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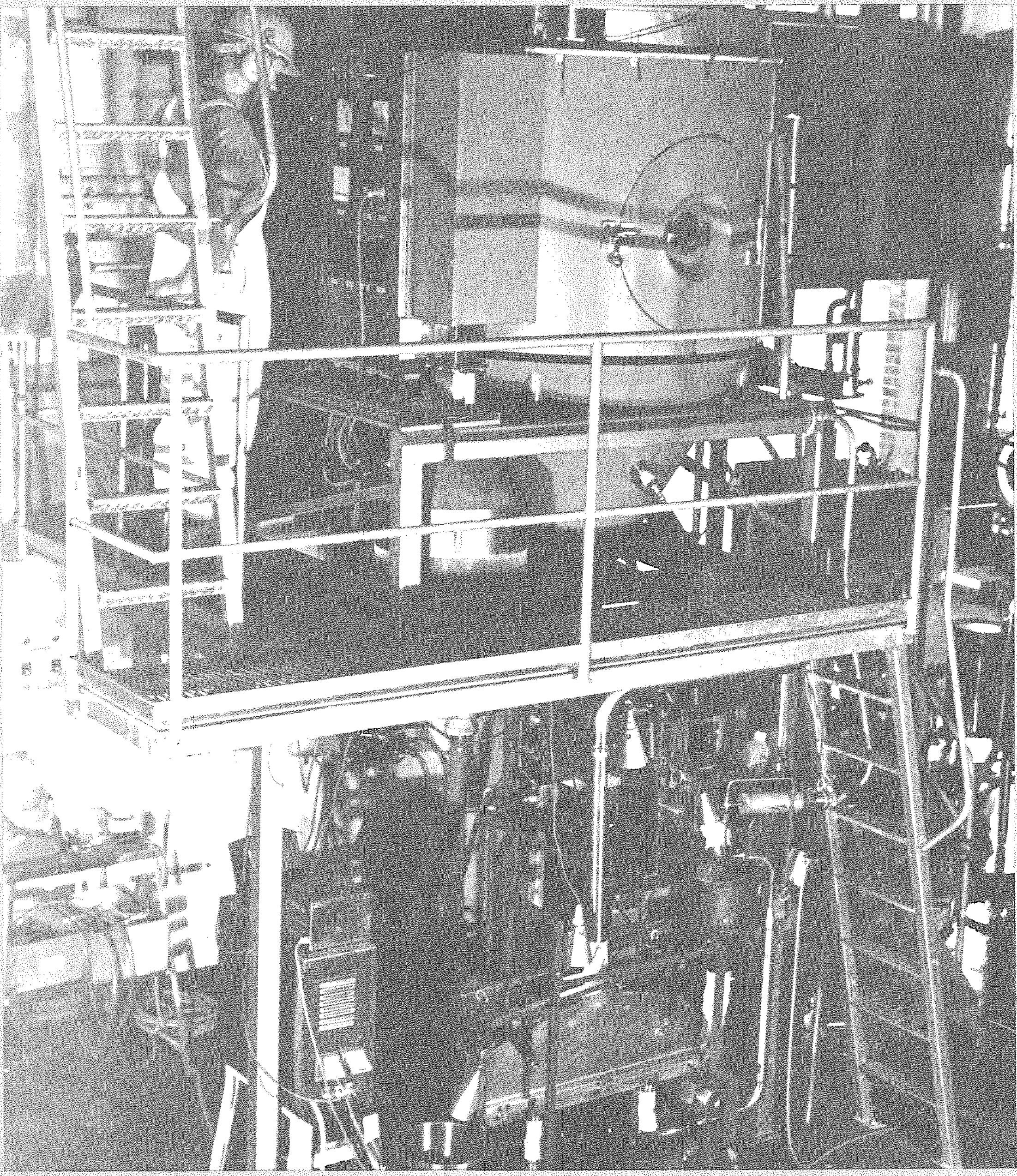

Recombined dairy products

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Milk and milk products have been supplied over a long period to many developing areas of the world in dried, frozen or sterilized forms in cans or cartons. Apart from the cost involved, delays in distribution and high ambient temperatures have an adverse effect on the quality and nutritional value of the products. These deficiencies have been largely eliminated by the introduction of recombining, a relatively new technology which has developed over the last 15-20 years. It is used, on site, for the preparation of a wide range of dairy products and in particular for products with a limited shelf life, eg. market milk and fermented milks which were previously not available. The process is used extensively in developing areas which have only a limited indigenous dairy industry, however it also finds application in dairying countries to meet seasonal shortfalls in the milk supply or in isolated areas. In Australia, the process is used for the production of milk for Darwin and for a number of isolated mining sites.

In a review of the recombining industry Gunnis (1982)* estimated that there are some 200-250 recombining plants in operation throughout the world using up to one million tons of non-fat-milk solids per annum.

In some applications, reconstitution of full cream milk powder is used. However, this approach has been restricted due to the development of oxidized flavours in the powder during storage.

The International Dairy Federation's definitions for recombined and reconstituted products are as follows: 'A recombined product is the milk product resulting from the combining of milk fat and milk solids-non-fat in one or more of their various forms with or without water. This combination must be made so as to re-establish the product's specified fat to solids-non-fat ratio and solids to water ratio', whereas 'A reconstituted product is the milk product resulting from the addition of water to the dried or condensed form of product in the amount necessary to re-establish the specified water/solids ratio'.

While the process has extended the available markets for anhydrous milk fat and non-fat-milk powders, opportunities have been established in developing areas where it offers an outlet for labour, provides a stimulus for the local sugar, edible oils and tinplate industries and has created demand in associated aspects such as printing and packaging. In several countries it has encouraged the development of an indigenous dairy industry, the milk being processed for the liquid milk trade with any surplus being incorporated in recombined products. In some instances the growth in liquid milk has been substantial and it would appear that the long term goal to completely replace the recombining industry could be achieved.

It has been estimated (Mahathanaphanij 1982)* that apart from these financial and social advantages up to 65% of the foreign exchange used to import prepared dairy products can be saved by local recombining. The impact has been such that in a number of cases it has resulted in a complete transfer of processing facilities to developing areas by well-established international manufacturers.

The recombining process has attracted world-wide interest and a number of publications have been prepared. The subject was extensively reviewed at an International Dairy Federation Seminar on Recombined Milk and Milk Products in Singapore in 1980. The IDF Document No. 142 (1982) covering the proceedings is recommended for further detail.

*Seminar held in 1980, but proceedings not published until 1982.

Raw materials

The successful production of recombined dairy products is dependent on the continuous availability of a range of raw materials with the requisite chemical, physical, bacteriological, organoleptic and functional characteristics. Due to the marked seasonal changes which occur in the composition of milk, variations can be expected in some of these aspects, in particular functional properties. It is therefore essential that strict specifications be established for all raw materials and that analytical results be available for assessment before acceptance. All specifications should be reviewed on a regular basis and adjusted as required.

Milk powders

Appropriately prepared milk powders provide the basis for most recombined dairy products; apart from their nutritional value they are, in the main, responsible for the functional properties of the recombined products.

Non-fat-milk powder (skim milk powder). – These powders normally are required to have a moisture content of less than 4.0% and a fat content of 1.25% maximum. Other factors which are included in specifications are, titratable acidity, solubility index, scorched particles, flavour, odour and colour.

The functional properties of the powders are established by the level of preheating applied during manufacture. Because some of the whey proteins in milk are heat labile, it is possible to establish a classification of powders based on the weight (in milligrams per gram of powder) of undenatured whey protein nitrogen remaining after a particular heat treatment. Such a system has been established by the American Dry Milk Institute (1971) in which the level of undenatured whey protein nitrogen is expressed as an index (WPNI) to give three classes of powder based on heat treatment. Standards are:

Powder class	WPNI (mg/g of powder)
High heat	Not more than 1.5
Medium heat	1.51-5.99
Low heat	Not less than 6.0.

This classification has been used extensively for the selection of milk powders; however, due to the fact that the whey protein content of milk varies throughout the season, from area to area and in its reaction to heat, the index is of limited usefulness for selecting powders with specific functional properties. Nevertheless, the WPNI is a useful guide as to uniformity of heat treatment on a day to day basis. Currently, a casein number (heat number) system of classification is under consideration by the International Dairy Federation. The casein number or heat number is defined as the amount of protein nitrogen precipitated at pH 4.8 expressed as a percentage of the total nitrogen. As the whey proteins complex with the casein during heating the casein number increases with increasing preheat treatment.

