MEETING AT C.S.I.R.O. MEAT RESEARCH LABORATORY, CANNON HILL, BRISBANE ON JULY 30, 1975.

PROBLEMS AND NEW DEVELOPMENTS IN MEAT PROCESSING

As market demand for beef becomes more sophisticated and competitive, meat processing technology must keep pace. Recent trends in the beef industry are highlighting the need for increased efficiency in processing with the reduction of spoilage by disease and handling. This is an area singularly characterised by increasing costs which must be borne by the industry.

Officers from the Meat Research Laboratory discussed these problems and the programs of research at Cannon Hill.

BRUISING IN CATTLE

F.D. SHAW
C.S.I.R.O., Cannon Hill.

In 1973 it was estimated that bruising of cattle was costing the Australian meat industry $22 million per annum. Although there has been a marked fall in cattle prices since then, the cost of bruising to the meat industry has probably not changed significantly because increases in the cost of labour required for the trimming of bruises have to a large extent negated the decreases in value of meat trimmed. Bruising of cattle is therefore still an important economic problem.

It has frequently been stated that the presence of horns on cattle increases the amount of bruising but there were no figures available to indicate how much bruising was caused by horns. In a co-operative project, officers of the CSIRO Meat Research Laboratory, the Australian Meat Board and the Queensland Department of Primary Industries undertook a series of eight trials designed to determine the contribution of horned cattle to the problem of carcass bruising. In each trial there were 3 groups of cattle, one group with horns, one without, and a mixed group in which some of the cattle were horned and some hornless. The cattle were slaughtered at various Australian abattoirs, and, after dressing of the carcasses, the bruised tissue was trimmed by abattoir employees to meet export inspection standards. The weight of trimmed bruised tissue was recorded for each carcass.

In seven of the eight trials the carcasses of the horned cattle had more bruising than the carcasses of the hornless cattle. In most trials the horned cattle had almost twice as much bruising as the hornless cattle. The mean values for the amount of tissue trimmed from the three groups are listed in Table 1.

TABLE 1.

	Hornless	Horned	Mixed
Average weight of tissue trimmed (kg)	1.66	2.76	2.47
Number of animals	187	206	206

It was found that the horned cattle in the mixed groups had the same amount of bruising as the cattle in the horned groups, however, the hornless cattle in the mixed groups had more bruising than the cattle in the hornless groups. Thus the introduction of some horned cattle into a group of hornless cattle can cause a marked increase in the amount of bruising occurring on the hornless animals. To minimize bruising losses, it is therefore essential that horned and hornless animals be kept separate.

Cattle can be bruised on the grazier's property, at saleyards, at abattoirs, and during transportation. Abattoirs are often unable to decide when bruises are inflicted, and a simple, accurate method of determining the age of bruises would assist in determining factors other than horns which contribute significantly to the problem of carcass bruising. Several methods of determining the age of a bruise have been investigated, but so far all methods examined have had their limitations.

A bruise involves the rupture of blood vessels and the escape of blood into the tissues. The haemoglobin in the blood is converted to the compound bilirubin. It has been shown that it takes at least two days for haemoglobin to be broken down to bilirubin and thus the presence of bilirubin in a bruise indicates that the bruise occurred at least two days previously. A simple method for the detection of bilirubin in bruised tissue has been developed and this method can be used to assist in determining when bruising occurred. The bilirubin test is of particular value where animals have been held at an abattoir for about two days or less before slaughter. In these cases the test can indicate the amount of bruising which occurred before the animal reached the abattoir.

Skeletal muscle contains many enzymes which are released into the blood stream in large amounts following muscle damage, e.g. bruising. The relative concentrations of two enzymes, CPK (creatine phosphokinase) and GOT (glutamic oxaloacetic transaminase) can on occasions provide an indication of when bruising occurred. These enzymes are released only when there is substantial muscle damage, thus the technique is not applicable when there is superficial bruising involving only the subcutaneous tissues.

At present the most accurate method of determining the age of a bruise is by histopathological examination of a section of the bruise. Unfortunately, the method requires a very careful examination of the sections by an experienced pathologist and is therefore not a suitable technique for the examination of large numbers of bruises. It is hoped that by using specific stains it may be possible to develop techniques which will enable inexperienced personnel to determine the age of a bruise by microscopic examination of the bruised tissue.

