Tissue</td>
<td>0.0841 3.16*</td>
<td>0.4177 4.47</td>
</tr>
<tr>
<td>General acceptability</td>
<td>0.7283 2.13</td>
<td>0.7833 2.81</td>
</tr>
</tbody>
</table>

**Mean values in same row with different superscripts differ P<0,05

Average of 3 slices

Tot cook loss, % = total cooking loss, % = \( \frac{\text{Thawed mass} - \text{cooked mass}}{\text{cooked mass}} \times 100 \)

Tot thaw loss, % = total thawing loss, % = \( \frac{\text{Freshly prepared mass} - \text{thawed mass}}{\text{Freshly prepared mass}} \times 100 \)

Exudate, % = \( \frac{\text{Amount of thawing loss in packet}}{\text{Freshly prepared mass}} \times 100 \)

Beef: Treatment 1: HB2 =
- CT
- FAT
- H2O
Treatment 2: HB4 =
- CT
+ FAT
+ H2O
Treatment 3: HB6 =
+ CT
+ FAT
+ H2O
Treatment 4: HB7 =
+ CT(M)
+ FAT
+ H2O (M=Mechanically tenderized)

Pork: Treatment 5: HV2 =
- CT
+ FAT
- H2O
Treatment 6: HV3 =
+ CT
- FAT
+ H2O
And

1. Cohesiveness: 1=extremely non-cohesive/brittle; 7=extremely cohesive/rubbery
2. Moisture release/Juiciness: 1=extremely dry; 8=extremely juicy
3. Initial tenderness: 1=extremely tough; 8=extremely tender
4. Chewiness/mouthfeel: 1=extremely chewy; 4=ideal bite; 7=extremely mushy
5. Flavour: 1=extremely unpleasant; 8=extremely pleasant
6. Fat content: 1=extremely fatty; 7=extremely lean; your preference? 4-5
7. Connective tissue residue: 1=excessive amount; 6=No residue
8. General acceptability: 1=No, won't buy; 2=neutral; 3=yes, would buy
content, connective tissue and general acceptability), using an analytical, descriptive, structured category scaling method (S.E.D., I.F.T., 1981a & 1981b), are summarized in Table 1.

RESULTS AND DISCUSSION

Technology

Utilization of an alginate/calcium lactate system represents a new and significant advance in meat technology. The fact that this tech-meat proteins can also be used to improve the water-holding capacity and textural properties of restructured meat products. Restructured meat products can be enhanced with the use of additives such as herbs and spices, battering and breading. After the product has been prepared and cooled for setting, it can be either vacuum-packed and frozen, or packaged in PVC-overwrapped trays for display.

A few advantages of this system are: Use of existing equipment, controllable fat content, handles like fresh meat and accurate portion control.

Sensory evaluation

The results are given in Table 1. Table 2 shows a comparison between super grade rump steak to Treatment 4 [(+CT(M), +FAT, +Water)].

Of noteworthy importance is the total amount of thawing loss (% of original raw mass) and the amount of exudate found after thawing. According to Table 1, for the restructured beef, there were significant differences for the amount of thawing loss (P=0.006) and exudate (P=0.0004). The least amount of both thawing loss and exudate (1.34 % & 0.34 % respectively) came from the control sample [Treatment 1 or (–CT, –FAT, –WATER)] and the most (4.23 % & 2.92 % respectively) from Treatment 2 [(–CT, +FAT, +WATER)], which was also mechanically tenderized showed the least amount of moisture loss (2.28 % & 1.03 % respectively). There were no significant differences for the pork.

The total cooking loss (%) was significant for beef (P=0.0292) as well as for pork (P=0.0023). For beef the losses ranged from 14.49 % (Treatment 1) to 21.10 % (Treatment 2). Again Treatment 4 was intermediate (17.59 %). For pork, the total cooking loss (%) was also significantly different (P=0.0023, or 14.31 % & 21.69 % respectively) for Treatments 5 & 6. In this case the samples without the added water also resulted in the lower cooking losses.

(The significant differences in sample size may probably be attributed to the differences in the diameters of the home-made casings used. The masses given in Table 1 are the total of 3 slices.)

The only sensory attributes for beef which are significantly different from one another are initial tenderness (P=0.0078) and chewiness (P=0.0176). The control Treatment 1 is the least tender and most chewy (mean scores of 3.97 & 3.19 respectively) whereas Treatment 4 was the best (mean scores or 5.19 & 3.94 respectively). (Please note that the chewiness score of 3.94 was the closest to the “ideal bite” value of 4). It is suspected that cohesiveness, initial tenderness, chewiness and connective tissue residue are different measures of basically the same characteristic.

Likewise, for the restructured beef-versus-rump steak session, the significantly different attributes are also initial tenderness, chewiness and amount of connective tissue residue. The restructured product was superior in both initial tenderness and chewiness (mean score of 3.92, indicating “ideal bite”) while the rump was thus considered to be more chewy. The restructured product also had less residue than the rump (as a score of 6=no residue).

As a matter of interest, the sensory panel preferred a “fat content” score of about 4-5 (“well-marbled” to “moderately lean”).

CONCLUSIONS AND RECOMMENDATIONS

After all is said and done, the onus is on the manufacturer to decide whether or not this new technology is a viable proposition. This topic was discussed during the 2nd Meat Workshop
held on the 13th May 1992. The above-mentioned research was conducted to determine whether lower grades of meat as well as quality trimmings may be restructured with the utilization of sodium alginate and calcium lactate and this method proved to be very successful.

The thawing and total cooking loss (%) results indicate greater yields for the mechanically tenderized samples.

Flavour was not considered to be significantly different in any of the treatments evaluated. This might be indicative of a need for flavour improvement/enhancement of some kind or another - e.g. by introducing a herb and spice formulation into the meat and/or battering or breading.

In sensory quality terms it may be stated that the treatment (No. 4) which included the mechanical tenderization step was the most superior of the four beef ones and both the pork ones were very comparable to one another. The mechanical tenderization step for the beef should not pose problems for industry as the machine used for this purpose is readily available and the added moisture retention properties are noteworthy.

REFERENCES


INTRODUCTION

The word sausage stems from the Latin word “salsus” which means preservation through the addition of salt. Sausages have been regarded as convenience foods from as early as 900 BC. During the Middle Ages each country developed its own characteristic sausage. These developments were influenced by national preference as well as by climate. Italian Bologna sausage, French Lyon sausage and German Bruchwurst are examples of these regional developments. Boerewors, a typical South African sausage, originated during the seventeenth and eighteenth centuries and was manufactured on farms from a mixture of pork and beef. The meat was flavoured with salt, pepper and various other spices, especially coriander. Originally the meat was stuffed into clean cattle, hog, or sheep casings using a horn. Fresh boerewors was prepared by grilling as a breakfast or supper menu item. Boerewors was also dried for later use as dry sausage (Steyn, 1989).

Until recently there was no legal requirement regarding the amount of or labelling for non-meat proteins in South African processed meat products. Due to a lack of such regulations, the situation came under scrutiny by the local press in recent years. Butchers were accused of adding substances such as soya, udder tissue, testicles and glands to boerewors (The Citizen, 1983).

With the new regulations governing the composition and labelling of raw boerewors, raw species sausage and raw mixed species sausage, manufacturers will be forced to declare the ingredients in these products (Government Regulation No. R.2718, 1990). According to these regulations raw boerewors may not contain protein ingredients such as soya, whey protein, ovalbumin, casein, etc. The only non-meat proteins allowed, are cereal products defined as products derived from the seed of any of the cultivated grasses of the family Poaceae, with a maximum protein content of 15 %. Spices and herbs are also permitted. Raw boerewors must contain at least 90 % of the meat of an animal of the bovine, ovine, porcine or caprine species or a mixture of the meat of two or more of these species. A maximum of 30 % of the total meat content may be fat and a minimum of 60 % must be fat-free meat. In the case of raw species sausage or raw mixed species sausage, the sausage must contain at least 75 % meat of the species referred to on the label. A maximum of 25 % may be the meat of other species, but must also appear in the list of recognised ingredients.

The aim of the present study was to conduct a survey on the composition of boerewors in two South African cities, one year after the implementation of the above-mentioned regulations.

MATERIALS & METHODS

Twenty percent of the butcheries in two South African cities (Bloemfontein and Kimberley) were sampled, using random sampling with replacement (Snedecor and Cochran, 1980). In Kimberley, 16, butcheries were sampled, while in Bloemfontein 30 butcheries were sampled. Each butchery was sampled only once, 300 g of boerewors being purchased, without informing the butcher of the purpose of the purchase.

The casings of the meat samples were removed and the samples were homogenized by passing them through a pre-chilled bowl cutter (Benchtop model, 1 HP, 22 RPM; two 3.5 in. knives, 2850 rpm; Model 84181, Hobart Corp., 711 Pennsylvania Ave, Troy, Ohio, 45374) (AOAC, 1984). Each (homogenized) sample was subdivided into 10 g portions, and vacuum
sealed. Samples were stored at -20°C until analysed. Duplicate analyses were conducted on each sample.

Samples were analysed using mainly AOAC (1984) methods, the paragraph numbers of which are indicated in brackets: protein nitrogen and protein (2.057); moisture by oven drying (24.003a); fat (24.005a; 7.062; 10.166). The L-hydroxyproline content was calculated from the L-hydroxyproline content assuming that collagen consisted of 14% L-hydroxyproline (Bailey and Light, 1989).

The fat-free meat content was calculated by multiplying the percentage of protein nitrogen by 30 (Government Regulation nr. R.2718, 1990) while total meat content was calculated as the sum of the fat-free meat and the fat, expressed as a percentage of the product mass (Government regulation nr. R.2718, 1990). Results were not corrected for any contribution of nitrogen from non-meat protein.

The boerewors samples were analysed for the presence of soya protein, whey protein, bovine casein, gliadin and chicken ovalbumin using the rapid dot blot ELISA procedure described by Janssen et al. (1987) and modified by Hugo (1992). A summary of this technique is presented in Table 1.

