# Update: The Meat Industry Research Institute of New Zealand

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## Introduction

New Zealand is a small Pacific nation 1600 km east of Australia and thus is far from the population centers of the Northern Hemisphere — its major markets. New Zealand has an area of approximately 268,000 $km^2$ (comparable to the area of the state of Colorado) and a population of just over three million. Its economy is based largely on the pastoral production of sheep and cattle: The meat industry is the nation's largest income earner, with dairy products and wool also providing significant export earnings.

New Zealand meat processors were amongst the first in the world to freeze meat, and New Zealand has just celebrated its centennial of frozen meat exports. Today the New Zealand meat industry is still in the forefront of modern technology, with specialized techniques for dressing carcasses and for guaranteeing meat tenderness. Many of its technological advances have been pioneered by the Meat Industry Research Institute of New Zealand (MIRINZ), which was formed in 1955.

## MIRINZ: Organization and Research Programs

MIRINZ undertakes research and development on behalf of the various commercial companies that make up New Zealand's meat export industry. This may be a rather unusual way of organizing industrial R&D, but because of New Zealand's small size, central research agencies like MIRINZ are needed if essential but expensive technological development is to be supported.

The Institute is financed and administered jointly by the New Zealand Freezing Companies Association on behalf of export slaughterhouses; the New Zealand Meat Producers Board, representing farmers; and the government, which, through the Department of Scientific and Industrial Research, supplies about 40% of the Institute's funds.

MIRINZ is located in the Waikato, a rich agricultural area in the northern half of the North Island. MIRINZ is adjacent to the Ruakura Agricultural Research Center, with which it shares an experimental slaughterhouse. The Institute houses laboratories for microbiology, meat science, sensory evaluation, protein chemistry, food technology and analytical chemistry; there are also workshops for instrumentation and engineering, a large engineering-development hall, a process-development area at the experimental slaughterhouse and a waste-treatment laboratory at a nearby large, commercial slaughterhouse. The staff consists of some 35 meat scientists and technologists, microbiologists, engineers and chemists, with a supporting technical and administrative staff of 60.

The Institute's primary tasks are to improve the industry's processing efficiency and the quality of its export products; MIRINZ does this by researching all aspects of the industry, from the farm gate to the consumer. Consequently, the Institute's R&D undertakings are many and varied and reflect both the complexities of a high-technology industry and changing marketing needs.

Because lamb provides the major portion of the industry's earnings, much of the Institute's work deals with better ways to process, freeze and transport sheepmeats. To give a complete account of all the R&D programs at MIRINZ is beyond the scope of this paper — there are over 100. Instead, I shall give an overview of some of our work.

The Institute's R&D programs are under the aegis of three Divisions: Science, Engineering, and Planning and Services.

## Science Division

The Science Division is divided into four sections: Meat Science, Meat Technology, Microbiology and Pollution. Recent areas of research include stunning and slaughter; muscle structure, physiology and biochemistry; accelerated conditioning (electrical stimulation for tenderness); processed meats; microbial spoilage; sensory testing of meat; and various techniques for treating slaughterhouse effluent.

### Stunning and Slaughter

We have recently developed a humane, effective system for Halal slaughter of sheep that ensures carcass stillness, worker safety and a reduced incidence of speckle bruising (petechial hemorrhages in the subcutaneous fat). This system has been developed to meet the requirements of our expanding markets in Moslem countries.

For Halal slaughter, the animal must bleed to death after having its throat cut. Therefore, the head-to-foreleg stun that is usually used with sheep is inappropriate, as it stops the heart. Using physiological studies of the effects of various electrical parameters and electrode placements, we have

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developed a new, two-stage system. The lamb is automatically stunned head-only and its throat is cut, thereby satisfying Halal slaughter; then an electrical current is applied along the spinal cord to eliminate spinal reflexes and so ensure carcass stillness during dressing. We are now working on a system for Halal slaughter of beef.

**Muscle Structure, Physiology and Biochemistry**

Electrical stimulation of carcasses is commonly used to accelerate muscle glycolysis, allowing carcasses to be chilled or frozen shortly after slaughter without the risk of cold shortening. Many people have assumed that electrical stimulation affects all muscles in the same way. Using ox muscles, we have found that after stimulation some muscles can still cold shorten — these are muscles that contain predominantly slow-twitch fibers. Interestingly, these muscles have neither the decline in pH during electrical stimulation nor the accelerated rate of pH decline after stimulation characteristic of other carcass muscles. This research indicates that the proportions of muscle-fiber types in each muscle determine its response to electrical stimulation. This finding may explain conflicting reports of the effects of electrical stimulation from studies using different muscles and different species.