PROCESSING FACTORS AFFECTING MEAT QUALITY

J.J. MACFARLANE
C.S.I.R.O. Cannon Hill

To the consumer, the term meat quality embraces all sought-after quality attributes, e.g. tenderness, juiciness, flavour and wholesomeness. Wholesomeness implies unimpaired nutritive value and freedom from significant health risks which might result, for example, from the presence of harmful micro-organisms or toxic chemical contaminants. Meat is a highly perishable commodity, and research into the control of microbial spoilage was dominant in the early investigations of meat quality. In spite of intensive efforts to find acceptable alternatives to refrigeration as a means of controlling microbial growth, none has been found that retains the 'fresh' character of meat. In addition, even when processes such as cooking, canning, dehydration (freeze-drying), salting, or curing are used, refrigeration almost invariably has been employed in earlier processing. In recent years increasing emphasis has been placed on research into the influence of meat processing conditions on the eating quality of meat, particularly tenderness. This discussion will be mainly concerned with meat tenderness and how it is affected by events at the processing plant.

For convenience, processing is divided into three periods; the pre-slaughter period, the pre-rigor period, and the post-rigor period. The pre-rigor period is that period after slaughter of the animal during which rigor mortis sets in. It is characterised by an increase in the acidity of muscle, resulting in a pH decrease from about 7.2 in the live animal to an ultimate pH of about 5.6. This pH decrease results from, and may be limited by, the breakdown of glycogen reserves in the muscle to lactic acid.

Pre-slaughter period

The events that occur to an animal over a period of some days before slaughter influence meat quality mainly through effects on the ultimate pH attained by the muscles. Meat of a high ultimate pH is, in general, more tender than meat of normal pH, it has increased water holding capacity, and modified flavour. However, its dark colour may cause it to be discriminated against in the market place. It is also more susceptible to microbial spoilage.

As mentioned earlier, the amount of glycogen present in muscle at the time of death limits the decrease in pH post-mortem. Should glycogen reserves be depleted, e.g. by excitation, activity uncompensated by rest, shortage of food, or stress due to exposure to adverse weather conditions then a relatively high ultimate pH can be anticipated. The musculature of cattle is less susceptible than that of pigs and sheep to glycogen depletion by such factors.

Pre-rigor period

During the early part of this period, muscle is still able to contract. If muscle is allowed to enter rigor in a contracted state there can be a loss in tenderness, the loss becoming greater as contraction increases from 20 to 40% of muscle rest length. Muscle contracted to 40% of its rest length is unacceptably tough. For the muscle from bovine and ovine species, the temperature during this period has an important effect on contraction state. Muscle allowed to remain at the body temperature of the live animal shows a marked tendency to contract (rigor shortening). This tendency decreases as the temperature is lowered to about 15° C, below which the tendency to contract increases (cold shortening). The sooner muscle temperature is lowered below 10° C following slaughter of the animal, the more pronounced is cold shortening. Once the pH has fallen below 6.3 there is little tendency for muscle to cold shorten. Before effects of muscle shortening on meat tenderness were known, the trend was to chill carcasses as rapidly as possible after slaughter for the dual purposes of inhibiting microbial growth and reducing evaporative weight loss from carcasses. It is likely that this trend will now be moderated.

In the carcass suspended in the traditional manner from the Achilles tendon, most of the economically important muscles of the hindquarter are not restrained from shortening. However, simply by resuspending the carcass from the aitch bone, virtually all muscles are tensioned via their attachments to the skeleton and therefore are not able to shorten. Whenever rapid rates of chilling are employed, aitch bone suspension should be considered to guard against toughness as a result of muscle shortening. In fact, whenever it is desired to produce high quality meat, aitch-bone suspension should be considered to avoid the ever-present tendency of pre-rigor muscle to either rigor or cold shorten.

Post-rigor period

After carcasses (or muscles) are set in rigor their tenderness improves with storage in the non-frozen state, a process referred to as ageing. The traditional practice was to hang the side of beef in a cool dry place. In recent years major changes have occurred in the application of the method and ageing is now carried out under carefully controlled conditions in chillers. Instead of ageing whole carcasses, it is now common only to age selected cuts of meat, packaged in special plastic films. The films help retard microbial growth by maintaining an atmosphere within the package that is low in oxygen but high in carbon dioxide.

Of the two main structural components of meat, the myofibrils and the connective tissue, the effects of ageing appear to be much greater on the former than the latter. Therefore, whenever connective tissue is the dominant cause of toughness (as is often the case in the meat from old animals), large improvements in tenderness cannot be expected from ageing. Also, the effectiveness of the ageing process is reduced if meat is tough because of muscle contraction. Indeed ageing is virtually ineffective on muscle that has contracted by about 40%.

Another way of improving the tenderness of meat is by application of enzymes to break down the structural components. Problems associated with this method are:—

(i) obtaining an enzyme appropriate to the source of toughness, e.g. an enzyme selective for connective tissue is not readily available;
(ii) avoiding under or over application of enzyme; and
(iii) achieving a uniform distribution of enzyme.