A heat classification scheme has been prepared as follows:

Heat Class	Casein No. (%)
Extra low heat	78.5 or less
Low heat	78.6 to 80.0
Medium heat	80.1 to 83.0
Medium high heat	83.1 to 88.0
High heat	88.1 or more

Unlike WPNI, the scheme is not dependent on the residual whey protein level and has an increased number of classes which could be of greater value than the WPNI system in the selection of powders where specific functional properties are not involved. If adopted, some confirmation of classes may be required for Australian conditions.

There are many applications in which specific product characteristics can only be established by the use of powder with the

Table 1. Effect of preheating conditions on the WPNI and inherent viscosity of non-fat-milk powders on a monthly basis

Month	Preheating conditions		WPNI	Viscosity
	Temp (°C)	Time (min)	(mg/g)	(poise)
March	77.8	10	6.4	28
April	82.0	5	6.0	37
June	82.2	12	6.9	43
July	78.9	12	5.3	33
September	77.0	5	4.4	41
October	77.8	5	3.6	39
November	77.8	5	4.5	38
December	78.9	5	4.2	34
January	79.5	5	3.1	30
February	80.5	5	2.7	35
June	77.8	5	3.3	43
July	77.2	5	3.5	45
August	76.7	5	3.8	41

required functional capacity. There is also an increasing appreciation of the value of testing for such functional characteristics as heat stability for recombined evaporated milk, inherent viscosity for recombined sweetened condensed milk and rennetability or curd tension for recombined cheese. While it is recognized that, in very general terms, a certain functional property may occur within a heat classification, there is no relationship with WPNI when taken over a season. This is demonstrated in Table 1 in which the preheating conditions for raw milk were adjusted to maintain the viscosity of the resulting powder within the range of 35 to 45 poise.

Buttermilk powder. — This is a by-product of the butter industry; its composition is variable. The fat content may be as high as 10%, the phospholipid content 5-6 times that of non-fat-milk powders and the heat treatment may vary from medium to high-heat. Buttermilk powder has been used in a range of recombined products to assist in emulsification of the fat and to improve the flavour, particularly in liquid milk where it may replace up to 20% of the non-fat-milk powder. It must be sweet cream buttermilk as an acid powder may adversely affect product properties. It requires cool storage as the high fat level and increased phospholipid content make it highly susceptible to oxidation.

Full-cream milk powders. — These powders have not been used extensively mainly because of oxidation problems which are passed on to the reconstituted product. This defect is greatly reduced in high heat powders due to the development of sulphydryl groups which extend the storage stability of this class of powder. With careful preparation the same functional properties can be established as for non-fat-milk powders.

Lactose-hydrolysed powders. — Lactose intolerance can be a problem in some areas where a high proportion of the population may be deficient in the enzyme β-galactosidase which normally hydrolyses lactose to glucose and galactose as the first step in its digestion. This can be overcome by treating the milk with β-galactosidase before preheating and manufacturing powders for use in recombining. Hydrolysis of lactose results in a powder with a sweet taste and a tendency to browning on storage. In the case of recombined high-temperature short-time (UHT) milk the enzyme may be injected into the sterile milk aseptically after packaging; the lactose is converted during storage.

Casein and coprecipitate. — These high protein products have been used on a limited scale in the production of recombined products. Their major role has been to increase the protein content, however, their use invariably results in a marked increase in product viscosity. Studies in this laboratory in which the protein was treated with proteolytic enzymes to reduce viscosity resulted in a marked increase in bitter flavour due to the increased level of peptides in the recombined product.

Powder manufacture

A number of physical attributes which play an important role in the recombining operation and in the overall quality of the final product are established during powder manufacture. These properties include bulk density, solubility, powder particle size distribution and occluded air. They can be varied by such factors as the level of solids and viscosity of the concentrate entering the spray drier and the design of the drier and its operating conditions.

The effects of preheating regimes to achieve specific functional properties depend on the method used, whether by direct steam injection or indirect heating, holding in vats

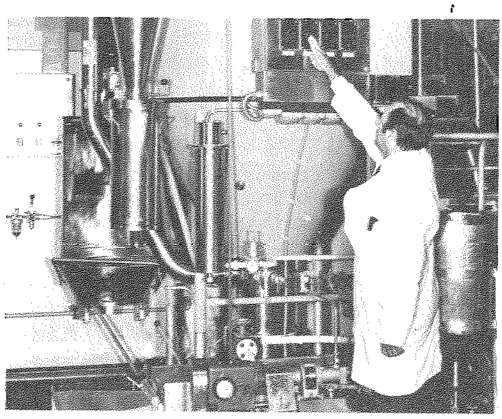

Fig. 1. Spray drying milk powder in preparation for recombining

or holding tubes and the method of adjusting time/temperature combinations. In some instances, the holding time is held constant while the temperature is varied. In other plants the situation is reversed. Whatever method is used the essential feature is that the level of heat treatment must remain constant during processing if powders with acceptable functional properties are to be manufactured. It should also be recognized that certain powders, particularly those types which need to meet specifications for viscosity or heat stability, can only be prepared satisfactorily over restricted periods of the year. Forward programming is necessary to meet market requirements.

The minimum heat treatment applied should be pasteurization (72.2°C/15s) to destroy pathogens. For low heat powders, slightly higher temperatures may be used to improve bacteriological counts. During some seasons the whey protein content of the incoming milk may be such that even with minimum heat treatment the WPNI may fall below that specified for low heat powder. In such cases a loss of less than 10-15% of the whey protein in the original milk may be acceptable. Slightly higher temperatures within the range of 75-82°C with holding times up to 5 minutes are used for medium heat powders. In some cases, higher temperatures without a holding period are used but variable results may be experienced. These time/temperature combinations are varied as required for specific purposes, e.g. adjustment of viscosity levels. High heat powders are subjected to time/temperature treatments of 80-95°C for periods of 20-30 minutes; in the case of direct preheating 120°C for 1-2 minutes is normally used. These treatments may have to be varied quite widely over a season when heat stable powders are being prepared.

Provided non-fat-milk powders are manufactured from good quality milk using sound processing technology and have a moisture content less than 4% they have a storage life of up to 12 months when held at 20-25°C.

Anhydrous milk fat. — All recombined dairy products contain anhydrous milk fat; in cases where it is replaced by vegetable oils the resulting products are designated 'filled'. When prepared from good quality milk or butter to a sound specification and held under nitrogen to reduce the incidence of oxidation the fat stores well at ambient temperatures. In the recombined product it contributes to the flavour. Indeed, it is often blended with vegetable oils to improve the flavour of a filled product. Some milk fats tend to oxidize more readily than others during storage. High levels of moisture and copper, particularly when associated with elevated storage temperatures, result in the development of peroxides and associated off-flavours. An analytical program combined with organoleptic assessment must be established to provide a basis for the selection of milk fat that has an adequate storage life. The use of antioxidants in anhydrous milk fat is prohibited. However, due to the stringent storage conditions to which it is often subjected, a thorough review of this prohibition is warranted.

Vegetable oils. — A range of vegetable oils is used as a replacement for anhydrous milk fat in the preparation of filled products. The quality of some oils may vary. They should be bleached, refined and deodorized with a low peroxide and free fatty acid level. Many oils contain natural antioxidants but they still require the same care during storage as anhydrous milk fat.

Water. — Many waters in their natural form are unsuitable for recombining either because of their colour, flavour or odour, which may directly affect the product, or due to the mineral content which may adversely influence the stability of the milk protein. In such cases water treatment is required. Small changes in pH resulting from unsatisfactory adjustment can also affect protein stability.

Pilot-scale trials in this Laboratory using the same powder with distilled water, local mains water and treated water from a plant in S.E. Asia have shown widely differing protein stability during the preparation of recombined evaporated milk.

The bacteriological quality of water is of particular concern since biological activity during mixing and holding stages can have a significant bearing on product quality. Water should reach the standards laid down by the World Health Organization International Standards for Drinking Water (1971).

Additives. — During the manufacture of non-fat milk powders and anhydrous milk fat a number of natural constituents that may influence the composition or properties of the recombined products are lost or altered. They include the milk fat globule membrane, some vitamins and flavour compounds. These changes may be adjusted by the use of additives that stabilize the milk fat emulsion, replace constituents lost or altered during processing, improve the body and flavour or contribute to the nutritional value of the product. The more important groups include:

- Stabilizers and emulsifiers that help to establish and maintain the milk fat emulsion, or, in the case of butter, assist in the dispersion of the aqueous phase and contribute to the stand-up properties of the product. The group includes carrageenan, lecithin, alginates and glycerol-monostearates either alone or in combinations.
- Salts. Various salts are used to improve dispersion, heat stability, assist coagulation (cheese) and enhance the flavour of products. These include phosphates, citrates, calcium salts and sodium chloride. The phosphates and citrates are in fact, essential to the production of recombined evaporated milk.
- Vitamins. Several of the vitamins of milk are reduced in concentration during the preparation of the raw materials and the processing of the recombined products. The main supplements used are vitamins A, D and B; others may be added in special circumstances. It is essential that they be appropriately dispersed before addition to recombined products.
- Flavours and colours. Such products may be used to enhance the acceptance of recombined products with varying success, e.g. butter flavours. A range of flavours has been added to recombined milks but their reactions to processing and storage require careful assessment.