### Table 1: Summary of dot blot procedure

<table>
<thead>
<tr>
<th>Step</th>
<th>Procedure</th>
<th>Solution</th>
<th>Dilution</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Protein extraction</td>
<td>SDS-buffer</td>
<td>1/10</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>Dilution</td>
<td>Diluent2 buffer</td>
<td>1/10</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Antigen application</td>
<td>0.5 µl on nitrocellulose</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Blocking of active sites</td>
<td>PBST</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>Primary antiserum</td>
<td>in PBST</td>
<td>1/100</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>Wash</td>
<td>PBST</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>Secondary antiserum</td>
<td>in PBST</td>
<td>1/200</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>Wash</td>
<td>Substrate buffer</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>Substrate</td>
<td>4-chloro-1-naphthol and H2O2</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>Stop</td>
<td>Water</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>Storage</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1. SDS-buffer: 0.38 M glycine and 50 mM Tris (pH 8.6) with 1% SDS and 0.1% DTT.
2. Dilution buffer: 0.05 mg BSA/mL extraction buffer.
3. Phosphate buffered saline with Tween-20 (PBST) pH 7.2 7.2 mM Na2HPO4,2H2O, 2.79 mM NaH2PO4,2H2O, 0.15 M NaCl and 0.05% Tween-20 (v/v).
4. All primary antisera (anti-soya, anti-casein, anti-whey protein, anti-ovalbumin, anti-wheat gluten were of rabbit antilype obtained from Behring Diagnostics.
5. Anti-rabbit-lg-peroxidase-linked-species-specific whole antibody from donkey obtained from Amersham.
6. Substrate buffer: 0.01 M Tris adjusted to pH 7.6 with HCl.
7. Substrate: dissolve 25 mg 4-chloro-1-naphthol in 5 mL ethanol.
8. Mix with 45 mL substrate buffer. Filter after 1 min through Whatman no. and add 0.1 mL H2O2 (3 % v/v) to the filtrate.
9. Values for Kimberley are the means of 16 butcheries, analysed in duplicate, while values for Bloemfontein are the means of 30 butcheries, analysed in duplicate.
10. Values in brackets refer to the standard deviations.
11. Differences between Kimberley and Bloemfontein samples were not significant.

Data obtained from proximate analysis of the samples of both cities (Kimberley and Bloemfontein) were statistically analyzed by means of an analysis of variance (CSS™ Statsoft™, 1988).

### RESULTS & DISCUSSION

Table 2 shows the results of the proximate analyses of the boerewors samples. The minimum moisture content of the 46 samples analysed was 45.96% and the maximum was 68.44%. The average moisture content was 59.59%. It is interesting to note that the sample with the lowest moisture content had the highest fat content (28.46%) while the sample with the highest moisture content had the lowest fat content (9.33%). The average fat content was 19.33%. None of the samples tested exceeded the legal maximum of 30% for the fat content. The protein nitrogen, crude protein and fat-free meat contents were closely related. This was because both the protein and fat-free meat contents were calculated by multiplying protein nitrogen by an appropriate factor (6.25 and 30, respectively). Protein nitrogen content varied from 2.06% to 2.75% with an average of 2.45%. The protein content varied from 12.87% to 17.39% with an average of 15.34%. The fat-free meat content varied from 61.77% to 83.48% with an average of 73.64%. None of the samples tested were below the legal minimum of 60% for fat-free meat content.

The total meat content (% fat-free meat + % fat) varied from 84.75% to 99.85% with an average of 92.98%. Four samples (25%) from Kimberley and eight samples (26.7%) from Bloemfontein were below the legal minimum of 60% for total meat content.

### Table 2: Proximate analysis of boerewors samples (percent)

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Kimberley</th>
<th>Bloemfontein</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>59.59</td>
<td>59.69</td>
<td>59.53</td>
<td>0.91m</td>
</tr>
<tr>
<td></td>
<td>(4.36)</td>
<td>(3.41)</td>
<td>(4.84)</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>19.33</td>
<td>19.17</td>
<td>19.42</td>
<td>0.86m</td>
</tr>
<tr>
<td></td>
<td>(4.40)</td>
<td>(2.51)</td>
<td>(4.86)</td>
<td></td>
</tr>
<tr>
<td>Protein nitrogen</td>
<td>2.45</td>
<td>2.49</td>
<td>2.44</td>
<td>0.33m</td>
</tr>
<tr>
<td></td>
<td>(0.17)</td>
<td>(0.13)</td>
<td>(0.19)</td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>15.34</td>
<td>15.56</td>
<td>15.23</td>
<td>0.33m</td>
</tr>
<tr>
<td></td>
<td>(1.07)</td>
<td>(0.82)</td>
<td>(1.18)</td>
<td></td>
</tr>
<tr>
<td>Fat-free meat</td>
<td>73.64</td>
<td>74.67</td>
<td>73.09</td>
<td>0.33m</td>
</tr>
<tr>
<td></td>
<td>(5.13)</td>
<td>(3.94)</td>
<td>(5.66)</td>
<td></td>
</tr>
<tr>
<td>Total meat</td>
<td>92.98</td>
<td>93.84</td>
<td>92.52</td>
<td>0.26m</td>
</tr>
<tr>
<td></td>
<td>(3.80)</td>
<td>(4.14)</td>
<td>(3.59)</td>
<td></td>
</tr>
<tr>
<td>L-proline</td>
<td>0.30</td>
<td>0.28</td>
<td>0.31</td>
<td>0.15m</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.08)</td>
<td>(0.07)</td>
<td></td>
</tr>
<tr>
<td>Collagen</td>
<td>2.15</td>
<td>1.99</td>
<td>2.33</td>
<td>0.19m</td>
</tr>
<tr>
<td></td>
<td>(0.53)</td>
<td>(0.57)</td>
<td>(0.49)</td>
<td></td>
</tr>
</tbody>
</table>

Values for Kimberley are the means of 16 butcheries, analysed in duplicate, while values for Bloemfontein are the means of 30 butcheries, analysed in duplicate. Values in brackets refer to the standard deviations.

m Differences between Kimberley and Bloemfontein samples were not significant.
The collagen content of the products varied from 1.06 % to 3.03 % with an average of 2.17 %. The average collagen content of 2.17 % was relatively high. According to Bailey and Light (1989), the collagen content of well-trimmed muscle ranged from 0.5 % to 1.76 %. Because of the dilution effect in boerewors (i.e. due to the addition of water, vinegar, Worcester sauce, spices and fat) one would expect much lower collagen values. The high collagen content may indicate the use of lower grade meat (older animals) as well as the use of a large quantity of forequarter meat (high connective tissue) for the manufacture of boerewors. Forequarter cuts such as shin and neck may contain up to 12 % collagen (Bailey and Light, 1989).

Analysis of variance (Table 2) showed no significant differences between the Kimberley and Bloemfontein samples for all the parameters tested.

The analysis for non-meat proteins using the dot blot technique (Fig. 1) showed that 4 samples (25 %) from Kimberley and 6 samples (20 %) from Bloemfontein contained gliadin, probably due to the addition of rusk, a legal ingredient. Dot blotting indicated that 3 samples (18.75 %) from Kimberley and 4 samples (13.33 %) from Bloemfontein contained soya. None of the samples were positive for chicken ovalbumin or milk proteins.

The very high total meat content of 6 of the samples, approaching 100 %, gave reason for concern. One of these samples contained soya and the high total meat content value for this sample was probably due to the presence of the soya protein which would directly influence the protein nitrogen and fat-free meat content estimation. The other five samples contained no non-meat proteins. The use of a nitrogen conversion factor for the calculation of the lean meat content of a meat sample as prescribed by Government Regulation No. R.2718 (1990) is obsolete. The latter urgently needs to be revised in order to take today's meat processing practices into account. The present method does not take into consideration the nitrogen contribution from connective tissue, monosodium glutamate (MSG), protein hydrolysates, nitrogen adulterants (urea and ammoniumchloride) and non-meat proteins (Olsman and Slump, 1981). The determination of the amino acid 3-methylhistidine shows the greatest potential as an indicator of lean meat content. In view of the high analytical variation regarding its identification further research must be conducted to evaluate the use of 3-methylhistidine as a routine indicator for lean meat content (Rønnestad, 1991).

In conclusion it may be stated that except for the total meat content, the boerewors samples complied with the chemical requirements of the Government Regulation No. R.2718 (1990). Twenty six percent of the samples tested had values of less than 90 % for total meat content. The relatively high collagen contents (no legal restriction) recorded for the various samples suggested the use of lower grade meat for the manufacture of boerewors. Adulteration of boerewors with soya protein still appears to be a problem since 15 % of the samples tested contained soya protein. None of the samples were positive for chicken ovalbumin or milk proteins. Rusk seemed to be a popular (permitted) ingredient since 22 % of the samples tested positive for gliadin.

REFERENCES


The Citizen, 16 August 1983. Boerewors contents were illegal.
Using a computerised data capturing system as a versatile tool for sensory evaluation

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INTRODUCTION

During the past decade, more and more reference has been made in scientific literature to the use of computerised systems in sensory evaluation (McLellan & Cash, 1983; Guinard et al., 1985; Lee, 1985; McLellan et al., 1987; Staff article, 1988; Winn, 1988). There are several advantages to using a computer data capturing system for sensory evaluation, the most important advantage being that there is a considerable reduction in time and labour intensive applications, since panelists immediately enter their scores onto the computer (McLellan & Cash, 1983; Guinard et al., 1985; McLellan et al., 1987; Winn, 1988). The delays caused by the initial recording and collecting of panelist information as well as the subsequent entering and correcting of the data are greatly decreased (Lee, 1985). This form of data capturing therefore also increases the speed at which the information may be further processed and analysed, thereby reducing paperwork (Staff article, 1988; Winn, 1988). Experience has proved that without direct data capturing, especially with research projects involving an overwhelming amount of data requiring processing, the task is mundane and tedious.

Another important advantage is that the incidence of error is greatly reduced (Guinard et al., 1985; Lee, 1985). With panelists entering their data onto a computer network system during the panel session, the data is immediately stored and greater reliability of results is ensured (Winn, 1988).

An example of such a program, TASTE© (Barnes et al., 1988), which uses file and data block locks to allow multiple concurrent access to data files for the “real time” capture of sensory data is described.

As panel data accessible to the supervisor is critical to data capture and the sequencing of the taste session or sessions but normally excluded from assessor access by experimental design, the supervisor options must be transparent to the assessor. Essentially, the main modular program backbone runs in the background, linking the various workstation assessor modules.

A network interface is integral to the program function thus allowing the panel organiser (“supervisor”) and all assessors to log on simultaneously.

AIM

To explain the use of and the main advantages of the sensory analysis computer data capturing system in use at the Meat Industry Centre.

MATERIALS AND METHODS

The sensory analysis computer package (Taste,© Version 1.9) used at the Meat Industry Centre, is a menu-driven modular program addressing the panel supervisor or the assessors. Since the software is designed for use on a network system and makes use of file locking, both the panel organiser or “Supervisor” and the sensory panelists or “Assessors” may be logged on simultaneously.

The supervisor

Initially, prior to any panel sessions being run, the supervisor defines the outlay of the project using the sensory analysis program. The options provided may present the supervisor with a free choice (options may be selected in any order or combination) or a fixed sequence of options to be taken. The supervisor main menu includes the following main options required for designing and executing the project:

1. Specify project name
2. Test selection
3. Parameter file handling
4. Question file handling
5. Check project files
6. Run a panel session
7. Print panel results
8. File utilities: Data transfer

These options should normally be run in the menu sequence except if an option is to be used for editing a project definition. The sequence may be completed in different logon sessions.