WEIGHT LOSS

L.S. HERBERT
C.S.I.R.O., Cannon Hill

Product wastage occurs at all stages in the processing of carcasses in abattoirs. Wastage may take the form of blood loss, drip, trimmings, or evaporation of water from the meat tissues. This last form of wastage occurs primarily during carcass cooling in abattoir chillers. The cooling process, which is necessary to reduce the growth of micro-organisms, causes a loss of 2-3% of the dressed carcass weight.

In response to concern within the meat industry for the lack of adequate engineering data on which to base chiller design and operation for minimum weight loss, investigations have been undertaken by the Meat Research Laboratory. The investigations involve measurement of weight loss in commercial chillers, as well as laboratory-scale experiments. In the chiller experiments, weight loss from up to 50 carcasses is measured simultaneously using special measuring devices developed at the laboratory. Studies have been carried out in beef, mutton and pork chillers. The work has indicated large irregularities in air distribution and temperature in some modern chillers, and has shown the advantages of rapid chilling. Carcasses chilled in high velocity, low temperature air lost less weight than similar carcasses chilled to the same deep leg temperature (7° C) in more moderate air conditions.

In laboratory experiments, lean mutton samples have been chilled under controlled air conditions in a wind tunnel, and changes in sample weight recorded. When chilled for 24 hrs, weight loss was found to decrease with decreasing air velocity and increasing relative humidity. Conversely, when chilled to a predetermined meat temperature, the relationship between weight loss and air velocity was reversed. The effect of relative humidity was similar, although reduced. The effect, on weight loss, of changes in the temperature of the cooling air, was investigated. Samples were found to lose less weight when chilled in air at a constant low temperature then when the air temperature was allowed to rise at the start of the chilling period, the normal practice in abattoirs.

To calculate weight loss, and quantitatively predict the effect of air conditions on evaporation rates from carcasses, basic mass transfer data for water in meat is required, and radioactively labelled water is being used to follow the movement of water through meat during chilling.

BYPRODUCTS — POSSIBLE NEW APPROACHES

V.H. POWELL
C.S.I.R.O., Cannon Hill

The meat processing industry in Australia has undergone immense growth in the last 100 years since the invention of mechanical refrigeration. Although there have been some changes in meatworks procedures, such as "on rail dressing", a foreman of thirty years ago would find relatively few innovations in his industry today. Little of the technological explosion in process industries during the last thirty years has penetrated the meat processing industry, and the number of processes and products has decreased due to the current high cost of labour intensive operations. The objective of any processing industry is to maximise profit. Revenue from meat products is normally positive, but some classes of products have negative values, e.g. liquid pollutants.

The object of the work of technologists is to assist the maximization of profit. It is important to look at all products to determine whether high profit materials can be produced, e.g.

Product	Selling price ($ per lb)
Pharmaceuticals	+ 10^2 (high)
meat	+ 1 (moderate)
tallow, meat meal	+ 10^{-1} (low)
wastes	- 10^{-2} (low negative)

MEAT PRODUCTS AND BYPRODUCTS

Traditionally, the meat industry did as little secondary processing as possible. Stability of products was all that was required and once achieved further steps were left to the customer. A similar attitude applied to byproducts such as tallow, hides, pelts, wool, meats, fertilizers, and a few specialized but profitable lines. In many cases, profitability is low, and processing is virtually a treatment of wastes. The range of more thoroughly processed, high profit products is potentially large. The aim should be to upgrade the value of the product sold as fertilizers to that of animal feed and if possible to that of human food. It would be highly desirable to sell all products having values similar to that of pharmaceuticals in order to achieve a greater return for the raw materials.

Protein products

Due to the ever increasing labour charges, significant amounts of muscle are being downgraded to lower valued products such as meat meals. An attractive method to recover the protein in an edible form is to render meat trimmings etc. to remove the bulk of the fat and then recover the protein or its hydrolysed products, such as amino-acids etc. The soft offals (hearts, lungs, kidneys etc.) may be treated in a similar manner. The products generated could be presented to the consumer in novel forms e.g. toppings, emulsifiers, encapsulating agents, meat flavours etc.

Blood

Animal blood is a potential source of large quantities of edible protein (.23 kg of dried blood protein from sheep and 2.3 kg from a steer). Apart from a small amount used in black puddings and some sausages, blood is either processed to animal feeds or disposed of as waste. Technology is now available for converting blood collected in a hygienic manner to whole blood, white whole blood protein, plasma, or haemoglobin. While this is a common practice in Europe, no commercial plants have been installed in Australia. The CSIRO Meat Research Laboratory is quite active in attempting to introduce this technology to Australia.