All additives should be of food grade quality and conform to approved standards.

Recombined products

With few exceptions, a full range of dairy products can be prepared using recombining technology. The composition of the various products is controlled by local legislation, or international standards, and consumer demands. A well-designed quality assurance program is essential to ensure that standards are regularly attained.

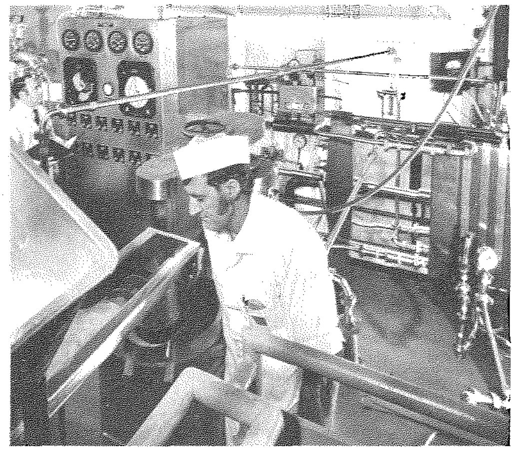

Fig. 2. Pilot plant recombining operation at CSIRO Dairy Research Laboratory — feeding skim milk powder into a Cowles dissolver.

Milk

Pasteurized milk. — This product is prepared using low or medium heat non-fat-milk powder and anhydrous milk fat. The flavour of the product is improved by replacement of up to 20% of the skim milk solids by buttermilk powder and a premium product is prepared by using unsalted butter as the source of fat. For maximum acceptance a product free of heated or oxidized flavour is essential. Composition may vary but is generally of the order of 9% solids-not-fat (SNF) and up to 3.5% fat. General acceptance is favoured by increasing total solids up to 12.5%. A range of stabilizers at a concentration of 0.1-0.5% may be added to improve the fat emulsion stability, while such materials as sodium chloride, sugar and citrates have been added to enhance flavour, with varying success.

The powder is dispersed in water at 50-55°C using a high speed blender or recirculating system. The molten fat is added and the mix subjected to two-stage homogenization at 14.0-17.5 MPa plus 3.5 MPa at 55-60°C. The fat may be metered into the milk just before the homogenizer or prepared as a homogenized 35% cream before addition to the dispersion of non-fat-milk. For large volume operations this reduces the size of the homogenizer required and results in energy savings. A 'cream line' milk which has consumer appeal in some markets can be produced by manipulation of homogenizing conditions. The milk is pasteurized (72.2°C/15s) and cooled to 4°C for packaging. When carefully prepared the product has good flavour but usually can be differentiated from the conventional product. In some areas, high ambient temperatures, limited refrigeration and difficult distribution restrict the use of this product.

Sterilized milk. – This product is used where the distribution of pasteurized milk is difficult. The composition is similar but it is canned and retort sterilized at 120°C/12 min. Because of the extended shelf life, greater attention must be given to homogenization. Stabilizers, in particular carrageenan (0.01-0.015%), are used to avoid fat separation during storage. The milk has a cooked but not unpleasant flavour and is somewhat darker than pasteurized milk. Sedimentation and fat separation can be major problems.

UHT milk. – The high-temperature short-time (UHT) process results in a sterile recombined milk with less processed flavours than retort sterilized milk. The product is made from a medium heat powder with a WPNI of about 4.0. Special attention is required in the selection of milk for the manufacture of powder for UHT milk since some difficulty has been experienced with the development of bitter flavours and coagulation during storage due to the action of proteolytic enzymes that have survived UHT processing. These enzymes arise from the activities of psychrotrophic organisms in milk stored for extended periods before powder manufacture.

Pending further investigation, specifications now require that powder be manufactured from milk collected daily.

The mix is prepared as for recombined milk, homogenization at this stage is sufficient only to disperse the fat before pasteurization and holding at 4°C in readiness for UHT processing. Some manufacturers regard a storage period before UHT processing as essential for protein hydration and product acceptance. In such cases the milk may be prepared as a concentrate to reduce storage requirements, being adjusted to normal composition before processing.

The results of trials, in which milk prepared in both normal and concentrated forms, with and without fat, and stored at

Table 2. Effect of holding the mix (18h at 4°C) with and without fat on the properties of recombined UHT milk

Sample	Trial 1		Trial 2	
	[B]Alcohol (%)	Flavour (0-5)	[B]Alcohol (%)	Flavour (0-5)
[A]Milk	85	3.2	85	3.2
Non-fat concentrate	80	3.1	85	3.0
Concentrate	85	2.9	90	2.7
Non-fat milk	90	3.0	85	3.3
Milk	85	2.3	85	3.3

[A]No holding period
[B]Percentage ethanol required to produce coagulation in the recombined UHT milk.

4°C for 18 hours before adjustment of composition and processing was compared with recombined milk processed immediately after preparation, are shown in Table 2. Results show no major differences in product stability as measured by the percentage of alcohol required to produce coagulation of the milks after processing or in the flavour of the milk processed immediately and milk and milk concentrates held without fat. The flavour difference in samples held for 18 hours at 4°C with fat were due to slight lipolytic action during the storage period. The recombined product is subjected to either direct or indirect UHT treatment at 135-150°C for 3-5 seconds.

Homogenization is of particular importance in both sterilized and UHT products as the emulsion must be stable to avoid fat separation during storage. Pressures used are usually slightly higher than those applied in conventional products, viz. 20-25 MPa on stage one plus 3.0-3.5 MPa on stage two. In UHT processing, homogenization can be applied before or after sterilization, i.e. upstream or downstream. Upstream treatment avoids the problems attendant on maintaining a sterile downstream unit but downstream homogenization has the advantage of reducing the amount of sediment in the final product. In some plants homogenization is split, the high pressure treatment being applied upstream with the low pressure stage downstream. It does appear that downstream homogenization offers an advantage for recombined UHT milk.

A range of additives may be used including vitamins, carrageenan, fat stabilizers, sugar (3%) and sodium chloride (0.04%). Main defects on storage are gelation, fat separation and sedimentation.

Cream

A wide range of recombined creams including dessert cream (20-40% fat), coffee cream (20-25% fat) and whipping cream (30-40% fat) with acceptable physical, functional and flavour characteristics have been prepared. The basic ingredients include non-fat-milk powder, sweet-cream buttermilk powder, anhydrous milk fat, unsalted butter and appropriate emulsifiers, stabilizers or whipping agents. Manufacturing techniques vary depending on properties required. Homogenization conditions must be carefully selected to establish a stable fat emulsion and stable whipping characteristics. Zadow and Kieseker (1975) prepared a recombined whipping cream with 35% anhydrous milk fat, medium heat powder and glycerol-monostearate. The product was relatively insensitive to the two-stage homogenization conditions used, had satisfactory whipping properties and could be processed using pasteurization, in-can or UHT sterilization.

Sweetened condensed milk

Sweetened condensed milk is one of the major recombined products manufactured in developing countries. It has the advantage that, provided it is protected from external contamination and is not diluted, it will keep without refrigeration for several days after opening. The major factor determining its keeping quality is the sugar/water ratio which should fall between 62.5% and 64.5%. A low ratio can lead to bacterial spoilage while a high figure may result in crystallization of the sucrose.

The type of milk powder used in the preparation of this product is of particular importance; it should have the capacity to impart to the milk an acceptable initial viscosity and at the same time not induce excessive age-thickening during storage. These characteristics are established during the preheating stage of powder manufacture. Initially, powder selection was based on the WPNI. This approach was not satisfactory. However, an assessment based on a determination of the inherent viscosity of the powder has been found to be reliable and has been widely adopted as a basis for selection of non-fat-milk powder for this product.

The use of powders with unsuitable viscosity characteristics may result in coagulation during recombining operations, a product too low or too high in initial viscosity and, in the latter case, an unacceptable rate of age-thickening with the early onset of gelation.