Specify project name

The supervisor is free to give the project a name consisting of up to eight characters. The program then opens a directory in this name where all relevant (e.g. parameter, question and data) files of the project will be written.

Test Selection

The supervisor is required to select a suitable test type (one only) from the options listed below (according to Barnes et al., 1988 and SED IFT, 1981):

Conventional Profiling (Descriptive test)

Assessors are required to evaluate the product using descriptors that are fixed and predetermined. The intensities of the characteristics are recorded on a linear scale.

Category Scaling (Descriptive test)

A set of samples is presented in each panel session and assessors are required to evaluate each sample relative to the others, according to certain characteristics and norms. Each characteristic consists of categories made up of a series of numeric values and corresponding word phrases. A score is assigned to each characteristic for each sample.

Paired Difference tests (Discriminative test)

Two samples are presented simultaneously and the assessor is required to compare the samples according to certain attributes.

Duo-Trio tests (Discriminative test)

Three samples are presented, where one sample is identified as the reference sample and the other two are test samples. The assessor is required to assess the two test samples and to decide which one is similar to the reference sample.

Triangle tests (Discriminative test)

Three test samples are presented. The assessor is required to decide which two are similar and which is the odd sample out.

Preference test (Affective test)

In the conventional and free-choice profiling tests, each sample is evaluated according to a predetermined range of descriptors. With ordinary preference testing a series of samples are compared using a single descriptor and a one-line scale.

Ranking (Discriminative test)

A number of samples are presented simultaneously and the assessor is requested to place the samples in order of his or her preference, according to selected criteria, e.g. from the least to the most preferred.

Free-Choice profiling (Descriptive test)

Assessors use their own descriptors and vocabulary to best describe their own perception of the product being evaluated.

Time Intensity tests (Descriptive test)

Duration, rate and intensity of specific characteristics of the sample being evaluated, is monitored within a specific time-span for which a timing device is incorporated into the program. A high response pointing device, e.g. a mouse, is required for this test.

Parameter file handling

Subject to the test choice above, the supervisor must define the test parameters to be used for the respective panel sessions. This data is written to a parameter file (Param.btr) created in the corresponding project directory. The following information is requested:

1. Number of samples
2. Sample names
3. Number of samples in each session
4. Sample identification
5. Sample codes
6. Sample presentation order
0. Finish

This file incorporates the experimental design of the project, including the title of the experiment (as well as for the assessors), the product name, details of the panel sessions as well as the ordering, names and codes for the samples. The number of assessors and their names, selected from a listing in the assessor file defined earlier during the set-up of the project.
When the design of the project has been completed, the supervisor or supervisor may be either asked to enter their name (and password if necessary) or, if a record of assessors is not necessary, they may merely be asked to press any key to continue. Further provision is made for a customised greeting or instruction to be displayed. This computer package makes provision for the use of a pointing device (e.g. a mouse) for data entry. The “Finish” option will save and close the parameter file if all the options have been completed. Further editing may be done at a later stage, but once the first session has been run, further editing is disallowed. Once saved, the parameter file may be printed to aid laboratory technicians in the preparation and presentation of the test samples.

Question file handling

The question file, like the parameter file, is saved under the project subdirectory. This file contains all information regarding the type of questions to be asked of the panellists and the prompts displayed, according to the test type selected previously. For example, if category scaling is chosen as the test type, then instructions together with the characteristics and category details, i.e. the corresponding values and word phrases, are specified. The file is then saved and printed. Once again further editing may be only done, prior to running the first panel session. It is advisable to prepare a separate file for a pilot study and initial training sessions.

Check project files

The option “Check the project files” checks for any inconsistencies which may exist between definitions in the parameter and question files.

Run a panel session

When the design of the project has been completed, the supervisor may run a panel session at any time. On selection of this option, the supervisor is prompted to specify which panel session or sessions are to be run and to list the work station numbers to be used by the assessors. Once all the panel assessors have logged on and are entering data the supervisor may select the option for the next session to be run or placed in the queue, in preparation of the next batch of samples to be served.

Print panel results

A built-in safety feature of this software is that on completion of the panel session being run, the data is automatically saved. The supervisor may then make a print-out of the panel results.

File utilities: Data transfer

Although the program provides a measure of statistically analysed results in the print-out, (e.g. for the category scaling test; means, standard deviations and frequencies are given in a data summary), the data may still need to be transferred to a statistical analysis program. This is carried out under the file utilities menu selected from the main menu. This package allows that the collected data may be stored in a specific format compatible with the following programs: SENPAK©, PSTAT© or LOTUS®. Otherwise, the data may be saved in a text file, thereby allowing further analysis by statistical analysis programs such as GENSTAT® or SPSS®. This option is also used if the data formats available are incompatible with target software. The text format is easily edited to transform the data base for direct input to the target software, e.g. for use with STATGRAPHICS® which does not support the LOTUS© data format.

The assessor

Logging on

The assessor will gain access to the taste panel session by one of the following methods:

a. Customised display; e.g. the assessor is greeted by name,
b. If the assessors use a defined pointing device (e.g. a mouse) to log on, they may be required to select their name from a list on display.
c. Typing in their name; where the assessor is asked to type in their name,
d. No logging on when the assessor’s name is not required.

Data entry

Once the assessor has logged on and pressed the enter key, he or she will proceed to enter his or her data, according to what is required for the specific test type being run. The category scaling test will be used here as an example, since this is the test type most frequently used by the Meat Quality section at the Meat Industry Centre.

The assessor is required to read a set of instructions before continuing with the evaluation. One sample is assessed at a time, with the assessors being requested to check that they have the correctly coded sample each time. The assessor is then required to evaluate each sample step-by-step according to the criteria defined. In some cases the assessor may edit the input, but not after he or she has progressed to the next sample or list. The characteristics e.g. aroma, flavour, texture, etc. are divided into categories, each on a 8-point scale, with 1...
being the most favourable score and 8 being the least favourable score. The assessor must evaluate the samples for each characteristic by indicating a score of 1 to 8 on the computer. The characteristic tenderness is expanded below according to the different scores and corresponding word phrases:

1: Extremely tender
2: Very tender
3: Moderately tender
4: Slightly tender
5: Slightly tough
6: Moderately tough
7: Very tough
8: Extremely tough

The assessor may only review scores given for a particular sample while he or she is still busy assessing the sample. However, once he or she moves on to the following sample, the scores for the previously assessed samples may not be reviewed and altered. Once all samples have been assessed, the program saves the data and indicates that the assessor has completed the session.

DISCUSSION

The greatest time-saving factor in using the program has proved to be in the processing of the data. However, another time-saving factor is that a print-out of panel results may be obtained almost immediately after the last person has completed the taste session. A further convenience is that a measure of statistical analysis is included in the print-outs, e.g. for the category scaling test; the means, standard deviations and frequencies are given in a data summary. This allows for, in the event of there being any errors, another session to be held using any remaining samples.

The user-friendly, menu-driven program promotes a positive attitude amongst assessors. Minimum instruction is required in training the panelists to use the program which, together with the novelty of using computers, provides motivation for people to serve on the panel.

A good sensory analysis computer package is versatile and flexible in terms of allowing for adaptation to various research programmes and computer hardware requirements. The package used at the Meat Industry Centre makes provision for a variety of test types, enabling researchers to decide on the test type best suited to their project. These tests include: Conventional Profiling, Category Scaling, Paired Difference test, Duo-Trio test, Triangle test, Preference test, Ranking, Free-choice Profiling and Time-intensity tests.

The program incorporates an assessor record file which is a useful tool in keeping track of the sensory history of panellists. This reduces the time spent having to screen for panellists and retrain them each time and may be used in assessing the ability and skill of the assessors.

Accuracy and reliability of results is improved with assessors entering their own results directly. For instance, sensory staff are afterwards not faced with such problems as attempting to decipher illegible handwriting on score sheets. All evaluation scores must be entered for each sample before the program allows the assessor to continue with evaluating the following sample. This avoids the error of scores being accidently left out, which tends to happen when paper score sheets are used.

Another advantage of assessors being allowed to evaluate only one sample at a time is that they are not influenced by seeing answers which they have previously given for other samples. Since the program is run on a network system and makes use of file locking, assessors may work simultaneously and at their own pace. Provision is made for a measure of leeway given for panellists who arrive slightly early or late for a session. However, late or early arrivals are only accommodated if the program is used under correct supervision, otherwise the order of panel sessions may be disrupted for the rest of the day.

However, during the paper-to-electronic transition it has been found through experience, that it is essential for panellists to fill in a score sheet first and then to enter data onto the program. This helps panellists to become confident with the program and provides a safety net against teething problems during the commissioning of the new system.

CONCLUSION AND RECOMMENDATIONS

The convenience of a saving in time and labour applications by using a computerised data capture system in sensory evaluation cannot be overemphasised. The mundane and tedious aspect of entering data by sensory staff after the sessions have been run is not ideal. Where computerisation can harness time-consuming data recording, an organisation benefits from increased productivity, an increased financial turnover and improved product research and development.

REFERENCES


A comparison of the quality characteristics of goat and sheep meat

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INTRODUCTION

Naudé and Hofmeyr (1981) reported that both kid and goat meat is quite acceptable to the consumer and, in certain cases, may even replace mutton, lamb or beef. It was pointed out, however, that sensory panels found goat meat less tender than either lamb or mutton, although the collagen solubility of Boer goat meat was not markedly lower than that of lamb, and it had a total collagen content in muscles similar to the Pedi and Merino lamb breeds (Heinze., 1986). However, collagen solubility and total collagen content may only account for part of the variation found in tenderness.

The similarity between the solubility of muscle collagen of Boer goats and that of certain sheep breeds led to the question as to whether it is reflected in the tenderness of the meat itself, and if tenderness differences were absent if it was still correct to differentiate between sheep and goat meat by using different classification and grading systems. Furthermore it was important to determine, if any, the differences between Angora and Boer goat meat.

AIM

The goats formulated for this study were to compare the cooking and juiciness related quality characteristics of the various grades of both Angora and Boer goat meat to those of sheep meat. To this end, the Mm. longissimus thoracis et lumbarum (prepared according to a dry heat cooking method) and the M. semimembranosus (prepared according to a moist heat cooking method) were used.

MATERIALS AND METHODS

Source of materials

Twenty seven carcasses of each of the following types: Angora goats, Boer goats and sheep were selected. The South African grading system incorporates two variables namely age classes (indicating tenderness) and fat codes (indicating lean yield). Ewe and castrate carcases of each of the three fat codes and age classes (nine in total) were compared. Subcutaneous back fat thickness measurements are not determined during grading, but merely serve as a guideline to grades in their visual assessment of carcase fatness. Bruwer (1984) found the fat content of fat code 1 carcases to be 14.30 %, and that of fat code 2 and 3 to be 17.26 % and 23.31 % respectively.