Another area of study is the role played by gap filaments in determining the toughness of cooked meat. The tensile strength of gap filaments in cooked meat of different sarcomere lengths is being studied, to relate toughness to muscle shortening. Gap-filament studies are part of a general strategy to sustain a basic research interest at the Institute. Studies on variations in isozymes amongst muscle fiber types, the structure of thick filaments and image processing for determining the nature of the interactions between thick and thin filaments are all part of this research endeavor.

**Accelerated Conditioning**

Accelerated Conditioning (AC) is an integrated process involving the electrical stimulation of carcasses shortly after slaughter, together with appropriate delay before freezing and controlled freezing rate. Used correctly, this process prevents most carcass muscles from cold shortening, and thus toughening, during chilling and freezing.

High-voltage AC is more effective in speeding rigor development than low-voltage, which is, however, safer to apply. We have been experimenting with low-voltage AC systems and have had encouraging results with lamb, beef and deer carcasses. We have found that combining low- and high-voltage stimulation increases the uniformity of carcass response and also reduces the conditioning time necessary to avoid cold shortening.

Another area of current study is the effect of high-voltage AC treatment on the aging of vacuum-packed chilled lamb.

**Processed Meats**

To meet the need for diversification of products, we are studying, in collaboration with the New Zealand Dairy Research Institute, the use of individual milk proteins as binders in processed meat products. So far, we have used these proteins to produce a salt-free boneless lamb roll with excellent binding characteristics.

We are also investigating various methods of defatting mutton, to produce a relatively lean product that can be used in processed meats. For example, we have used deboning/desinewing machines to remove mechanically more than half the fat from mutton at various temperatures. We have also defatted whole mutton carcasses by grinding them and rendering the minced material in the MIRINZ Low Temperature Rendering System (MLTR) operated at lower-than-normal temperatures. The resulting lean ground-meat substance retains the functional properties of raw meat and serves as a useful base raw material for a diversity of end uses.

**Microbiology**

Even though New Zealand has been trading in frozen meat for over a century, we still suffer losses due to mold spoilage. Therefore, MIRINZ has been investigating the conditions that promote fungal spoilage of meat during cold storage.

Bacterial growth must be inhibited if mold spoilage is to occur. It is usually supposed that mold spoilage is caused by a few species of fungi that can withstand the low temperatures and desiccation associated with frozen meat. However, we have found that four species causing 'black spot' spoilage and one causing 'white spot' spoilage are only moderately xerotolerant, whereas a species causing 'whiskers' spoilage has a low xerotolerance. Black-spot, white-spot and whiskers spoilage forms all have a practical minimum growth temperature of −5°C, but growth at this temperature is extremely slow. Therefore, we believe that most mold spoilage occurs when "frozen" meat is held at temperatures approaching 0°C with surface desiccation inhibiting bacterial growth. Thus, such spoilage indicates serious and extensive temperature abuse during frozen storage. We have also found that meat held at marginal freezing temperatures (−5°C) had high numbers of cold-tolerant yeasts, which, however, imparted no spoilage odors or flavors to the meat.

Another area of study concerns spoilage of offals. Offals are usually assumed to have a very short shelf life at chill temperatures. From studies with sheep livers, we have found that a short shelf life is due solely to mishandling: livers are bulk-packed without chilling and remain warm for several hours, a practice that allows heavy growth of spoilage and pathogenic microorganisms. Chilling before packing in plastic tubs would prevent growth of disease organisms and give the livers a shelf life of at least two months at 0°C.

We have also studied the effects of oxygen and carbon dioxide levels on the microbial flora of vacuum-packed chilled meat. Unpackaged chilled meat is spoiled by strictly aerobic bacteria. In vacuum packages, the growth of these aerobic organisms is inhibited either by the absence of oxygen (which is necessary for their metabolism) or the build-up of carbon dioxide (which inhibits their growth). Our studies have shown that it is the absence of oxygen that is more important. This conclusion was confirmed by examining microbial spoilage of meat vacuum packed with films of different oxygen permeabilities: storage life was inversely proportional to permeability. These studies lend further support to the concept that environmental factors play a major role in determining the storage life of meat by selecting the type of flora that develops on meat and meat products.