In the system most commonly used the initial mix is prepared at high concentration (approximately 72%) to obtain the highest level of economy. This requires the powder to be dispersed at a high SNF/water ratio (46%). It is therefore essential that powders have good dispersibility characteristics. Powders with high levels of occluded air or an unsatisfactory particle size distribution generally give mixing problems. In practice it has been established that there is considerable advantage in blending batches of powder. It provides for greater product uniformity and, in particular, allows control of initial viscosity and age thickening properties. The powder is dispersed in the water at 55 °C, sugar is added and heating of the mix is commenced to compensate for temperature loss. The molten fat is introduced and the mix is filtered, homogenized at 2.1-2.8 MPa and pasteurized at 88-90 °C for 30 s. Homogenization pressures can be varied as required to adjust the initial viscosity. The product is subjected to vacuum cooling and at 30 °C is seeded with finely ground lactose at the rate of 0.05-0.1% to induce crystallization. In some plants wet seeding is used, however, trials in this Laboratory (Table 3) have demonstrated improved lactose crystallization with dry seeding, as judged by the proportion of smaller crystals.

The product must be packed under 'commercially sterile' conditions to avoid contamination from yeasts and moulds and the cans should be filled to give a minimum of 'head space' so as to inhibit the growth of any mould spores which may gain access. The main problem with recombined

Table 3. Effect of method of seeding on lactose crystal size in recombined sweetened condensed milk

	% seed	% Distribution of crystal sizes				
Method	lactose	$<4\mu m$	$5\text{-}8\mu m$	$9\text{-}12\mu m$	$13\text{-}16\mu m$	$>16\mu m$
Wet	0.05	26	51	16	5	2
Dry	0.05	47	38	9	4	2
Wet	0.10	25	34	30	7	4
Dry	0.10	37	38	16	4	4

sweetened condensed milk is the rate and extent of viscosity development or age thickening during storage. While other defects occur from time to time such as sandiness, sediment, and mould contamination, they are generally within the control of the processor.

Evaporated milk

In contrast to sweetened condensed milk, recombined evaporated milk is a sterile product of good keeping quality which is subject to deterioration once opened. It is widely manufactured and is, in many instances, prepared as a filled product using indigenous vegetable oils.

Main standards are:

	Filled	UK Standard	US Standard
Fat (%)	6.0	9.0	7.9
Milk solids-not-fat (%)	20.0	22.0	18.0
Total solids (%)	26.0	31.0	25.9

The successful production of this product is dependent on the manufacture of powders with satisfactory heat stability characteristics.

Heat stability may be defined as the time taken for milk or milk concentrates to thicken or coagulate when heated under standard conditions. The longer the time the greater the stability. For milk, the temperature is normally 140°C and for 20% concentrates, 120°C.

While considerable research has been directed to this scientific and commercially important property of milk there is at this stage, no satisfactory understanding of the fundamental basis of the problem. In addition to such cow-associated factors as stage of lactation, plane of nutrition and weather conditions, there is a marked seasonal effect on the heat stability of milk, which extends through to the powder. Under Australian conditions, heat-stable powders are generally produced from October to late February. However, this period may be extended or curtailed by prevailing weather conditions.

Apart from the inherent variability of the milk itself, the main factor influencing the heat stability of milk powders is the level of heat treatment applied during the preheating stage. The most obvious change resulting from this heat treatment is the complexing of whey proteins with the κ-casein and an associated reduction in the WPNI. While all heat stable powders are of the high heat type this heat treatment does not necessarily confer heat stability. Because of the lack of understanding of the principles involved, preheating is carried out on an arbitrary basis, changes in preheating conditions being based on the results of heat stability determinations on the powders. Preheat treatments range from 80-90°C for 20-30 minutes; in some instances direct heating of 120°C for 1-2 minutes may provide better heat stability during some periods of the year.

The pH of the milk also exerts an important influence on heat stability. It has been found that the point of maximum heat stability does not always coincide with the natural pH of the milk. Attempts to improve heat stability by adjustment of the pH using hydrochloric acid or caustic soda have not given consistent results as the heat stability of the concentrate bears little relationship to that of the original milk. Appropriate analytical methods have been established to determine the heat stability characteristics of powders and at the same time test their reactions to added phosphates. For the manufacture of 26% total solids evaporated milk, specifications normally require a minimum heat stability of 21 minutes for the control sample or for samples to which commercially acceptable levels of mono or disodium phosphate have been added to improve the heat stability of the recombined product during sterilization. For more concentrated products, e.g. 31% total solids, a higher level of heat stability is required.

In manufacture, the blended powders are dispersed in water at 50-55°C along with any additives. The fat is then added. The product should be filtered and, possibly, de-aerated since incorporated air may influence homogenization efficiency. Homogenization is carried out at 50-60°C using pressures of 14.0-17.5 MPa on stage one followed by 3.5 MPa on the second stage. While efficient dispersion of the fat is essential, unduly high temperatures and pressures can have an adverse effect on protein stability. The product is cooled to 4°C. After trials to establish stabilizer requirements, all the milk is stabilized using either mono or disodium phosphate, double phosphates, citrate or in a few instances, calcium. It is unfortunate that the complex reactions involving pH change, salt equilibrium and protein stability are not, as yet, fully understood. The product is canned and sterilized at 120°C/12 min or equivalent. Fat separation can be a major problem in recombined evaporated milk due, in part, to the loss of the fat globule membrane material during the preparation of the anhydrous milk fat. The problem is compounded by the tendency of the product to fall in viscosity during storage (age thinning). The use of carrageenan (0.01-0.15%) has reduced the incidence of the defect.

High-solids (31%) recombined evaporated milk. — The manufacture of conventional high solids evaporated milk is often restricted to certain periods of the year to avoid coagulation problems during sterilization or storage. Similar difficulties are experienced in the preparation of the recombined product. Kieseker (1970) demonstrated that by using powder with high heat stability characteristics and protecting the protein from the destabilizing influence of homogenization, a satisfactory product could be prepared. Only 10% of the powder was dispersed in the water and submitted to homogenization with the fat, the remaining powder being added after homogenization. Pilot-scale studies have shown that this technique reduced the level of protein complexed with the fat from a ratio of 0.17 for the normal method to 0.05. This method has been adopted commercially for the preparation of the high-solids product.

UHT-sterilized recombined evaporated milk. — With the increasing costs of tinplate, UHT processing of recombined evaporated milk offers economic and technological advantages. The main problem with UHT-sterilized concentrated milks has been the early gelation of the product. A reduction in the level of total solids from 26% to 18% has resulted in an extended but limited storage life. High-temperature preheating of the product before sterilization has also been useful but has an adverse effect on flavour and colour. Because of the obvious advantages, considerable research is currently being devoted to the UHT processing of this product.

Fermented products

A range of fermented products has been made both locally and overseas using recombining technology. Recombining offers a number of advantages. Where the selection and storage of the basic powder and anhydrous milk fat is sound it ensures uniform quality from day to day, avoids the problems of inhibitory milk and seasonal effects and allows considerable flexibility in product composition. Powders are normally of the low or medium heat type and tested to be free of antibiotic or inhibitory residues. High heat powders can be used but they do not always produce the required body and texture in the final product. For yoghurt, the milk is prepared in the conventional manner using two-stage homogenization (12.6 + 3.5 MPa). Techniques vary but the milk is subjected to high heat treatment of 80-90°C for up to 30 minutes — this treatment is adjusted as required to give the required consistency to the product. Overheating must be avoided. The inclusion of up to 1% whey protein in the mix has been suggested to improve the gel strength. The milk is cooled and inoculated with the appropriate culture and treated in the conventional manner.

Cheese

The varieties of cheese manufactured using recombining technology include Cheddar, Gouda, Edam, Camembert, Mozzarella, Cottage and many others. In some plants, suitable non-fat-milk powders are used to advantage to adjust the solids-not-fat to fat ratio of cheese milk during certain periods of the year. Powders used for recombination are of the low heat type with a WPNI greater than 6.0. Such powders however do not necessarily produce a suitable milk with the required characteristics such as coagulation time, curd tension and water-holding capacity. Some of these characteristics, particularly those relating to rennetability, are now being included in powder specifications for cheese manufacture. Low heat powders have a high level of ionic calcium which contributes to satisfactory coagulation, high heat powders on the other hand do not necessarily give a satisfactory response to the addition of calcium. It has been suggested that ionic calcium levels could be determined to select powders with good renneting characteristics. Calcium has also been added to the milk before drying, however, addition at too high a level may result in difficulties with moisture retention in the cheese. Calcium is usually added at the rate of 20 g calcium chloride per 100 litres of milk just before renneting.