The Angora and Boer goat carcases were produced by the Meat Board representatives at the Port Elizabeth and Cato Ridge abattoirs. All carcases were electrically stimulated (600 volts for 60 seconds or 800 volts for 45 seconds) to prevent toughening caused by rapid chilling (cold-shortening), aged for seven days at between 1 and 7°C, then wrapped in stockinette and overwrapped by plastic bags, labelled and stored at -20°C until transportation in a frozen state to the Irene Animal Production Institute (IAPI). The required sheep carcases were produced from the abattoirs at City Deep in Johannesburg or Chamdor in Krugersdorp and were similarly treated.

Sample preparation

Thecarcases were repacked in thick plastic bags on arrival at IAPI to exclude as much air as possible, and stored at -20 °C
until subdivision (still in the frozen state) into seven wholesale cuts (Bruwer, 1984), coding and vacuum packaging.

The Mm. longissimus thoracis et lumborum samples were cut from the 8 to 13th thoracic vertebrae (rib cuts) and from the 1st to the 6th lumbar vertebrae (loin cuts). The left side loin and rib cuts were sensory analysed, while shear force resistance, expressible moisture and chemical analyses were performed on the right side loin cuts. Collagen determinations were performed on the right side rib cuts. The leg cuts were held for a standing period of 10 minutes at room temperature following cooking during which time the M. semimembranosus muscles were dissected. The latter left and right side M. semimembranosus muscles were analysed similarly to the rib and loin cuts except for the omission of collagen determinations due to insufficient sample matter.

The Mm. longissimus thoracis et lumborum cuts were defrosted at 10 °C for a period of 24 hours. The M. semimembranosus cuts were defrosted at 10 °C for periods varying between 24 and 36 hours, depending on mass. The rib and loin cuts were roasted on a rack in an uncovered oven pan at 160 °C to an internal temperature of 75 °C (dry heat cooking method). The M. semimembranosus cuts were placed individually in cooking bags, closed with a piece of string and cooked in an oven at 160 °C, to an internal temperature of 75 °C (moist heat cooking method).

A set of three samples, representing the three meat types within a single age and fat code group, was cooked and analysed together. This procedure was repeated three times for the three replications per cell. Each age – fat code of each meat type was similarly analysed.

The following data were recorded during the study:

Total cooking losses

All the cuts were weighed pre- and post-thawing as well as after roasting or basting respectively, for the determination of total moisture losses during the thawing and cooking processes respectively. Percentage thawing, drip, evaporation and total cooking losses were calculated.

Sensory evaluation

Aroma intensity, initial impression of juiciness, sustained juiciness, tenderness, residue, flavour and characteristic species flavour were evaluated for each sample. A six point measuring scale with one denoting the least favourable condition and six the most favourable was used. Sensory evaluation was carried out by a trained ten-member sensory panel of the Meat Industry Centre of the Irene Animal Production Institute (IDPI).

### Table 1: Standardized specifications for sheep and goat carcases

<table>
<thead>
<tr>
<th>Sheep carcases</th>
<th>Angora and Boer goat carcases (respectively)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td>Age* Fat code Cold mass (kg) No. of carcases</td>
</tr>
<tr>
<td>Super lamb</td>
<td>A 3 15-25 3</td>
</tr>
<tr>
<td>Lamb 1</td>
<td>A 2 10-20 3</td>
</tr>
<tr>
<td>Lamb 2</td>
<td>A 1 10-20 3</td>
</tr>
<tr>
<td>Prime B</td>
<td>B 3 20-30 3</td>
</tr>
<tr>
<td>Top C</td>
<td>C 3 20-30 3</td>
</tr>
<tr>
<td>C1</td>
<td>C 2 15-25 3</td>
</tr>
<tr>
<td>C2</td>
<td>C 1 15-25 3</td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
</tr>
</tbody>
</table>

* A Age group (lamb of kid age group with no permanent incisors); B age group (1 to 6 permanent incisors); C age group (7 to 8 permanent incisors)

b Fat code (medium) of between 4.1 and 7 mm subcutaneous back fat thickness (SCfat); fat code 2 (lean) of between 1 and 4 mm SCfat; fat code 1 (very lean) of 1 mm SCfat (Government Gazette, 1985)
Tenderness was measured as the maximum force required to shear a 12.5 mm diameter cylindrical sore of cooked meat perpendicular to the grain. The shear force was generated with a Warner Bratzler shear attachment fitted to an Instron Universal Testing Machine Model 1140. The higher the reading obtained, the greater the shear force required to cut through the meat, therefore the tougher the meat.

Press fluid determination

A direct indication of the water holding capacity of the cooked meat was obtained from the amount of expressible moisture measured as a percentage of the initial unpressed mass of sample which was subject to a compressive force of 1 metric ton for 60 sec by means of a Carver laboratory Press Modal C. A quadruplicate test was performed on each sample.

Table 2: Significant levels for three-way analysis of variance for sensory characteristics, shear force resistance and collagen measurements of rib and lion cuts as influenced by species (S), age (A) and fat code (F) (n=809)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Species (S)</th>
<th>Age (A)</th>
<th>Fat code (F)</th>
<th>S x A</th>
<th>S x F</th>
<th>A x F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species flavour</td>
<td>0.0001</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Aroma intensity</td>
<td>0.0012</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Flavour</td>
<td>&lt;0.0001</td>
<td>NS</td>
<td>NS</td>
<td>0.0246</td>
<td>NS</td>
<td>0.0022</td>
</tr>
<tr>
<td>Tenderness</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.0525</td>
<td>&lt;0.0001</td>
<td>0.0010</td>
<td>NS</td>
</tr>
<tr>
<td>Residue</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>NS</td>
<td>0.0001</td>
<td>0.0253</td>
<td>NS</td>
</tr>
<tr>
<td>Shear force resistance</td>
<td>&lt;0.0001</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>&lt;0.0001</td>
<td>NS</td>
</tr>
<tr>
<td>Collagen solubility</td>
<td>0.0012</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>NS</td>
<td>&lt;0.0001</td>
<td>NS</td>
</tr>
<tr>
<td>Collagen content</td>
<td>0.0055</td>
<td>0.0052</td>
<td>0.0002</td>
<td>NS</td>
<td>0.0232</td>
<td>NS</td>
</tr>
<tr>
<td>NS = P&gt;0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Significant levels for three-way analysis of variance for sensory characteristics and shear force resistance of leg cuts as influenced by species (S), age (A) and fat code (F) (n=809)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Species (S)</th>
<th>Age (A)</th>
<th>Fat code (F)</th>
<th>S x A</th>
<th>S x F</th>
<th>A x F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species flavour</td>
<td>0.0050</td>
<td>0.0029</td>
<td>0.0168</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Aroma intensity</td>
<td>0.0005</td>
<td>NS</td>
<td>NS</td>
<td>0.0488</td>
<td>0.0254</td>
<td>NS</td>
</tr>
<tr>
<td>Flavour</td>
<td>NS</td>
<td>0.0004</td>
<td>0.0283</td>
<td>NS</td>
<td>NS</td>
<td>0.0017</td>
</tr>
<tr>
<td>Tenderness</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.0057</td>
<td>NS</td>
<td>&lt;0.0001</td>
<td>NS</td>
</tr>
<tr>
<td>Residue</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>NS</td>
<td>NS</td>
<td>0.0004</td>
<td>NS</td>
</tr>
<tr>
<td>Shear force resistance</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.0114</td>
<td>0.0474</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>NS = P&gt;0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Significant levels for three-way analysis of variance for cooking and thawing loss, sensory evaluation and proximate chemical analysis of rib and lion cuts as influenced by species (S), age (A) and fat code (F)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Species (S)</th>
<th>Age (A)</th>
<th>Fat code (F)</th>
<th>Sx A</th>
<th>SxF</th>
<th>Ax F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drip loss</td>
<td>0.0001</td>
<td>0.0004</td>
<td>&lt;0.0001</td>
<td>NS</td>
<td>NS</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Evaporation loss</td>
<td>NS</td>
<td>NS</td>
<td>0.0220</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Total cooking loss</td>
<td>NS</td>
<td>NS</td>
<td>&lt;0.0001</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Thawing loss</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Initial impression of juiciness</td>
<td>NS</td>
<td>0.0476</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>0.0002</td>
</tr>
<tr>
<td>Sustained juiciness</td>
<td>0.0028</td>
<td>0.0038</td>
<td>0.0004</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Expressible moisture</td>
<td>NS</td>
<td>0.0016</td>
<td>0.0285</td>
<td>NS</td>
<td>NS</td>
<td>0.0002</td>
</tr>
<tr>
<td>Moisture</td>
<td>NS</td>
<td>0.0314</td>
<td>&lt;0.0001</td>
<td>NS</td>
<td>NS</td>
<td>0.0317</td>
</tr>
<tr>
<td>Protein</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Fat</td>
<td>NS</td>
<td>NS</td>
<td>&lt;0.0001</td>
<td>NS</td>
<td>NS</td>
<td>0.0025</td>
</tr>
<tr>
<td>Ash</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>0.0109</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Dry matter</td>
<td>NS</td>
<td>0.0169</td>
<td>0.0001</td>
<td>NS</td>
<td>NS</td>
<td>0.0069</td>
</tr>
<tr>
<td>NS = P&gt;0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Biochemical analysis

The total collagen content of the M. longissimus thoracis was determined as well as the solubility of the collagen. Collagen solubility was expressed as the percentage hydroxyproline in the filtrate as compared to total amount of hydroxyproline (filtrate plus residue.)

Proximate chemical analysis

Determination of the percentages of total moisture, fat, nitrogen and ash of the cooked samples were done according to the accepted AOAC-methods (1985).

RESULTS AND CONCLUSIONS

Refer to Tables 2 to 5 for a complete summary of the results. The sheep meat was juicier, more tender, contained less connective tissue residue, had a more intense aroma and the species aroma is more typical than that of either the Angora or Boer goat meat. In general, the meat of goat carcases was found to be significantly less acceptable than that of sheep carcases, the Angora to a lesser extent, however, than the Boer goat.

The study confirms the fact that the meat of younger animals (irrespective of species) is juicier, more tender, contains less connective tissue residue and the species aroma is less typical than that of older animals and contains collagen with higher solubility resulting in lower shear force values of cooked meat.

Significant differences in the palatability attributes with an increase in the fat thickness, the juices of the cooked cuts tended to decrease and the tenderness, species flavour and solubility of collagen to increase.

In general, goat meat was found to be significantly different from sheep meat, the Angora to a lesser extent, however, than the Boer goat.