**Sensory Testing**

MIRINZ uses taste panels, both trained and untrained, to

evaluate organoleptic characteristics (aroma, flavor, juiciness, tenderness and texture) of meat and meat products. Recent studies have included the organoleptic quality and consumer acceptability of meat from sheep of different ages; influence of pasture type on the flavor of sheepmeats; flavor changes of lamb during frozen storage; organoleptic changes in chilled lamb as influenced by different processing treatments; and sources, intensity and importance of taint in meat.

### Pollution

Slaughterhouses produce large quantities of wastes, and the treatment of these to facilitate disposal without causing pollution of receiving waters is a major concern. The ready availability of land adjacent to many New Zealand slaughterhouses has led to the use of land-intensive systems for treating effluents. MIRINZ has studied the use of anaerobic and aerobic lagoons and also the irrigation of primary-treated effluent onto pasture. Our irrigation studies have concentrated on the ultimate fate of the irrigated nitrogen at different levels of application, because at high loadings, nitrate can pollute the groundwater, and nitrate levels in the vegetation can become high enough to be a health risk. Our pilot-scale trials indicate that slaughterhouse effluent can be irrigated at rates of up to about 1000 kg nitrogen per hectare per year with very little effect on the groundwater. Irrigation at rates much above this limit can cause the nitrate nitrogen levels of both the vegetation and the leachate to exceed recommended limits.

Another area of study is the chemical treatment of slaughterhouse effluent to recover protein. We have developed several alternative systems involving the use of flocculants and precipitants and the adjustment of effluent pH. Processes involving a two-stage adjustment of pH appear to be particularly promising. With some procedures, the recovered solids can be dried and fed to pigs or chickens and so offset the cost of treatment. For example, we have fed recovered solids to growing pigs at up to 10% of the diet by weight with no ill effects. If the solids are to be used in this way, however, the treatment must not use toxic chemicals or chemicals that are not approved ingredients of animal feeds, because these substances could contaminate the feed, making it unusable. Although chemical treatment has been developed for slaughterhouse wastes, it is also applicable to other types of protein-rich effluents. Because of our expertise in chemical treatment, we are looking at the commercial exploitation of this technology.

## Engineering Division

The Engineering Division is large compared with those in similar meat research organizations overseas. MIRINZ has taken on the role of engineering design and development to a greater degree than perhaps would be necessary if New Zealand had a larger industrial base.

The Engineering Division contains four sections: By-products Development, Meat Processing, Works Services and Engineering Services (Electrical). Its work is extremely diverse and encompasses rendering technology; mechanical dressing; shrinkwrapping of carcasses; container-loading efficiency; refrigeration, energy, and heat- and mass-transfer studies; and design of electronic equipment.

### Rendering Technology

MIRINZ has designed and developed a low-temperature rendering system, called the MLTR (Fig. 1). This system was designed after MIRINZ surveyed existing rendering systems