Phosphate, which in combination with calcium may contribute to curd syneresis, can be added as phosphoric acid or sodium phosphate if required. The pH of the milk also contributes to successful coagulation. Considerable variation is reported in the preparation of the milk. It has been suggested that the reconstituted non-fat-milk should be held for a period to allow hydration of the protein, however recent information suggests that this may not be necessary. The powder is dispersed in the water at 50°C and recombined with the fat using single-stage homogenization pressures varying from 3.5 MPa to 7.7 MPa or two-stage treatment using 14 MPa plus 3.5 MPa on the second stage. In order to minimize protein damage the fat is often prepared as a 30-35% cream using all the fat and a portion of the powder. The cream is homogenized separately and dispersed in the reconstituted milk. This milk is pasteurized (72°C/15 s) and calcium and any other supplements are added. Normal starters such as *Streptococcus lactis* and/or *S. cremoris* are used, however, *S. thermophilus* and various Lactobacilli are included to facilitate ripening. The level of rennet may also be increased to aid ripening and higher cooking temperatures used to assist with moisture expulsion.

In general, recombined Cheddar cheese does not develop the same body and texture as the conventional product and lacks typical Cheddar flavour. It can be blended with Cheddar cheese to give a good quality processed product. Good quality Cottage cheese can be made using low heat powder; powder of increased heat treatment tends to increase the moisture content. Variable results have been reported with other varieties of cheese made from recombined milk. These range from satisfactory to lacking in flavour, flavour defects from powder or anhydrous milk fat, and body or texture problems.

Butter

Recombined butter has the advantage over its conventional counterpart in that the basic ingredients can be stored at ambient temperatures and manufacture may be regulated to demand, thereby keeping storage problems to a minimum. Particular attention should be given to the manufacture, packing and storage of the anhydrous milk fat. A regular quality assurance program is required to select fat with low peroxide values and suitable organoleptic properties. Although little work has been done on this aspect, selection of butter fat of higher melting point could be advantageous in tropical areas. Skim-milk powders are the source of solids-not-fat; butter milk powder and full-cream milk powder have been used to improve the flavour but they are subject to oxidation problems. A number of emulsifiers can be added to assist in the dispersion of the water throughout the fat phase. The addition of lecithin reduces the level of 'spitting' during heating and such materials as monoglycerides can provide better 'stand up' properties to the product during storage and distribution. The composition of the product is generally: butter fat — 80% minimum, moisture — 16% maximum, milk solids-not-fat — 1.0-1.5%, salt — 1.5%, emulsifiers — 1.0%. In some countries canned butter may contain up to 6% salt and up to 3% SNF which may assist in avoiding fat and serum separation. In such cases the fat content is adjusted accordingly.

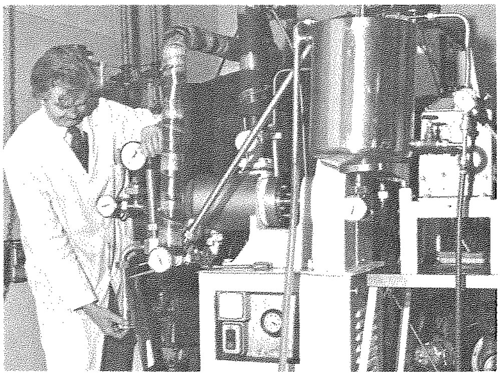

Fig. 3. Making recombined butter — pilot scale.

For manufacture, the milk powder is completely dispersed in the water before the addition of salt, the blend then being filtered and pasteurized. The anhydrous milk fat is melted and any emulsifiers added. The fat should be completely liquid to avoid premature crystallization but the temperature should not be too high because of the increased cooling load on the refrigeration system. The fat and aqueous phases are blended and must be efficiently agitated before chilling to ensure uniformity of the product. The blend is cooled in a swept-surface heat exchanger to 10 °C or below, good heat transfer is achieved by applying a back pressure on the product. Further blending occurs in a 'working' section where crystallization of the fat is completed. The texture of the butter for packing into cans or parchment is determined by the level of working applied. Recombined butter has a slightly different flavour to conventional butter and does not have equivalent keeping quality. However, it does fulfill a need in many areas.

Dried products

Full-cream milk powder. — Unless packed under gas in metal containers full-cream milk powder may oxidize before marketing because of high ambient temperatures and transport problems. In such cases it is prepared locally as a recombined product. Composition is generally: fat 26% minimum, moisture 2.5-3.0% maximum.

The non-fat-milk powder is of the medium heat type; high heat powders produce a concentrate with too high a viscosity for efficient atomization. The solids level in the concentrate for spray drying should be as high as practical not only for economic reasons but also to produce a powder with best physical characteristics. For driers with nozzle atomization, 42-44% is usual and 48-50% for rotary atomization. For a concentrate of 48-50% total solids, a SNF to water ratio of approximately 41% is required before the addition of fat. This requires the powder to have a good solubility index and satisfactory dispersibility characteristics.

The mix is preheated and de-aerated. This latter operation is essential as incorporated air has an adverse effect on homogenization and pasteurization and will result in powder with a high level of occluded air, poor dispersibility and low bulk density. Following filtration, the mix is homogenized at 7-14 MPa followed by 0.7-3.5 MPa on the second stage. High homogenization pressures may result in marked increases in the viscosity of the concentrate. The product is dried in the normal manner and may be agglomerated and instantized. This product has good keeping quality and satisfactory flavour. Some work is still required to optimize aspects of manufacture and to improve acceptability.

Dried whipping cream. — Recombined creams with satisfactory whipping characteristics can be produced in the dry or powdered form (Kieseker *et al.* 1979). The product is made by recombining medium heat powder and anhydrous milk fat (SNF: fat ratio 0.49:1), xanthan gum, glycerol monstearate and sugar and vanilla if required. After mixing, the blend is homogenized at 1.4 MPa plus 0.7 MPa on the second stage and pasteurized at 72 °C for 60 s and spray dried. As the dried product contains up to 50-70% fat, depending on formulation, all of which is in the liquid form immediately after drying, the use of pressure or shearing forces must be avoided in removing the dried cream from the dryer. Rapid cooling over a fluidized bed can be helpful.

The cream is whipped using cold water or milk at 3-4 °C in such proportions to give a 35% fat cream. The thermal history of the powder is important for whipping properties. When the powder is stored at low temperatures the cream may not whip and the overrun is invariably poor. If the product is held at 20 °C for 24 hours the whipping properties are restored. This has been shown to be related to the ratio of liquid to solid fat in the powder. Cream powder held at 25-30 °C when whipped gave good overrun and a firm body. The use of low melting point fat fractions in the powder resulted in an increased overrun at lower storage temperatures; the reverse effect was noted when high melting point fractions were used. The product stores well; there is a slight decrease in whip rating and overrun with time. The inclusion of 0.1% butylhydroxy anisole in the formulation slowed the rate of peroxide development during early storage.

Filled products

Filled products, that is, recombined products in which the anhydrous milk fat is replaced by vegetable oils are used in developing areas mainly for economic reasons or as an outlet for indigenous oils. Main oils used are coconut, palm, soy, peanut and, to a limited extent, maize oil which is added to coconut oil to improve the nutritional value by increasing the linoleic acid content of the blend. The oils should be refined and deodorized and reach international standards. They are used in a similar manner to anhydrous milk fat. With evaporated milk, claims have been made that fewer problems are experienced with filled products than with the recombined equivalent. Trials carried out in this Laboratory reveal little difference in the physical and chemical attributes of the two products made to the same formulations

Table 4. Comparison of filled and recombined evaporated milks

Composition	20% SNF, 6% fat		18% SNF, 8% fat	
Fat	AMF	coconut oil	AMF	coconut oil
Init. viscosity (cp)	15.5	15.5	14.0	17.0
Storage — 6 weeks at 25°C				
Viscosity (cp)	13.4	13.4	12.2	11.6
Fat separation (0-5)	1.5	1.0	1.0	1.0
Solubility index (ml)	0.2	0.2	0.2	0.3
pH	6.35	6.35	6.3	6.3

Depending on the oils used, the filled product often tends to have an oily flavour. Blends of anhydrous milk fat with various oils have been used to advantage.

The continual use of some filled products, particularly for the feeding of infants has been challenged on nutritional grounds.

Reconstituted products

An important consideration influencing the use of recombining was the flavour stability of the non-fat-milk powder and anhydrous milk fat during storage at ambient temperatures. In recent years there have been many advances in the production of full-cream milk powders resulting in improved storage stability. Additionally, there has been a better understanding of the establishment of functional properties so that the technology required to prepare reconstituted products is now becoming available. The main advantage of reconstitution is that a single product, a full cream milk powder with the required SNF to fat ratio and functional characteristics has to be manufactured and handled. In some reconstituted products it has not been possible to fully re-establish the milk fat emulsion without the application of homogenization at the reconstitution stage. The system also loses much of the flexibility of recombination in that changes in types and levels of proteins and fats are not always possible. Prolonged storage of full-cream powders, particularly low and medium heat types invariably results in the development of off-flavours which are transferred to the reconstituted product. High heat powders exhibit a much higher level of storage stability.