REFERENCES


Survival of *Salmonella* in cooked South African fresh sausage (boerewors)

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**INTRODUCTION**

Potential pathogens such as *Salmonella* may occur in or on beef, lamb and pig carcasses from which fresh meat products are processed (FAO/WHO, 1979). Stomach disorders may arise as a result of the ingestion of fresh sausage containing such organisms (Brown, 1982).

Due to *Salmonella* infections, foodborne disease outbreaks in the United States have increased; in particular outbreaks due to *Salmonella enteritidis* (Bean & Griffin, 1990). In a preceding study of commercial fresh sausage, 8.3% of South African boerewors samples tested contained *Salmonella enteritidis* (Steyn, 1989). Fresh beef sausage in Iraq contained *Salmonella enteritidis* in 35% of the sausage samples studied (Abbar & Tahir, 1989). Fresh sheep sausage or Turkish kokaric had a mean *Salmonella* count of 3.0 x 10^2 colony-forming units (cfu)/g (Göktan et al., 1991).

In fresh meat products the growth of *Salmonella* is limited by competing microorganisms. When the meat is cooked, the majority of micro-organisms are destroyed. Under favourable conditions, the surviving organisms including *Salmonella*, can grow rapidly. Earlier studies indicated that *Salmonella enteritidis*, if present on meat can, under appropriate conditions, produce hazardous levels of enterotoxin (Sobeh & Vadehra, 1984).

Growth temperature can influence the heat resistance of *Salmonella*. Although *Salmonella enteritidis* can multiply at refrigeration temperatures (Silliker & Elliot, 1980), higher growth temperatures (15 °C and above) lead to increased heat resistance. Such conditions increase the possibility of foodborne infections. To destroy any *Salmonella* which may be present in fresh meat products, the product should be heated to an internal temperature of not less than 80 °C (Anon., 1989).

Raw boerewors is a fresh sausage with water activity in the range of 0.971 to 0.986 and a pH value of between 5 and 6 (Steyn, 1989). The sausage is therefore a favourable environment for pathogens and 8.3% of commercial samples tested in a preceding study, were found to contain *Salmonella enteritidis* (Steyn, 1989). Serovars included Infantis, Anatum, Blockley and Cerro.

Boerewors is popular as a breakfast dish or at barbeques. In the latter process the surface temperature may reach 74 °C (Sawyer et al., 1983), while the internal temperature remains at only 66 °C (Bryan et al., 1980). At an internal temperature of 60 °C the sausage may be regarded as rare, at 70 °C as medium-rare and at 80 °C as well done (Smit, 1985). In this study the survival of the serovar Cerro was studied in pre-inoculated sausage cooked at the latter three temperatures.

In a previous study (Steyn, 1989) *Salmonella* was isolated from 8.3% of commercial raw sausage samples. The heat resistance of the organism under practical cooking conditions is unknown. *Salmonella enteritidis* serovar Cerro in particular has been found to be associated with foodborne infections in the Bloemfontein area (Botha, 1988).

The purpose of this study was therefore, to determine whether the serovar Cerro of *Salmonella* survives in cooked fresh sausage. To this end, boerewors was inoculated with the isolate and subjected to different cooking temperatures under standardized conditions.
EXPERIMENTAL PROCEDURE

Salmonella strains used

Strains of Salmonella (ser. Cerro), previously isolated from commercial boerewors, were freeze-dried in peptone-glucose solution (7.5% : 7.5% m/v) and stored at -20 °C. Reactivated cultures were used to determine the heat survival of Salmonella in cooked fresh sausage.

Preparation of artificially contaminated boerewors

A total of 0.01 ml of a thawed culture of Salmonella (ser. Cerro) was inoculated into Nutrient Broth (Oxoid CM115) and plated directly onto Nutrient Agar (Oxoid CM3) plates for development of colonies. A single colony was transferred to Nutrient Broth and incubated at 35 °C for 24 hours. It was then washed twice by centrifugation in phosphate buffer and diluted until the suspension had the same turbidity as a McFarland no. 2 turbidity standard (Difco 0691-32-8). A traditional sausage formulation, consisting of 3 kg meat (1 kg pork with a fat content of 70/30 plus 2 kg beef with a fat content of 90/10), 20 g coriander, 30 g table salt, 5 ml black pepper, 2 ml cloves and 2 ml nutmeg was used to prepare a “boerewors mixture”. This “mixture” was inoculated so as to ensure that the manufactured sausage would have a count of $10^5$ cfu Salmonella/g. The presence of Salmonella was tested for in 5 g, 10 g, 25 g and 50 g quantities of cooked boerewors as well as in similar quantities of the raw, inoculated control samples.

Standardized cooking procedure to determine heat survival of Salmonella in boerewors

The stuffed, inoculated boerewors was cut into 600 g portions and stabilised at 4 °C for 24 hours. Nine replicate portions per cooking temperature, were cooked in an electric fryer to internal temperatures of 60 °C, 70 °C and 80 °C respectively. The cooking temperature, were cooked in an electric fryer to internal temperatures of 60 °C, 70 °C and 80 °C respectively. The temperatures were determined using internal probes connected to electronic thermometers. The cooked samples were cooled at room temperature for 15 minutes, and then stored overnight at 4 °C.

Detection and identification of Salmonella in boerewors before and after cooking

Five g, 10 g and 25 g portions of each boerewors sample were placed in plastic “Whirlpak” bags (NT Laboratories, NT House, 34 Newton Street, Village Main, Johannesburg) together with 50 ml, 100 ml and 250 ml Rappaport Vassiliadis Broth respectively (Vassiliadis et al., 1981; Becker et al., 1987). The bags and contents were homogenized in a Lab Blender 400 Stomacher for 2 minutes. The stomacher bags containing the samples, were incubated at 37 °C for 48 hours, after which they were plated on MacConkey Agar (Oxoid CM115) and incubated at 37 °C for 24 hours. All colourless (non-lactose fermenting) colony-forming units on MacConkey agar were inoculated onto Triple Sugar Iron Agar (BIOLAB C18) and incubated at 37 °C for 48 hours. A red slant and a yellow butt section with black colouring due to H₂S in the butt section was regarded as positive. These organisms were subsequently brought into pure culture on Nutrient Agar (Oxoid CM3) plates and identified using API Z followed by API 20E (Path Ident, P.O. Box 774, Kempton Park, 1620). Serotyping of Salmonella isolates was performed at the South African Institute for Medical Research (P.O. Box 1176, Johannesburg, 2000).

Statistical analysis of results

A chi-square test for proportions was carried out to determine differences with regard to the presence of Salmonella in ninefold 5 g, 10 g, 25 g and 50 g samples of raw as well as cooked sausage samples. The Tukey procedure for proportions was subsequently applied to prove the relative differences between the samples (Zar, 1984).

RESULTS AND DISCUSSION

In Table 1 the test organism was recovered in at least seven out of nine replicate samples of raw sausage mix, regardless of the sample size.

Table 1: Presence of Salmonella in inoculated boerewors before and after cooking to 60 °, 70 ° and 80 °C

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Sample Size</th>
<th>Salmonella-positive cases in 9 samples of the indicated boerewors mass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 g</td>
<td>10 g</td>
</tr>
<tr>
<td>Raw</td>
<td>8/9</td>
<td>8/9</td>
</tr>
<tr>
<td>80 °C</td>
<td>0/9</td>
<td>2/9</td>
</tr>
</tbody>
</table>

When the inoculated sausage was heated to 60 °C, the frequency of recovery of the Cerro serovar was 2/9 in 5 g samples to 4/9 in 50 g samples. Sausage heated to 70 °C had a similar rate of recovery while internal temperatures of 80 °C resulted in recoveries of between 0/9 (5 g) and 2/9 (10 g).

Table 2 shows that the recovery of Salmonella in each of the 4 groups of sample sizes (5 g, 10 g, 25 g and 50 g) differed significantly between treatments (raw, 60 °C, 70 °C and 80 °C). The chi-square values, however, indicated differences within
Table 2: Chi-square values for indicating significant differences in the incidence of Salmonella in 36 boerewors samples.

<table>
<thead>
<tr>
<th>Sample mass</th>
<th>Model</th>
<th>Salmonella +</th>
<th>Salmonella -</th>
<th>Total</th>
<th>E-value*</th>
<th>Critical value**</th>
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<td>5g</td>
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<td>1</td>
<td>9</td>
<td>13</td>
<td>&gt;7,81</td>
</tr>
<tr>
<td></td>
<td>60 °C</td>
<td>2</td>
<td>7</td>
<td>9</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70 °C</td>
<td>3</td>
<td>6</td>
<td>9</td>
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<td></td>
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<tr>
<td></td>
<td>80 °C</td>
<td>0</td>
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<tr>
<td></td>
<td>Total</td>
<td>13</td>
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<tr>
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<tr>
<td></td>
<td>60 °C</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>17</td>
<td></td>
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<tr>
<td></td>
<td>70 °C</td>
<td>4</td>
<td>5</td>
<td>9</td>
<td>17</td>
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</tr>
<tr>
<td></td>
<td>80 °C</td>
<td>2</td>
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</tr>
<tr>
<td></td>
<td>60 °C</td>
<td>4</td>
<td>5</td>
<td>9</td>
<td>16</td>
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<td>70 °C</td>
<td>4</td>
<td>5</td>
<td>9</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>1</td>
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<td>16</td>
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</tr>
<tr>
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<td>Total</td>
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<tr>
<td></td>
<td>60 °C</td>
<td>4</td>
<td>5</td>
<td>9</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70 °C</td>
<td>5</td>
<td>4</td>
<td>9</td>
<td>18</td>
<td></td>
</tr>
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<td></td>
<td>80 °C</td>
<td>1</td>
<td>8</td>
<td>9</td>
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<tr>
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<td>18</td>
<td>18</td>
<td>36</td>
<td>11.12</td>
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</tr>
</tbody>
</table>

* $E = \frac{C_1 \times R_1}{n}$, $X^2 = \sum \frac{(O - E)^2}{E}$
** Standard for these chi-square values

the groups but were unable to specify between which treatments the differences existed.

Using the Tukey procedure (Table 3) the treatment within each group of sample sizes were compared statistically. Irrespective of sample size, recovery of Salmonella from raw samples differed significantly when compared with recoveries from heated samples (60 °C, 70 °C or 80 °C). The recovery of Salmonella from samples heated to 60 °C and 70 °C did not differ significantly irrespective of sample size. Results after heating to 80 °C however, differed significantly from those of 60 °C and 70 °C regarding Salmonella recovery. According to Table 1, this implies that an internal heating temperature of 80 °C is significantly more effective in reducing the levels of Salmonella in boerewors than either 60 °C or 70 °C, while the latter two temperatures are equally effective (or ineffective). This experiment confirms the findings of the FAO/WHO (1979) that the health risk inherent in Salmonella contamination can be reduced by the proper cooking of meat products.