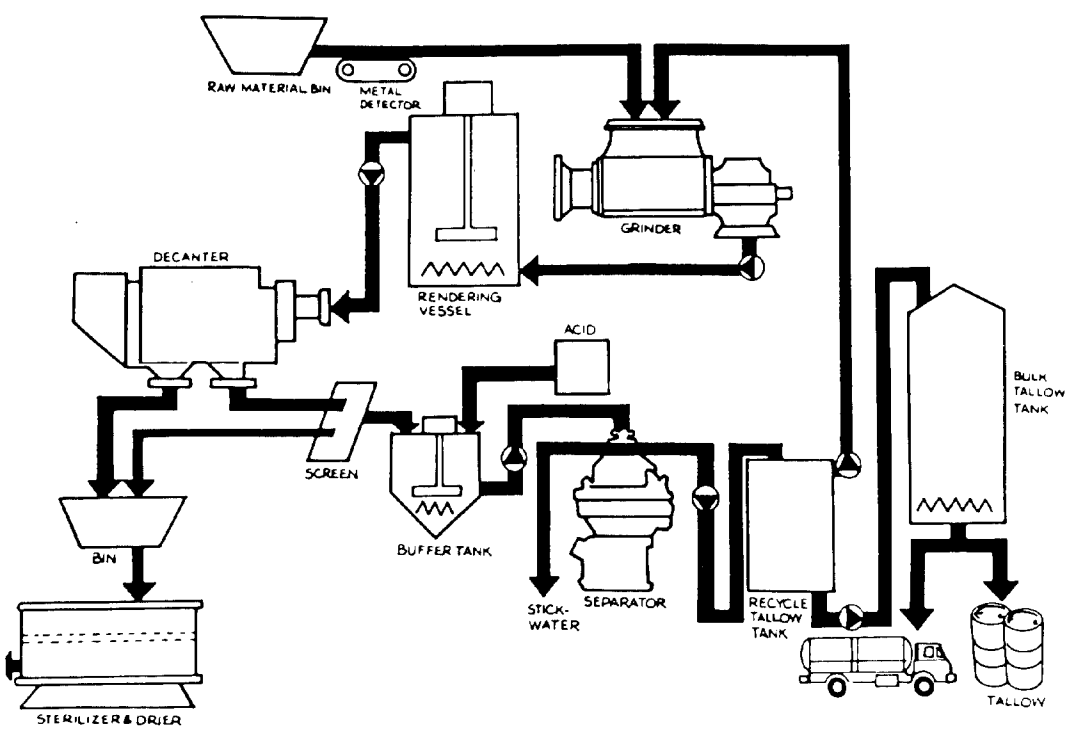


Figure 1. Schematic diagram of the MIRINZ Low Temperature Rendering System (MLTR).

in Australasia and assessed their drawbacks. Using that information, we drew up the criteria of an 'ideal' low-energy, low-cost system and used those criteria in designing the MLTR.

With traditional dry rendering, the meal is in effect fried in tallow at high temperatures (110-130°C). These high temperatures degrade both the bleachability of the tallow and the nutritive value of the meal. The MLTR renders at low temperatures (up to 95°C) and uses recycled tallow for fluidization. With this design, a good-quality tallow can be produced from unwashed raw materials; the meal is low in fat (6-8%); a variety of raw materials can be processed; and the tallow and meal can be sterilized separately. Energy costs are low. This year two full-scale MLTRs have been commissioned, bringing to four the number of MLTRs now operating in the New Zealand meat industry. A full-scale MLTR has also been built for rendering fish.

We are now evaluating the use of an edible-grade MLTR for rendering bone and fatty trimmings from boning and cutting rooms to yield a low-fat meat substance that could be used in comminuted meat products. With this technique, the industry could recover some of the approximately 20,000 tons of edible-grade meat tissue that is now discarded from boning and cutting rooms and downgraded to meat and bone meal for use in animal feeds and fertilizers.

**Mechanical Dressing**

Mechanization of the slaughter process has the potential to reduce costs and to improve hygiene and dressing standards.

MIRINZ has participated with industry in a major development project aimed at substantially mechanizing the slaughter and dressing of lambs, from stunning to evisceration. Most advanced are an automatic stunner (Fig. 2) and an automatic pelt remover. A semiautomated system of evisceration is also being developed. The automatic stunner is compatible with Halal slaughter and can be used on sheep, pigs or calves at a success rate of over 99.7%. MIRINZ has recently taken over responsibility for the ongoing project and is concentrating on further development of the pelt removal process and evisceration. There are often industrial difficulties with the introduction of new technology, and these will have to be overcome for this project to be successful.

**Shrinkwrapping of Carcasses**

Traditionally, the frozen lamb carcasses that New Zealand exports have been wrapped in stockinet. However, with such a wrap the carcasses suffer desiccation, resulting in weight loss and poor carcass appearance. Whole-carcass shrinkwrapping provides an improved carcass appearance and a greatly reduced weight loss. One technique is to shrinkwrap carcasses after freezing. The mechanical challenge is that this must be achieved at a rate of about one carcass every 1.5 seconds. Because some plants have logistical problems with post-freeze wrapping, we have been participating in an investigation of pre-freeze shrinkwrapping. Carcasses shrinkwrapped before freezing lose substantially less weight than those wrapped frozen. If this regime is used, however, hygiene standards must be very high, because the conditions engendered when warm, moist carcasses are shrinkwrapped could promote microbial growth.