Nutritional and flavour aspects of recombined products

Only limited studies have been reported on these aspects. It has been shown that, even though the various heat treatments result in some reduction in vitamins, particularly vitamin C, these are not of major concern (Thompson 1969). While some losses occur during evaporation and drying there is little reduction in protein quality even during severe heat treatments (Bender 1971). Perhaps the most likely loss in protein quality is due to involvement of the essential amino-acid lysine in the Maillard (browning) reaction, the extent of which is influenced by the raw milk processing, product composition and storage conditions. On the other hand, many recombined products are fortified with vitamins and/or minerals during recombining operations. Where substitutions are involved, such as the replacement of anhydrous milk fat by coconut oil, the nutritional implications should be fully appreciated.

With flavour there are two distinct areas involved. The first relates to the difference in flavour between the freshly made recombined product and the conventional counterpart, e.g. liquid milk. This is perhaps not unexpected due to the associated heating and removal of volatiles during powder manufacture and the removal of the fat globule membrane material in the preparation of anhydrous milk fat. It has been established that milk fat, depending on treatment during manufacture can make a significant contribution to milk flavour. Untreated milk fat or partially deodorized fat is superior to other fats and oils in this regard. It appears that the non-volatile as well as the volatile compounds contribute to the desirable flavour. The use of unsalted butter for the preparation of recombined liquid milk has resulted in greater consumer acceptance of the product. Trials in this Laboratory in which cream replaced anhydrous milk fat in recombined sweetened condensed milk resulted in improved flavour acceptance both initially and after storage. In some products, for example evaporated milk, the effect of added phosphates and, in particular, the high sterilization temperatures involved may well override any inherent differences.

The second area relates to the development of flavours during storage of ingredients. Oxidation flavours in milk fat and stale flavours in milk powders resulting from extended storage, particularly when associated with elevated temperatures, are transferred to the recombined products and can influence consumer acceptance.

Fig. 4. Anhydrous milk fat from Australia is combined with skim milk powder in this plant in Indonesia to make a range of concentrated milk and pasteurized liquid milks.

Future trends

Interest in recombining technology remains at a high level. It is currently being introduced on a large scale in a number of developing countries; in some projects the manufacture of a complete range of products from market milk to cheese is planned. Concurrent with some of these programs is the development of an indigenous dairy industry which may, in the longer term, replace recombining operations totally or in part. Such schemes are not always feasible, being limited in some countries by the availability of land or general production problems.

In a number of areas the recombining process is being adapted to the preparation of a wider range of foods incorporating dairy and non-dairy ingredients. This trend is increasing and is being supported by research and development from within the recombining plants or through local institutions.

Changing patterns in milk production in some established dairying areas may well lead to the introduction of recombining technology to meet seasonal deficiencies in 'non-storable' products such as market milk, cream, fermented products and some cheese varieties. Close attention to detail will be required in the selection and storage of ingredients and the preparation of these products, as acceptance by a more discerning market will be influenced to a large extent by their physical and, in particular, flavour characteristics. With the overall improvement in the quality of milk powders and the utilization of alternative and more acceptable forms of fat such as unsalted butter or frozen cream, recombined products which compare favourably with conventional products can be marketed successfully.

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Countercurrent extraction of soluble solids from foods*

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Countercurrent extraction (CCE), or diffusion extraction as it is sometimes called, was conceived in the sugar industry for extraction of sugar from sugar beets. The process requires that the semi-permeable nature of the cell wall is eliminated by the action of heat or other means so that soluble materials within the cell can diffuse out under the influence of a concentration gradient. The original diffusers consisting of a series of tanks or cells known as the 'Robert battery', have now been replaced by continuous diffusers.

The use of continuous diffusion in the fruit juice industry was first described by Warcollier (1920) for the production of apple juice. It was not until the 1960s however, that serious interest was awakened in the use of this technique for fruit juice extraction (Ott 1965). In 1969 Brüniche-Olsen, the father of the De danske Sukkerfabrikker (DdS) system for extracting sugar from sugar beet, described a method for the extraction of fruit juices by a technique using a stepless countercurrent diffusion extraction in an inclined screw. The application of the DdS system to the production of apple juice was carried out at the Swiss Federal Institute of Technology, Zurich. Commercial application followed in an apple juice factory in South Africa (Lüthi and Glunk 1975; Dousse and Lüthi 1976).

Kjaergaard (1971) describes similar developmental work for the countercurrent extraction under pressure of solubles from ground roasted coffee.

In an optimization study of the CCE of apple juice, Østerberg and Sørensen (1981) measured concentration profiles along the screw in the free liquid and in the juice cells of the apple slices at various extraction temperatures and countercurrent flow rates. They found that the data could be described by a theoretical model taking into account the time of the plasmolysis as a function of temperature.

Equipment

DdS diffuser

This unit consists of two partially intermeshed inclined screw conveyors fitting closely into a W-shaped trough which is jacketed for temperature control. The screw flights are usually slotted but may be perforated. Material to be extracted is fed to the lower end of the inclined screw conveyor and is moved up the incline by the conveying action of the screws to be discharged either by means of a scoop-wheel or screw elevator at the upper end of the conveyor. The two screws rotate in opposite directions and tend to pile the material being extracted at the centre of the trough.

Fresh water for the extraction is added at the top of the conveyor and weak juice pressed from the discharged solids is added back further down the screw at an appropriate concentration point. The fresh extraction water and the press water flows downwards by gravity, countercurrent to the solids.

The level of the juice is controlled at the lower end of the trough and the level along the screw is determined by the resistance to flow of the liquid through the bed of particulate solids and the angle of the screw.

Niro Extractor

Kjaergaard (1971) described a continuous inclined twin screw extractor which was

*Based on a paper presented at a Joint New Zealand Institute of Food Science and Technology/International Union of Food Science and Technology Symposium on Product and Process Development in the Food Industry, Auckland, November 1980.

developed by Niro Atomiser, Copenhagen, for the extraction of coffee solubles from ground roasted coffee beans or tea leaves. This extraction process replaced the method using a battery of percolators traditionally used to obtain coffee solubles for spray drying.

A two-stage extraction was suggested in order to obtain optimum quality; a first stage at atmospheric pressure extracted the water soluble material and a second stage operated under pressure (temperatures up to 190 °C) to hydrolyse a number of naturally occurring polysaccharides. The second stage increased the yield of water soluble material which may be obtained from the roasted ground coffee. The inclusion of these water soluble hydrolysis compounds increased the yield from 24–30% up to 45–65%.

In this pressurized extractor the roasted ground coffee is fed through a pressurized entry chamber at the lower end of the trough and conveyed by the twin intermeshing screws, which rotate continuously in opposite directions, up the incline against the downward gravitational flow of the extracting water which is added at the top of the screw. The spent grounds discharged at the upper end of the screw are blown out of the pressure vessel at intervals, while the extract passes through a self-cleaning strainer at the lower end before it is discharged through an overflow pipe which controls the liquid level in the extractor.

Approximation to countercurrent plug flow means high capacity with high efficiency and results in a better quality extract.

CSIRO-Howden countercurrent extractor

In single screw extractors which rotate continuously in the one direction, contact between liquid and solid is not efficient as the solids tend to ride up one side of the conveyor trough while the liquid flows relatively unimpeded down the other. Also, compaction pressure due to the screw rotation is continuous and uniform and inhibits efficient contacting between liquid and solids.

However, the CSIRO unit overcomes these problems in a single screw extractor as the screw rotation is intermittently reversed. The compacted solids being conveyed high along one side of the trough move down through the extraction liquid in the bottom of the trough and up the other side where they are again subjected to compaction until the rotation is again reversed. The screw is operated with more forward than backward motion. The solids are thereby given an overall movement in the forward direction as well as a see-sawing motion across the screw. In addition, the solid mass is alternately compacted and opened up. This intermittent reversing of the screwing direction results in efficient contacting in a unit which is simple and cheap to fabricate and is the subject of Australian Patent Application No. PE 2383/80. Patent protection is being applied for in a number of other countries.