The present experiment showed that even in boerewors samples heated to 80 °C, there is an 11 % survival rate of Salmonella. The ultimate temperature for cooked food of between 74 °C and 77 °C laid down by legislation in the USA (USD-HEW, 1978), is consequently not high enough for a 32 mm to 34 mm diameter fresh sausage such as boerewors.

CONCLUSIONS

Thirty-six boerewors models were inoculated with $10^5$ cells/g of Salmonella (ser. Cerro). The raw inoculated boerewors yielded more Salmonella-positive samples than those heated to internal cooking temperatures of 60 °C, 70 °C and 80 °C. While no differences in survival rate were evident at internal temperatures of 60 °C and 70 °C, the results of both temperatures differed statistically from those obtained at 80 °C. Because 11 % of the samples heated to 80 °C still contained Salmonella, an internal temperature exceeding 80 °C is recommended for the cooking of boerewors. Internal temperatures of 60 °C (rare) and 70 °C (medium-rare) may consequently be regarded as potentially hazardous with respect to possible foodborne infections. The results confirmed the FAO/WHO (1979) recommendations that the health of consumers could be safe-guarded by cooking meat sufficiently.

People who prefer rare (60 °C) or medium-rare (70 °C) cooked boerewors, are therefore in danger of contracting foodborne illness if Salmonella is present in the meat product. The risks of possible foodborne infection can be reduced through rapid chilling to 4 °C of the raw or cooked boerewors. Boerewors should however, never be consumed raw and should preferably be cooked to an internal temperature of more than 80 °C. Cooked boerewors should never be served in the container in which the raw product was kept before cooking as this may lead to recontamination by Salmonella (Anon., 1989).

REFERENCES


Table 3: Tukey procedure for ratios of differences regarding the incidence of *Salmonella* in 36 boerewors models

<table>
<thead>
<tr>
<th>Mass</th>
<th>Comparison</th>
<th>Difference*</th>
<th>Standard-error (SE)</th>
<th>q**</th>
<th>q 0.05 00.4*** Conclusion</th>
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<tbody>
<tr>
<td></td>
<td>Raw vs 80 °C</td>
<td>67.50</td>
<td>4.6474</td>
<td>14.52</td>
<td>&gt;3.63                  Raw ≠ 80 °C</td>
</tr>
<tr>
<td></td>
<td>Raw vs 70 °C</td>
<td>31.28</td>
<td>4.6474</td>
<td>6.73</td>
<td>&gt;3.63                  Raw ≠ 70 °C</td>
</tr>
<tr>
<td></td>
<td>Raw vs 60 °C</td>
<td>37.61</td>
<td>4.6474</td>
<td>8.09</td>
<td>&gt;3.63                  Raw ≠ 60 °C</td>
</tr>
<tr>
<td></td>
<td>60 °C vs 80 °C</td>
<td>29.89</td>
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<td>6.43</td>
<td>&gt;3.63                  60 °C ≠ 80 °C</td>
</tr>
<tr>
<td></td>
<td>70 °C vs 80 °C</td>
<td>36.22</td>
<td>4.6474</td>
<td>7.79</td>
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</tr>
<tr>
<td></td>
<td>70 °C vs 60 °C</td>
<td>6.33</td>
<td>4.6474</td>
<td>1.36</td>
<td>&gt;3.63                  70 °C = 60 °C</td>
</tr>
<tr>
<td></td>
<td>Raw vs 80 °C</td>
<td>37.61</td>
<td>4.6474</td>
<td>8.09</td>
<td>&gt;3.63                  Raw ≠ 80 °C</td>
</tr>
<tr>
<td></td>
<td>Raw vs 70 °C</td>
<td>25.38</td>
<td>4.6474</td>
<td>5.46</td>
<td>&gt;3.63                  Raw ≠ 70 °C</td>
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<td>4.6474</td>
<td>6.73</td>
<td>&gt;3.63                  Raw ≠ 60 °C</td>
</tr>
<tr>
<td></td>
<td>60 °C vs 80 °C</td>
<td>19.62</td>
<td>4.6474</td>
<td>4.22</td>
<td>&gt;3.63                  60 °C ≠ 80 °C</td>
</tr>
<tr>
<td></td>
<td>70 °C vs 80 °C</td>
<td>19.62</td>
<td>4.6474</td>
<td>4.22</td>
<td>&gt;3.63                  70 °C ≠ 80 °C</td>
</tr>
<tr>
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<td>Raw vs 80 °C</td>
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<td>8.09</td>
<td>&gt;3.63                  Raw ≠ 80 °C</td>
</tr>
<tr>
<td></td>
<td>Raw vs 70 °C</td>
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<tr>
<td></td>
<td>Raw vs 60 °C</td>
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<td>4.6474</td>
<td>3.87</td>
<td>&gt;3.63                  Raw ≠ 60 °C</td>
</tr>
<tr>
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<td>60 °C vs 80 °C</td>
<td>19.62</td>
<td>4.6474</td>
<td>4.22</td>
<td>&gt;3.63                  60 °C ≠ 80 °C</td>
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<tr>
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<td>70 °C vs 80 °C</td>
<td>19.62</td>
<td>4.6474</td>
<td>4.22</td>
<td>&gt;3.63                  70 °C ≠ 80 °C</td>
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<td>4.6474</td>
<td>4.23</td>
<td>&gt;3.63                  Raw ≠ 70 °C</td>
</tr>
<tr>
<td></td>
<td>Raw vs 60 °C</td>
<td>25.38</td>
<td>4.6474</td>
<td>5.46</td>
<td>&gt;3.63                  Raw ≠ 60 °C</td>
</tr>
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<td>60 °C vs 80 °C</td>
<td>19.62</td>
<td>4.6474</td>
<td>4.22</td>
<td>&gt;3.63                  60 °C ≠ 80 °C</td>
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<tr>
<td></td>
<td>70 °C vs 80 °C</td>
<td>25.39</td>
<td>4.6474</td>
<td>5.46</td>
<td>&gt;3.63                  70 °C ≠ 80 °C</td>
</tr>
<tr>
<td></td>
<td>70 °C vs 60 °C</td>
<td>5.77</td>
<td>4.6474</td>
<td>1.24</td>
<td>&gt;3.63                  70 °C = 60 °C</td>
</tr>
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</table>

* $\frac{1}{2}\left[\arcsin(\sqrt{n}) + \arcsin(\sqrt{n-1})\right]$

** $\frac{\text{difference}}{\text{SE}}$

*** Standard for this q-value

---

OTHER, P.L., 1988. Personal communication, Department of Medical Microbiology, UOFS, PO Box 339, Bloemfontein 9300.


Cooking related and sensory quality characteristics of meat from lambs fed supplemenations of either calcium soap or grain sorghum

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INTRODUCTION

During the dry season, the nutritive value of natural pastures in the summer rainfall regions of South Africa falls to a level below that required to maintain body mass of sheep. As a result, supplementary feeding with sources of energy and protein has become common practice. Although grains such as maize and sorghum have been used as energy sources and urea and cottonseed oilcake are included in supplements as sources of protein, fats have not yet been utilized as energy supplements in this context. In the past, the use of fatty acids for ruminant nutrition was restricted due to an inhibitory effect on fibre-digesting microbes in the rumen (large stomach) of grazing animals such as sheep. However, several methods have been devised for “protecting” fatty acids from reacting in the rumen, while still enabling them to be absorbed in the lower gut. In work reported by Cronjé & Oberholzer (1990:3-9), fatty acids produced as a by-product during the processing of cottonseed oil were protected by complexing them to form calcium salts (“soaps”). In the latter experiment, the growth rate of lambs consuming a roughage diet was doubled by supplementation with 100 g Ca-soap/day and the authors concluded that substantial benefits may be derived from supplementation of ruminants fed low quality roughages together with protected fats.

THE PURPOSE OF THE STUDY

The purpose of the study was to evaluate the eating quality characteristics of cooked Mm. longissimus thoracis et lumborum and M. semimembranosus, M. semitendinosus and M. biceps femoris-containing cuts obtained from lambs receiving a Ca-soap dietary supplement in comparison to certain reference diets. Special attention was also paid to the cooking-related attributes of these meat cuts.

MATERIALS AND METHODS

Lambs and dietary treatments

Sixty South African Mutton Merino lambs were divided into six treatment groups (Table 1). All the lambs were fed a basal diet of teff hay ad lib, plus molasses (56 g/d) and urea (11 g/d). Three of these six groups were fed on a lower protein level, namely 25 g cottonseed oilcake/day and the other three on a higher protein level of 75 g cottonseed oilcake/day. The three dietary supplementations for these two protein groups were: a basal diet with no extra supplementation; a protected fat (Ca-soap made from cottonseed soapstock) and grain sorghum (Cronjé & Oberholzer, 1990).

After seventeen weeks, the lambs were slaughtered, electrically stimulated at 800 V for 120 seconds, dressed, chilled for a total of 24 hours at 0-5 °C, graded, reweighed and halved. The right sides were subdivided into retail cuts according to Bruwer, et al. (1984:63a), namely: neck, raised shoulder, leg, shanks, breast and rib plus loin. Each labelled cut was individually wrapped, protruding bones covered with Bone-guard and vacuum-packaged in Cryovac Barrier bags (BB1; Darex Africa (Pty) Ltd). The cuts were aged at 0-7 °C for seven days and frozen at -20 °C for two months. Of these, five carcasses of the most representative lambs (i.e those closest to the par-
Table 1: Experimental design indicating lamb allocations to the two cottonseed oilcake levels and supplementation levels with either Ca-soap or grain sorghum

<table>
<thead>
<tr>
<th>Dietary treatment &amp;/or supplement</th>
<th>Low Protein Level 1 Cottonseed oilcake flour 25g/day (P25)</th>
<th>High Protein Level 2 Cottonseed oilcake flour 75g/day (P75)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dietary Treatment 1: Basal diet, controls, no extra supplementation (E)</td>
<td>OP25 10</td>
<td>OPT5 10</td>
<td>20</td>
</tr>
<tr>
<td>Dietary treatment 2: Ca-soap (manufactured from cottonseed oil) 100g/day (F)</td>
<td>FP25 10</td>
<td>FP75 10</td>
<td>20</td>
</tr>
<tr>
<td>Dietary treatment 3: grain sorghum, 100 g/d (E)</td>
<td>EP25 10</td>
<td>EP75 10</td>
<td>20</td>
</tr>
<tr>
<td>Lamb totals</td>
<td>30</td>
<td>30</td>
<td>60</td>
</tr>
</tbody>
</table>

Where:
- D = (Controls) = without supplementation
- F = (Fat/“Vet”) = calcium soap, obtained from cottonseed oil, alone
- E = (Energy) = grain sorghum alone
- P25 = (Protein) = 25 g/day of cottonseed oilcake flour
- P75 = (Protein) = 75 g/day of cottonseed oilcake flour
- FP25(=Fat + Protein) = calcium soap (100 g/day) + cottonseed oilcake flour (25 g/day)
- FP75(=Fat + Protein) = calcium soap (100 g/day) + cottonseed oilcake flour (75 g/day)
- EP25(=Energy + Protein) = grain sorghum (100 g/day) + 25 g/day cottonseed oilcake flour
- EP75(=Energy + Protein) = grain sorghum (100 g/day) + 75 g/day cottonseed oilcake flour

Cooking-related data

Cooking-related data were collected from the 30 whole Mm. longissimus thoracis et lumborum cuts and the 30 whole leg cuts respectively. The cooking times, internal endpoint temperatures, total cooking loss, drip loss and evaporation loss fractions were recorded. Drip loss fractions were poured into coded measuring cylinders, left for 24 hours and then the volumes (total volume, volume of fat and volume of stock, in ml, respectively) were read off and noted. These volumes were then converted to an index by expressing them as a percentage of the cut’s initial raw mass and were also referred to as total volume drip loss index, fat volume drip loss index or stock volume drip loss index respectively. The nature of the fat was evaluated subjectively once the volumes of the drip loss fractions had been read. A four-point scale was used, with 1 denoting oily fat (more unsaturated fatty acids), 2 creamy fat, 3 fairly hard fat and 4 solid fat (more saturated fatty acids).