Pharmaceutical products

After initial popularity, animal derived pharmaceuticals have been eclipsed in many areas by microbial or synthetic products but there is evidence that the animal sources of raw materials for this industry are again becoming important. Due to the high labour charges, economic removal of glands and other tissues for pharmaceuticals requries some form of mechanisation. This is a challenge for both materials handling and industrial relations.

Bones

Fertiliser and stock feed are formulated from protein wastes and crushed bones. These are very low value products which probably do not pay their processing costs. If protein is to be diverted to edible products this leaves the problem of "what do we do with the bone?" Only a small proportion may be processed to bone flour or to gelatine. New means of increasing the value of bone must be obtained by research.

CONCLUSION

The meat works is not simply producing one product (meat) or even an existing range of products. It is handling various inputs including animals, services and people, organised in a manner to produce outputs of differing potentials. As times change the value of these outputs changes, and at present there is increased emphasis on environmental reactions, hygiene, and maximum added value. Maximisation of profit requires a thorough analysis of the total system in order to obtain information for the development and evaluation of new products and processes.

SALMONELLA

M.G. SMITH
C.S.I.R.O., Cannon Hill

The salmonellae are a closely related group of bacteria which, when ingested in large numbers, may cause human food poisoning. All domesticated animals and birds used for human food — pigs, poultry, sheep and cattle — can at times be infected with these organisms and the meat obtained may sometimes be contaminated with salmonellae. To reduce the incidence of human infection, the public health services of many countries have adopted testing programmes and may condemn meat on which these organisms are found. This is a constant economic threat to the Australian pastoral industry and all possible precautions must be taken to minimise salmonella contamination.

Sheep and cattle destined for slaughter at abattoirs in Australia are often confined in, or pass through, areas in which salmonellae have been detected e.g. cattle trucks, sale-yards, and abattoir holding pens. It is not uncommon for animals to spend several days in transport and then be held in pens at abattoirs for 7 days or more, as sufficient numbers must be acquired several days in advance to ensure continuity of operations.

After leaving the farm, sheep and cattle are seldom fed regularly, and research by the CSIRO Division of Food Research at its Meat Research Laboratory in Brisbane has shown that after about 24-36 h without food these ruminant animals become highly susceptible to salmonella infection. This is due to the decrease in the amount of volatile fatty acids formed in the rumen as the metabolisable substrates are exhausted. The volatile fatty acids are inhibitory to salmonellae and other enterobacteriaceae, and, if not constantly produced, the level soon falls and the ruminal environment no longer exerts a controlling effect on these organisms. Even a few salmonella cells ingested at this critical time can multiply rapidly in the rumen. Soon after, the lower gastro-intestinal tract also becomes highly infected, and within 3 days such animals are excreting large numbers of these organisms in their faeces. Subsequent groups of animals held in the same area encounter an increasing risk of infection as greater numbers of salmonellae are now present. In this way, a "cycle of infection" is built up and maintained whenever animals are held for periods of at least a few days in one area and fed intermittently.Up to 10^6 salmonella cells g^{-1} of soil have been found in the surface layers of some holding yards. Recent evidence also suggests that under certain conditions salmonellae can multiply in the soil and excreta detritus of animal pens. The organisms are able to survive for months or even years in such material.

When infected animals are slaughtered at an abattoir, salmonellae may be inadvertently transferred to the carcass meat during dressing operations. Distribution of such contaminated meat carries salmonellae to the consuming public. Thus, contaminated holding yards at abattoirs may be regarded as a "focus of infection" from which salmonellae are constantly carried to the human community.

When salmonella-infected animals are slaughtered the effluent from the abattoir also contains these organisms, sometimes in quite large numbers (*c* 10^2-10^4 ml^{-1}). Salmonellae have also been isolated from the anaerobic and aerobic waste-treatment ponds constructed by abattoirs to partially purify their discharged effluent. Wild life, especially water fowl, have a ready access to these ponds. Whether animals and birds, either native or domestic, become infected with salmonellae from abattoir effluents in Australia is unknown, but the possibility that such infection can occur and lead to the widespread dissemination of salmonella organisms in the environment cannot be discounted. The results of investigations carried out in the U.S.A. and Europe have shown that salmonellae can be isolated from fish, wild animals, and birds. In this way, the organisms can be carried to other areas away from the original site of infection.