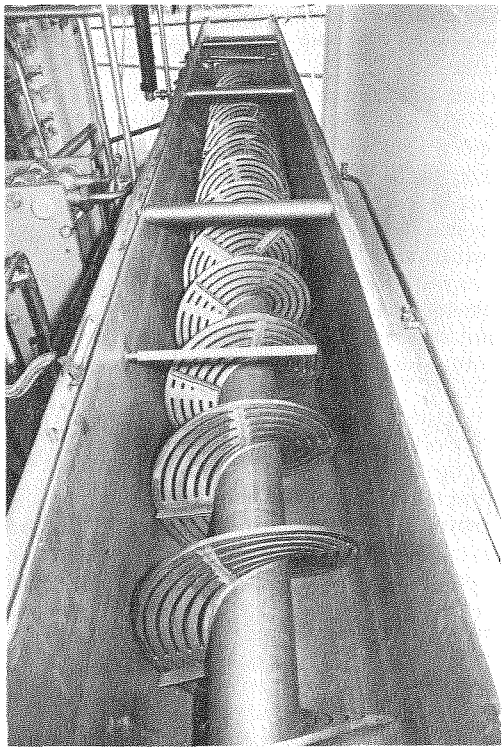

Fig 1. Pilot-scale counter current extractor with intermittent reversing of 500 mm diameter screw.

Trials with a small single-screw pilot unit fed with sliced apples showed that intermittent reversing of the screw increased the rate of discharge of juice as a result of opening up the apple mass and increased the soluble solids content of the juice because of more effective contact between the liquid and solid fractions.

Operating temperature

Countercurrent extraction is usually a hot extraction procedure; for instance for fruit juices a typical temperature for the extracting water is 60 °C. Easy removal of soluble material from within fruit cells requires that the cells lose their organized structure and the cell walls become permeable to soluble materials in the cell contents, i.e. the cells must be killed. It should be noted that this aim is different from pressing and centrifugal separation procedures where the objective is to rupture the cells physically. Because of the filtering action of the cell walls, countercurrent extracted juices tend to contain less suspended solids than pressed juices.

For practical purposes the disorganization of the cell is most readily achieved by heat, and the hot extraction also has the added advantages that microbial growth is controlled, the diffusion rate is increased, and the solubility of oxygen is decreased. Consequently, it is not necessary to use sulphur dioxide as an antioxidant or yeast growth inhibitor when extracting apple or grape juice by this process. Because of the elevated temperature, microbial build-up does not occur and the unit can be run for long periods without the need for down-time for cleaning.

Applications of countercurrent extraction

Grapes

The initial application studied by the CSIRO team was the extraction of juice from grapes. A grant was received from the Rural Credits Development Fund for a project to examine the application of the process to grapes, particularly red varieties which were in gross oversupply, for the production of grape juice to be marketed mainly as a chilled juice.

To obtain more detailed information regarding the desirable operating parameters and to demonstrate the technique to the industry, the pilot unit, complete with electrically heated hot water system, was mounted in a truck and the unit was operated at two wineries and two canning plants during the 1979 season.

The extractor was able to handle all the available varieties of grapes: Shiraz, Grenache, Gordo, Semillon and Sultana. No problems were encountered with the slippery-skinned Gordo variety, which is difficult to press.

The unit satisfactorily handled both hand-picked grapes fed to the unit as bunches complete with stems, mechanically harvested fruit, and grapes discharged from a stemmer-crusher. Inclusion of stems and other vine debris such as petioles and leaves which are normally associated with machine harvested grapes did not appear to influence juice quality.

The grape juices produced were of high quality, especially with respect to aroma and flavour, and particularly attractive red-purple juices were obtained from red varieties. The excellent colour of juices from red varieties was expected, but the intensity and fruity quality of the aroma was surprising. Williams *et al.* (1980) found that heat treatments of the same order as the grapes were receiving in the countercurrent extraction process greatly enhanced the headspace aroma of Muscat grape juice, owing to the production of desirable aroma compounds from non-volatile precursors already present in the grapes. A similar mechanism may have accounted for the unexpectedly rich aroma of the countercurrent extracted juices.

Fermented grape products

Heat treatment of grapes, mash or juice, is not common in wine making, but there are many advantages in such treatments and Heimann (1977) and Williams *et al.* (1980) have discussed the implication of thermal processing and the technology of wine.

Wines made from countercurrent extracted juices during the 1979 vintage were examined by an expert taste panel. The production of these wines differed from conventional procedures in that no sulphur dioxide was added at any stage during the preparation of the juice or during fermentation. However, sulphur dioxide was added to the white wines at the time of bottling, but not to the red.

The general opinion of the panel, tasting the wines three months after fermentation in four-litre batches, was that the white wines were acceptable but not outstanding. However, the red Shiraz wine was considered by all the judges to have an excellent intense colour and excellent full fruit aroma characteristic of the variety. It had a good overall nose, and a soft tannin flavour without any bitterness. However, the judges could not agree as to the desirability of the palate, most considering the wine to have a light palate. In general the wine was considered to be very promising for its age, having many excellent characteristics.

Larger scale fermentations of Shiraz juice in the 1980 vintage have confirmed the high colour and odour qualities observed in the previous trials but evaluations are not yet complete.

The wine industry is by tradition very conservative and resistant to change but even at this early stage countercurrent extraction processes appear to have much to offer the winemaker, especially as regards colour extraction and enhancement of aroma in red wines.

Grape marc

Grape marc contains residual soluble materials such as sugar, acid and flavour and colour components. At present most of the marc from Australian wineries is collected and after a crude fermentation process is distilled to produce "grape spirit". Countercurrent extraction can recover at least 85% of the sugar present in the marc which on fermentation should yield about 55 litres of ethanol per tonne of marc. If not required as grape spirit the surplus ethanol could be used as a liquid fuel. Other valuable products which could be recovered from grape marc include tartrates and red pigments for use as natural colouring materials in foods.

Apples and pears

The yields of soluble solids that can be recovered from apples by different methods of extraction are shown in Table 1. In pressing and centrifugal methods of juice extraction, yields depend to a large degree on the maturity of the fruit. The more mature fruit is very difficult to handle in presses and press-aids are often added, which apart from being an additional expense are discharged wetted with juice, so causing loss of yield. There is also the possibility that the juice may pick up taints from the press-aid materials.

It can be seen from Table 1 that the countercurrent extractor gives the highest recovery of soluble solids. There is some dilution of the 'juice' but it is usually within the 2° Brix of the juice pressed from the apples. This has caused some doubts as to whether the extract may legitimately be described as apple juice but it may be noted that the EEC Directive 75/726 EEC allows member states to permit the use of diffusion

Table 1. Yields of juice and sugar recovered from apples using different methods of extraction

	Extraction Method			
	Press	Screening centrifuge	Decanting centrifuge	Counter-current extractor
Typical juice yield (%)	75	67.5	68	106^{A}
Sugar recovered from 100 kg of apples (kg)^{B}	8.25	7.4	7.5	10.1
Sugar recovered (%)	77.3	69.3	70.3	95

^{A}Allowing for dilution to 9.5° Brix

^{B}Assuming apples contain 3% insoluble solids and the mechanically expressed juice is 11° Brix.

and extraction processes for the manufacture of fruit juice from certain fruit for the production of concentrated juices (Gierschner *et al.* 1978).

A number of trials have been conducted on the countercurrent extraction of apples in the form of ripple-cut slices using the single-screw extraction with reversing motion of the screw. Data from some of these trials which are shown in Table 2, demonstrate that this process is able to produce apple juice in high yield and of high quality as regards flavour, although the concentrate produced from green skinned apples is green/yellow in colour rather than the usual amber/yellow. When extracting red skinned varieties, skin pigment is extracted and the juice is pinker. However, it was observed that this colour was lost during depectinization and clarification treatments. Detailed studies of the clarification process showed that the red skin pigments were strongly absorbed by the bentonite and hence were not present in the clarified juice. The extracted juice clarifies readily, has less suspended solids than pressed juice and can be concentrated without any problems.

Assessment of apple essences collected during the concentration of countercurrent extracted and pressed juices from Granny Smith apples showed that the essence from the countercurrent extracted juice had a more generally characteristic apple character with a marked 'pippy' note. The component responsible for the 'pippy' note was tentatively identified by gas chromatography/mass spectrometry as

Table 2. Operating data for trials of countercurrent extraction of Granny Smith apples

Run	1	2	3
Screw forward (rpm)	5.7	6	1.33
Screw backward (rpm)	9.4	6	1.33
Time forward (s)	58	55	60
Time backward (s)	22	30	33
Forward motion (%)[A]	23	29	29
Slope of screw (deg.)	5	5	5
Temperature (°C)	60	60	60
Total run time (h)	5.25	7.17	8.0
Feed rate (kg/h)	400	315	296
Juice production rate (kg/h)	251	264	305
Solids discharge rate (kg/h)	181	188	154
Feed apple (°Brix)	9.8	10.8	10.7
Juice (°Brix)	9.0	9.5	8.8
Bulk juice			
Soluble solids (°Brix)	–	10.0	9.5
Titratable acidity (%)	–	0.369	0.315
pH	–	3.50	3.66
Suspended solids (%)	–	0.7	0.3
Yield of soluble solids[B] (%)	89.2	89.2	91.5

[A]Calculated as:

$$\frac{\text{Revolutions of screw forward} - \text{Revolutions of screw backward}}{\text{Revolutions of screw forward} + \text{Revolutions of screw backward}} \times 100$$

[B]Buchi-Guyer presses were giving a juice yield of 68-69% from this fruit.