Shear force resistance measurements (Instron) were also conducted on all the sensory analysis samples, to determine the tenderness/toughness of the meat using a Warner Bratzler shear attachment fitted to an Instron Universal Testing Machine, Model 1140 (Instron Food Testing Instrument, 1974:5.3). Standardised 12.5 mm cores of meat were used and cut perpendicular to the grain or fibre bundle direction. The tougher the meat, the greater the force required to cut through it and the higher the reading.

Sensory analysis data

Ten double sensory analysis sessions were held, during which three Mm. longissimus thoracis et lumborum samples, one from each of the three dietary treatments from either the P25 or P75 level, were evaluated, followed by three samples, one from each of the three dietary treatments from either the P25 or P75 levels, obtained from the M. semimembranosus-containing leg cuts. A seven-point Likert type measuring scale was used, with 7 denoting the most favourable attribute and 1 the least favourable, except the scale for “residue” which was from 1 to 6, where 6 denoted no residue (also the most positive aspect of the attribute) and 1 an excessive amount (most negative aspect of this attribute).

Statistical analysis

The sets of data obtained for the various dependent variables were initially subjected to the following statistical analysis procedures using STATGRAPHICS® version 5 (1991): two-way analysis of variance, with the dietary treatment (basal diet, protected fat supplement and grain sorghum supplement) and protein level (Level 1 or P25 and Level 2 or P75) as the main effects of variation (independent variables, Table 1). This was done for each of the dependent variables. A table of means for treatment, protein level and treatment-protein level interactions and multiple range analysis tables for both dietary treatment and protein level for each variable were then printed and 95 % Least Significant Difference (LSD) graphs plotted. Due to unavoidable variation in the internal endpoint temperatures of the meat, cooking-related and sensory analysis data were re-analyzed in a similar fashion, using internal endpoint temperature as a covariant.

RESULTS AND DISCUSSION

Significant results are summarised in Tables 2 and 3. Readers are referred to Van Rensburg et al. (1992), for a more detailed discussion.

CONCLUSIONS

In conclusion, it would appear that meat obtained from lambs fed on the protected fat diet was not as acceptable as meat obtained from lambs fed on the basal diet or the grain sorghum diet groups. The conclusion drawn from this research is...
that, from a sensory quality characteristic point of view, especially the legs obtained from lambs fed on the basal as well as on the grain sorghum diets were more acceptable than the protected fat equivalents. The loins from lambs fed on the lower protein level of 25 g of cottonseed oilcake per day also appeared preferable in comparison to the higher 75 g/day protein level.

It should be kept in mind that the original purpose of the study was to evaluate a Ca-soap supplement in the diet of lambs in times of pasture nutrient deficiency. It may therefore be suggested that the Ca-soaps should only be supplemented for short periods and/or that animals should not be marketed immediately after supplying the protected fat diets. Sufficient time should be allowed for foreign flavours and odours to disappear from the animal’s body before slaughtering.

**RECOMMENDATIONS**

In order to determine whether or not the negative results relating to the sensory quality characteristics improve with a withdrawal period, a trial designed to determine the optimum length of the withdrawal period of the calcium soap supplementation before slaughter, may be carried out.

**Table 2:** Comparative table of a summary of cooking-related variables showing significant differences (P<0.05) and differences approaching significance (tendencies) (P<0.05 to P<0.099) for treatments 1, 2 and 3 as well as for protein levels 1 and 2 for lamb loins and legs

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Dietary treatments¹</th>
<th>Protein levels</th>
<th>Protein treatments</th>
<th>Protein levels</th>
</tr>
</thead>
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<tr>
<td></td>
<td>P value 1 2 3</td>
<td>P value 1 2</td>
<td>P value</td>
<td>P value 1 2</td>
</tr>
<tr>
<td>Calculated raw sample mass, g</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drip loss, %</td>
<td>0.0428* 3.88 4.61*</td>
<td>5.59 NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Total volume drip loss index, %</td>
<td>0.0509* 2.38 2.94*</td>
<td>4.1† 0.0516*</td>
<td>2.58 3.71 NS</td>
<td>2.0995 2.40 2.17</td>
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<tr>
<td>Fat volume drip loss index</td>
<td>NS</td>
<td>0.0307*</td>
<td>1.90† 3.11* NS</td>
<td>NS</td>
</tr>
<tr>
<td>Heating rate, °C/g</td>
<td>0.0185* 0.036*</td>
<td>0.035* 0.032*</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Means in the same row with different superscripts differ significantly (95 % LSD)

Table 3: Comparative table of a summary of sensory analysis variables showing significant differences (P<0.05) and differences approaching significance (tendencies) (P<0.05 to P<0.099) for treatments 1, 2 and 3 as well as for protein levels 1 and 2 for lamb loins and legs

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Dietary treatments¹</th>
<th>Protein levels</th>
<th>Protein treatments</th>
<th>Protein levels</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>P value 1 2</td>
<td>P value</td>
<td>P value 1 2 3</td>
<td>P value 1 2</td>
</tr>
<tr>
<td>Fat odour</td>
<td>NS</td>
<td></td>
<td>0.0034*</td>
<td>4.98° 4.36° 4.49° NS</td>
</tr>
<tr>
<td>Sustained juiciness</td>
<td>NS</td>
<td>0.0064**</td>
<td>5.24° 4.83°</td>
<td>NS</td>
</tr>
<tr>
<td>Tenderness</td>
<td>NS</td>
<td>0.0124*</td>
<td>4.91° 4.32° 4.73°</td>
<td>0.0640 4.49 4.83</td>
</tr>
<tr>
<td>Flavour</td>
<td>0.0926 5.07 4.75 5.10</td>
<td>0.0233* 5.19° 4.80°</td>
<td>0.0128° 5.11° 4.59° 4.82°</td>
<td>NS</td>
</tr>
<tr>
<td>General acceptability</td>
<td>NS</td>
<td>0.0779 5.12 4.85</td>
<td>0.0141° 4.76° 4.25°</td>
<td>4.49° NS</td>
</tr>
</tbody>
</table>

Means in the same row with different superscripts differ significantly (95 % LSD)

* P<0.05, mean values rounded up to 2 decimal places
** P<0.01, mean values rounded up to 2 decimal places

NS Not significant

Dietary treatment 1=Basal diet
Dietary treatment 2=Fat supplement
Dietary treatment 3=Grain sorghum supplement
Protein level 1=Low
Protein level 2=High

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REFERENCES


The incidence of *Listeria* in vienna sausages, cervelat and ham in a metropolitan city (Pretoria) of South Africa

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**INTRODUCTION**

Vienna sausages, cervelat and ham belong to the category of ready-to-eat food products which usually do not undergo further preparation or cooking treatment at the hands of the consumer. The presence of pathogenic bacteria in meat is of particular concern because of their ability to grow at refrigeration temperatures. In addition, *Listeria* is relatively resistant to heat and curing salts and may survive some processing treatments (Farber, 1989).

**AIM**

This study was undertaken 1) to determine the occurrence of *Listeria* in vienna sausages, cervelat and ham obtained from supermarkets in the Pretoria area, 2) to find a possible relation between the total bacterial count and the occurrence of *Listeria*.

**METHODS**

**Sampling**

The 134 samples were collected at random during Spring. Shoulder ham and cervelat were purchased from the delicatessen section of supermarkets, with the exception of those supermarkets which have all their products pre-packed. One specific manufacture’s vienna sausages were obtained from all the supermarkets, with the exception of those supermarkets which do not stock this specific manufacture’s vienna sausages. The samples were transported under refrigeration (2-7 °C) to the Meat Industry Centre at the IAPI where isolation and purification procedures were preformed. The meat was sampled on three occasions from 17 supermarkets, giving three replicates.

**Analytical procedures**

The samples were analysed for total bacterial plate count on Standard 1 Agar (Merck) and incubated at 30 °C/3 days (Nortjé, *et al*. 1990)

**Procedures for the demonstration of *Listeria***

Meat samples (25 g from each sample) were aseptically added to 225 ml *Listeria* Selective Enrichment Broth (LSEB, primary enrichment broth) (Oxoid), and homogenized for two minutes in a Colworth Stomacher 400. The IDF recommended method for the detection of *Listeria* was followed (International Dairy Federation, 1989). Colonies presumptively identified as *Listeria* were confirmed by DNA hybridization testing (Gene-Trak Systems, Framingham, M.A., U.S.A.) and biochemical and serological testing.

**RESULTS**

A total of 47 samples were taken from vienna sausages, 43 from shoulder ham and 44 from cervelat. The total plate counts for the three types of monitored processed meats varied. Five vienna sausage samples (11 %), one ham sample and no cervelat samples were in the range of less than 10⁵ organisms/g. In the range 1 x 10⁵ - 5 x 10⁶ organisms/g, vienna sausages contributed to 12 (26 %), ham to 27 (63 %), and cervelat to 15 (34 %). The range 5 x 10⁶ - 1 x 10⁷ organisms/g consisted out of 6 (13 %) vienna, 4 (9 %) ham and 5 (11 %) cervelat samples. The range 1 x 10⁷ and higher, consisted out of 24 (51 %) vienna, 11 (26 %) ham and 24 (55 %) cervelat samples.
Of all the processed meat samples monitored, 11 (8.2%) were contaminated with Listeria. Two (4.3%) vienna sausages contained Listeria, one was identified as Listeria welshimeri, the other L. grayi. Seven (16.3%) ham samples contained Listeria. One sample contained L. welshimeri and L. innocua, the other six only L. welshimeri. Two (4.5%) cervelat samples contained Listeria, both being L. welshimeri.