Figure 2

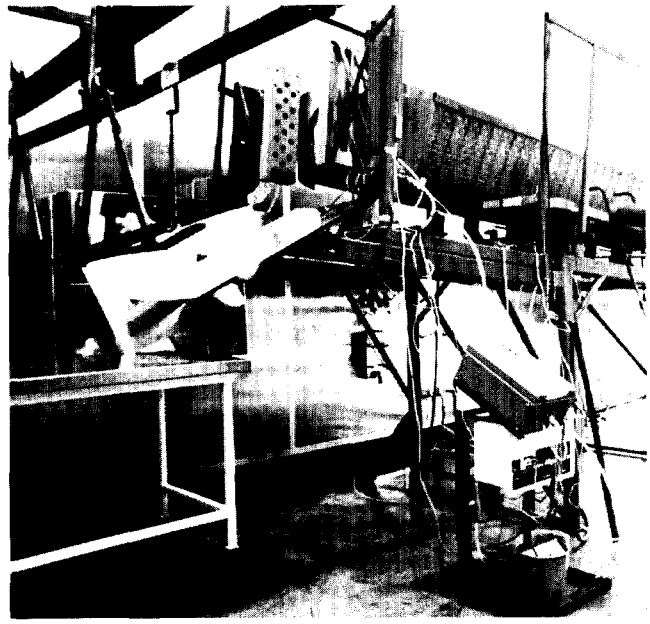

Figure 2. Automatic stunning system designed for easy attachment to existing small-stock restraining conveyors.

**Container-Loading Efficiency**

Because most New Zealand lamb is exported as frozen carcasses stacked in containers, MIRINZ has been investigating ways of improving stowage density. Changes in stacking patterns and minor changes in carcass shape can increase stowage density to some degree, but major improvements can be gained by either removing the low-value neck, shanks, brisket and leg knuckles, making the rest of the carcass rectangular, or by "compacting" the carcass. Carcass compacting involves cutting through the backbone, folding the hind legs into the body cavity, and trimming the shoulders. This "telescoped" carcass is then vacuum-packed in a polyethylene bag. This technique results in a product that resembles a vacuum-packed turkey. Pairs of compacted carcasses can be packed into lamb-cut cartons for easy handling. Advantages of this method include reduced carcass desiccation and the potential for mechanized handling in freezers and cold stores and during loadout.

**Plant Studies and Design of Electronic Equipment**

Works Services staff study a variety of topics, including the infiltration of air into cold stores, thawing techniques, carcass weight loss during cold storage, the performance of carton freezers and energy usage in slaughterhouses.

Items of equipment that have been developed recently by our instrumentation staff include a microprocessor to calculate and automatically select the optimal focus setting for low-dose electron microscopy of biological samples, a simple chilling- or freezing-time monitor that measures the time for the deep-leg temperature to reach a pre-determined value, a

portable gas-sampler for determining air infiltration into cold stores, a solid-state meter for measuring the stimulation current of a carcass during Accelerated Conditioning (this device clips onto and travels with the carcass selected for testing) and a low-voltage pulse generator for immobilization of sheep after Halal slaughter.

## Planning and Services Division

This division, formed only last year, contains two sections: Management Services and Engineering Services (Mechanical).

Management Services has the general task of identifying and evaluating ways of improving the profitability of the meat industry. This section will be involved in market research, technological and economic forecasting, investment appraisal and cost analysis, operations research and systems analysis and methods engineering. At present, this section is carrying out the second stage of an interplant survey comparing costs and productivity.

The mechanical engineering section provides workshop facilities and light engineering and toolmaking to meet the needs of our R&D projects. Some recent projects include construction of ink-branding stamps for use on frozen meat, equipment for weighing loaded containers on railroad cars, devices for calibrating load cells and components for the mechanical dressing project and for the MLTR.

## Equipment Development and Licensing

Because of the relatively small scale of commercial engineering enterprise in New Zealand, the Institute has committed itself to overseeing much of the transfer of new technology into industry. MIRINZ usually follows a project from inception, to pilot-scale trials in our laboratories or in a slaughterhouse, to full-scale experimental installations in slaughterhouses. When appropriate, patents are applied for and commercial companies are formally licensed to manufacture and market the equipment. Although we have let exclusive licenses, we normally use non-exclusive licensing, to induce a spirit of commercial competitiveness.

## Confidential Surveys

MIRINZ is frequently asked by an individual slaughterhouse or parent company to investigate some aspect of its operations. These investigations can encompass a variety of topics, such as whether a plant's Accelerated Conditioning procedure meets specifications, analysis of energy usage in a slaughterhouse, evaluation of effluent treatment procedures, investigation into causes of carcass desiccation or sensory evaluation of meat exposed to smoke for insurance purposes. Results of the investigations are confidential to the client involved.

## Information Transfer

The Institute has an Information Section, which is responsible for disseminating technical and advisory information to the meat industry. This section guides the production of several types of publications, each geared to a specific audience. In addition, the section organizes conferences and seminars and is also involved with public and media relations.