VACUUM PACKAGING

B.Y. JOHNSON

C.S.I.R.O., Cannon Hill

A feature of fresh meat is the short time it remains an edible, acceptable food product. This time period, or shelf-life, is determined mainly by microbial growth. Vacuum packaging is one method of controlling the growth of bacteria on meat in wholesale cut or carcass form. By controlling the conditions of storage, shelf-life can be extended from about 3 weeks up to at least 8 weeks.

HISTORY OF CHILLED BEEF

Early 1930's

Experimental shipments by CSIRO in 1933-34 of chilled hanging quarter beef in 10% CO_2 clearly demonstrated the feasibility of the shipment of chilled beef to the U.K. These and subsequent commercial shipments all included measures which are the successful ingredients in present vacuum packed chilled beef shipments: strict hygiene on the slaughter floor and boning room, good temperature control at just above freezing point, and transport in a CO_2 atmosphere.

Recent developments

In 1968 a small shipment of vacuum packed chilled beef left Brisbane for Japan having been packed by a consortium of the Australian Meat Board, CSIRO, Thos. Borthwick & Sons, and W.R. Grace. In 1970 the first commercial shipment of vacuum packed chilled beef cuts was sent from Australia to Japan. The growth in this trade was spectacular until in 1974 almost 50% of beef for Japan was chilled. The availability of containers also gave Australia access to other markets for chilled meat, and in the same period approximately 9% of all beef exported was in the chilled form. Of the small amount of beef entering Japan in the last 12 months about 31% is chilled. In the Middle East there is an important demand for chilled carcasses. Of the total Australian beef and veal exports to the Middle East about 3% is chilled and about 5% of sheep meat exports is chilled.

TECHNICAL ASPECTS OF VACUUM PACKAGING

Equipment

There are two main types of packaging equipment — nozzle evacuating equipment operating on vacuums of 250 to 600 mm Hg, and chamber evacuating equipment operating on vacuums of around 700 mm Hg. The choice of equipment makes little difference to the storage life of meat packed in conventional packaging materials.

Bags

Vacuum Packaging restricts the growth of the normal spoilage organisms (*Pseudomonas*). This organism needs oxygen for growth and its growth is retarded by the presence of carbon dioxide. After evacuation and sealing, the meat and bacteria inside an impermeable bag consume oxygen and release carbon dioxide, which cannot escape and therefore accumulates, so that eventually the oxygen level inside falls below 1%, while the carbon dioxide level rises to 20-30%. High carbon dioxide and low oxygen levels are desirable. To achieve this, bags of low permeability are used and size is chosen to minimize the area of film available for gas permeation. Organisms resistant to carbon dioxide can grow, but growth is slow at the temperatures employed. If the meat is held too long, these resistant organisms produce a cheesy souring of the product instead of the usual slime associated with fresh spoiled meat.

For packs where there are large cavities which make evacuation of air difficult (e.g. mutton and lamb carcasses) it has been found necessary to gas flush. When using nozzle evacuating equipment it is common to draw a vacuum of about 80 mm Hg, gas flush with 35% carbon dioxide in nitrogen, evacuate again and seal.

Throughout storage and transport it is important to hold the meat at a temperature as close as possible to the freezing point of meat (-1.5° C). The maximum number of microorganisms is reached after about 6 weeks. Since the maximum number of bacteria is reached before the end of the storage life, the actual life can be determined by taste only (although colour deterioration is generally the limiting factor).

ANIMAL REQUIREMENTS

The Japanese market requires well marbled meat with about 1.3 cm subcutaneous fat over the tenth rib. Heavy animals (over 318 kg dressed) bring the best price. The fat should be white or light creamy coloured. Marbling is due to the presence of fat within muscles (intramuscular fat). To produce carcasses with a high degree of marbling, it is necessary to produce carcasses with a high total fat content. Yellow fat results in downgrading, and is normally due to the presence of carotene pigments. The carotene content of the diet determines the colour of the fat. Green pasture contains large quantities of carotene pigments, and the carotene content of hay and silage is usually high despite losses during storage. Grains, other than maize, contain very little carotene. Experiments with feedlot cattle indicate that after a 3-month period using grain-based rations there are negligible quantities of carotene in the fat.

The Meat Board considers that the future of the Middle East chilled sheep meat market for West Australia lies with yearling or hogget Merino sheep, the age of sheep meat traditionally sold in this market. It is a meat which is reliably tender, lean, with a meaty flavour stronger than lamb, but lighter than mutton.

Animals should be well rested and slaughtered in the unexcited state to avoid the occurrence of dark cutting meat, pH 6.0 or higher.

CONCLUSION

A successful vacuum packaged chilled meat trade calls for extreme care from the time the animals are selected and leave the farm to consumption of the final product. Short cuts anywhere along the line will reduce the storage life of the product.