CONCLUSION

In the present study a higher incidence of Listeria and fewer total counts in excess of $10^7$ CFU were noticed in ham samples than in cervelat and vienna samples. According to these results there appears to be some relation between a low total count and the occurrence of Listeria.

The incidence of Listeria observed in processed meats confirms the view that this organism is a frequent contaminant of animal products, and South Africa is no exception. Although none of these species have been implicated in foodborne outbreaks, it is important to recognise their presence. Methods should be implemented to prevent these and pathogenic strains of Listeria from entering processed meats.

REFERENCES


INTRODUCTION

Fat quality is becoming an increasingly important factor in lamb and mutton. Diet does not change the body fat composition in ruminants as much as in monogastric animals, but past and recent research (Orskov, Frazer & Gordon, 1974; Orskov, Grubb, Webster & Corrigal, 1979; Duncan, Orskov, Frazer & Garton, 1974; Mayes & Orskov, 1974; Casey & Van Niekerk, 1985; Casey, Van Niekerk & Spreeth, 1988; Webb & Casey, 1992) has indicated diet-induced changes in ruminant fat composition.

In wethers reared on high-maize diets significant increases in the deposition of C15:0, C17:0, C17:1 and C18:1 fatty acids in the subcutaneous adipose tissue were observed (Webb & Casey, 1992). These researchers also reported significant increases in the deposition of both total unsaturated fatty acids and fatty acids of the trans-configuration in the subcutaneous adipose tissue depots.

Owing to these changes, a study was conducted to investigate the effect of dietary energy treatments on the sensory properties and cooking losses of lamb.

MATERIALS AND METHODS

Two rations containing 11.76 and 10.18 MJ metabolizable energy per kg dry material (ME/kg DM), compiled on an isoproprotein and mineral basis (Webb & Casey, 1992), were fed ad libitum to 48 Dorper and 48 SA Mutton Merino wethers from 20.51 ± 2.51 and 22.30 ± 3.99 kg to 37 and 43 kg live masses respectively. The sheep were slaughtered and the carcasses electrically stimulated (21 V, 60 Hz, 120 sec) and chilled overnight (4 °C).

In order to give an estimate of total carcass composition a three-rib loin sample was taken from the left side of each carcass. The ventral extremity of the sample was on a line drawn from the cranial point of the pubic symphysis to the middle of the first rib (Casey et al., 1988). Fat percentage was included as covariant in the statistical analysis procedures so as to compensate for fatness between and within breeds.

Meat pH was measured by using an Orion pH meter and inserting a combination glass pH electrode into the M. longissimus lumborum (at a point over the 13th rib, 25 mm from the midline), allowing the pH to stabilise and then taking the average of three measurements.

The left M. longissimus lumborum samples (hereafter referred to as loin samples) were removed, vacuum packed and stored until evaluated. During the preliminary sensory study all methods and techniques regarding the preparation, cooking, serving and evaluation of loin samples were evaluated and standardised. After thawing, the loin samples were roasted in an oven (160 °C) to an internal end point temperature of 70 °C.

Percentages total cooking loss, drip loss and evaporation loss were determined by weighing the unroasted loin, oven rack and oven pan before and after roasting. The volume of fat (ml) and meat extract (ml) in the drip, as well as the total volume of drip (ml) were also measured in order to characterise the composition of the drip loss.

A trained taste panel evaluated sensory parameters (aroma, incipient juiciness, sustained juiciness and overall acceptability) on a 10 cm unstructured scale. The sensory evaluation proce-
dure consisted of two phases. Phase 1 consisted of a training program, followed by a performance evaluation which was aimed at determining the accuracy and repeatability of individual standard evaluations. The levels of confidence obtained for both the taste panel and individual panellists indicated that the taste panel was adequately trained and could be regarded as an accurate scientific measuring instrument (Winer, 1960).

RESULTS AND DISCUSSION

Carcass fat content and subcutaneous fat thickness measured at a point over the 13th rib differed between breeds (Table 1) and consequently affected the acceptability of lamb (P<0.01).

*M. longissimus lumborum* samples with thick subcutaneous fat depots (SCF13-measurement) were regarded as unacceptable (*rxy*=-0.60, P<0.001) and these samples were less flavoursome (P<0.01). Of the Dorper samples, 91.8% contained too much fat while only 8.3% of the samples from SA Mutton Merinos contained abundant amounts of fat (Chi2=33.3, P<0.001).

Dietary energy level also influenced the number of days fed for both breeds (P<0.01). Wethers on the high dietary treatment required 56.6±29.2 days to reach their target mass, while those on the medium dietary treatment required 75.0±27.3 days.

Neither breed, treatment nor slaughter mass affected the cold carcass pH, as measured at a point over the 13th rib (approximately 24 h after slaughter). High energy treatment improved the aroma of lamb (P<0.05), but its effect on the other sensory variables was negligible. Slaughter mass significantly affected all the sensory properties investigated. Both the flavour (P<0.01) and overall acceptability (P<0.01) of sensory samples from SA Mutton Merinos were higher than those of Dorpers. Neither breed, treatment or slaughter mass affected the sustained juiciness. However, with the inclusion of the percentage fat as covariant, breed significantly affected the incipient juiciness (P<0.05), sustained juiciness (P<0.05), flavour (P<0.1) and overall acceptability (P<0.1). The effect of treatment on aroma remained significant (P<0.05).

Drip loss (P<0.01) and evaporation loss (P<0.01) during cooking were influenced by breed, but not by treatment. Higher drip losses and evaporation losses were recorded for samples from SA Mutton Merinos. Slaughter mass influenced both cooking loss (P<0.01) and drip loss (P<0.01), but not evaporation loss. Cooking and drip losses increased with increasing slaughter mass.

Table 1: The influence of breed on subcutaneous fat thickness as measured over the 13th rib (SCF13) for wethers on different energy treatments.

<table>
<thead>
<tr>
<th>Breed</th>
<th>Treatment</th>
<th>SCF13(cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA Mutton Merino</td>
<td>High Energy</td>
<td>0.232 ±0.112*</td>
</tr>
<tr>
<td></td>
<td>Medium Energy</td>
<td>0.162 ±0.058*</td>
</tr>
<tr>
<td>Dorper</td>
<td>High Energy</td>
<td>0.330 ±0.215*</td>
</tr>
<tr>
<td></td>
<td>Medium Energy</td>
<td>0.320 ±0.274*</td>
</tr>
</tbody>
</table>

Values with different superscripts in each column differ significantly (P<0.01).

Table 2: The influence of breed (BR) on the sensory properties (A=Aroma, IJ=incipient juiciness, SJ=sustained juiciness, F=flavour and OA=overall acceptability) of lamb.

<table>
<thead>
<tr>
<th>BR</th>
<th>A</th>
<th>IJ</th>
<th>SJ</th>
<th>F</th>
<th>OA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorper</td>
<td>6.57</td>
<td>7.32</td>
<td>6.67</td>
<td>7.45</td>
<td>7.29</td>
</tr>
<tr>
<td></td>
<td>±0.51*</td>
<td>±0.58*</td>
<td>±0.72*</td>
<td>±0.72*</td>
<td>±0.77*</td>
</tr>
<tr>
<td>SAMM</td>
<td>6.57</td>
<td>7.43</td>
<td>6.76</td>
<td>7.06</td>
<td>6.55</td>
</tr>
<tr>
<td></td>
<td>±0.52*</td>
<td>±0.72*</td>
<td>±0.79*</td>
<td>±0.77*</td>
<td>±0.98*</td>
</tr>
</tbody>
</table>

Values with different superscripts in each column differ significantly (P<0.05).

Table 3: The influence of treatment (TR) on the sensory properties (A=Aroma, IJ=incipient juiciness, SJ=sustained juiciness, F=flavour and OA=overall acceptability) of lamb.

<table>
<thead>
<tr>
<th>TR</th>
<th>A</th>
<th>IJ</th>
<th>SJ</th>
<th>F</th>
<th>OA</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>6.63</td>
<td>7.33</td>
<td>6.69</td>
<td>7.29</td>
<td>6.97</td>
</tr>
<tr>
<td></td>
<td>±0.49*</td>
<td>±0.74*</td>
<td>±0.75*</td>
<td>±0.72*</td>
<td>±0.89*</td>
</tr>
<tr>
<td>M</td>
<td>6.51</td>
<td>7.42</td>
<td>6.74</td>
<td>7.23</td>
<td>6.87</td>
</tr>
<tr>
<td></td>
<td>±0.54*</td>
<td>±0.67*</td>
<td>±0.75*</td>
<td>±0.87*</td>
<td>±1.02*</td>
</tr>
</tbody>
</table>

Values in the same column with different superscripts differ significantly (P<0.05).

Table 4: The influence of slaughter mass (SM) on the sensory properties (A=Aroma, IJ=incipient juiciness, SJ=sustained juiciness, F=flavour and OA=overall acceptability) of lamb.

<table>
<thead>
<tr>
<th>SM</th>
<th>A</th>
<th>IJ</th>
<th>SJ</th>
<th>F</th>
<th>OA</th>
</tr>
</thead>
<tbody>
<tr>
<td>37 kg</td>
<td>6.52</td>
<td>7.34</td>
<td>6.68</td>
<td>7.26</td>
<td>6.96</td>
</tr>
<tr>
<td></td>
<td>±0.49*</td>
<td>±0.69*</td>
<td>±0.68*</td>
<td>±0.78*</td>
<td>±0.89*</td>
</tr>
<tr>
<td>43 kg</td>
<td>6.61</td>
<td>7.41</td>
<td>6.75</td>
<td>7.26</td>
<td>6.89</td>
</tr>
<tr>
<td></td>
<td>±0.54*</td>
<td>±0.73*</td>
<td>±0.81*</td>
<td>±0.77*</td>
<td>±1.02*</td>
</tr>
</tbody>
</table>

Values in the same column with different superscripts differ significantly (P<0.05).
CONCLUSIONS

Meat quality needs to be defined so as to fully appreciate the needs of the consumer (Naudé, 1985). Appearance, palatability, nutritive value, processibility and shelf life contribute greatly to meat quality. Fat quality affects all the above-mentioned meat quality characteristics. Results obtained in previous studies (Webb & Casey, 1992) emphasize the significant effects of dietary energy levels on the fatty acids in the subcutaneous adipose tissue of wethers.

Results obtained in the present study indicate that high energy treatment significantly improved both the aroma and incipient juiciness of sensory evaluation samples. However, the increased amount of fat, coupled with its poor consistency impaired the overall acceptability of sensory samples. Total cooking loss, drip loss and evaporation loss were influenced by breed and slaughter mass, but not by dietary energy level.

REFERENCES


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