6-methyl-hept-5-en-2-one, and its concentration in the essence from the countercurrent extracted juice was four to five times greater than that from the pressed juice.

Countercurrent extractor trials were also carried out on pears, and pear peels and cores from Atlas-Pacific peelers. A good quality juice was prepared from pears, and the juice from the peels and cores was such that it could be utilized in canning syrups to add flavour and reduce the quantity of cane sugar needed. There does not appear to be any reason why apple peels and cores and other trimmings from a canning line could not be utilized in a similar manner.

Crustacean residues

In the processing of most crustaceans, e.g. prawns, lobster and crabs, a large proportion of the raw material is not conventionally edible and, hence, becomes a waste material. This waste material, because of its susceptibility to microbial putrefaction, often poses a difficult disposal problem. However,the residues contain valuable seafood flavours and protein material.

Crayfish residues were coarsely milled and countercurrent extracted with water at 85°C. The 'juice' obtained contained 6.4% solids by weight and could be evaporated to produce a concentrate containing 41% total solids. Disagreeable amine-type odours were stripped off during the concentration process and the concentrate had a pleasant crayfish taste and odour.

After the addition of 10% starch the concentrate was readily drum dried to produce a crayfish powder which could be used as a flavour base for soups, sauces, and snack foods.

Citrus products

West Indian lime juice is traditionally prepared by crushing the whole fruit and holding the crushed fruit in contact with the expressed juice for 30 days at ambient temperature in wooden tanks. During this 30-day holding period most of the pulp settles as a sludge but some pulp and peel oil floats and forms a surface layer. The desirable intermediate clear phase (lime juice) is then drawn off, preservatized and stored in barrels.

Because lime juice derives its characteristic flavour from skin as well as juice components, countercurrent extraction removes a desirable amount of oil and other components necessary for a high quality lime juice and can therefore replace the traditional West Indian process. The process time is reduced from 30 days to about three hours.

Taste panel assessment of lime cordial made from juice countercurrent extracted from Australian limes did not show any significant preference between this and a commercial lime cordial made from imported West Indian lime juice. Similarly the extract obtained from sliced whole lemons gave a very acceptable base suitable for the preparation of lemon drinks or cordials.

The countercurrent extraction of citrus peel, a fraction often considered as waste, also resulted in a peel juice, which was about 8° Brix and could be used for the preparation of drink bases or fermented to produce orange liqueur or other alcohol products.

Conclusions

The countercurrent extraction process has a wide range of applications for the recovery of soluble materials (sugars, flavours, colours, proteins, etc.) from particulate solids. As it is a continuous multistage process there are advantages with respect to processing costs and increased yields are obtained. Particular attention should be given to the recovery of components from residues which are now considered waste fractions in food processes.

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News from the Division

Visiting workers

Miss Fe Esperanza Parian of the National Institute for Science and Technology in the Philippines, was attached to FRL for a four-month period ending early in June 1983. She worked on aspects of food packaging under the supervision of Mr E. G. Davis and will be responsible for the establishment of a new program on her return to Manila. Whilst in Australia, Miss Parian was able to attend the 1983 Convention of the Australian Institute of Food Science and Technology, in Melbourne.

Several members of the Division also participated at the AIFST Convention and papers were presented by Drs Egan and King, and Messrs Eustace and Smith of MRL, Drs Olley and McBride of FRL and Dr Ramshaw of DRL.

Mr Wayne Norumu of Papua New Guinea University of Technology recently spent some weeks at FRL working with Mr Peter Board on the development of soy-based biscuits and canned soy milk. These products will be used in nutritional studies with school children in Lae, Papua New Guinea.

High voltage electrical stimulation of beef carcasses and sides

By D. T. Kerr, N. G. McPhail and V. H. Powell

CSIRO Division of Food Research, Cannon Hill, Qld, 4170.

It is well documented that electrical stimulation of beef carcasses ensures a more tender product (Bendall 1980). Commercial confidence in this is borne out by the fact that over 120 Australian abattoirs and slaughterhouses now use the technique. Carcasses may be effectively stimulated using either extra low voltage (ELV; below 32V RMS A.C.) or high voltage (HV; above 32V RMS A.C.). ELV stimulation must be applied within 8 min of stunning but HV can be effective up to 60 min from stunning.

The requirements of electrical stimulation (ES) in individual meatworks will vary considerably. For example, ELV is more suited to slaughterhouses with a small throughput where the labour component can be absorbed into an existing task, whereas the higher capital cost of an automatic HV installation can be justified in a large works where additional labour would be required to apply an ELV system.

Electrical parameters

Pulse rate

A pulsed current is necessary for effective ES, and for HV-ES between 5 to 16.6 pulse/s is the most effective range (Chrystall and Devine 1978). A pulse rate of 14.3 pulse/s (Fig. 1) is recommended because it can be conveniently obtained from a 50 Hz, A.C. supply. It is an alternating pulse thus preventing electrode polarization and producing less muscle tremor than do lower frequencies.

Voltage/time requirements

The effectiveness of ES decreases markedly with time and if stimulation is delayed beyond one hour from death, its effectiveness, even if HV is used, is minimal even though the muscles will still contract with the application of ES (Bouton *et al.* 1981).

The duration for which HV-ES is applied is dependent on the time after slaughter and

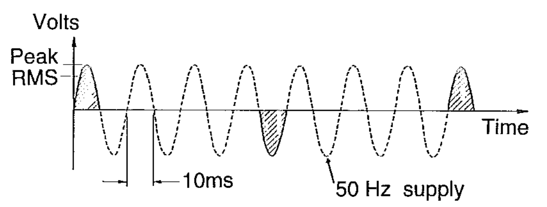

Fig. 1. Recommended wave form for high voltage electrical stimulation.

the voltage applied. From Fig. 2, appropriate voltage/time parameters may be selected.

For example, if the interval between stunning and ES is 35 minutes, then the voltage/time combination could be 800V for 53 s, 700V for 60 s, 600V for 70 s or 500V for 84 s. These stimulation times are the minimum recommended and it is suggested that they be increased by 50%, if the space is available.

Normal line stoppages must be included when assessing the total time from stunning to stimulation. This time, the duration of stimulation and the voltage should then be checked to ensure that they are within specification (Fig. 2) at the slowest chain speed.

Location of ES equipment

On an existing slaughter line, available space will probably dictate where ES can be sited. If a new works is being built or major modifications are undertaken, then ES should be sited where it is most appropriate to that slaughter line.

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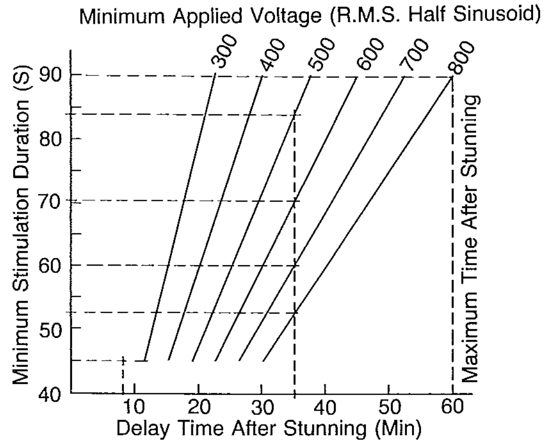

Fig. 2. Voltage/time parameters for the application of high voltage electrical stimulation to beef carcasses and sides.

In bleeding area

HV-ES can be applied to carcasses after sticking by inserting an electrode into the nose. After ES, the electrode is manually removed and returned for reuse. Special consideration must be given to safety aspects due to the wet dirty area. If downward hide pullers are used, the stiffening probes will be ineffective and many broken backs will result. The free and shackle legs of the carcasses may be stiff and straight causing a change in dressing technique. In Australia, no ES units have been installed in this position but a number have been in South Africa.

Before hide removal

A HV-ES cabinet can be located before hide removal after the carcass is suspended by the Achilles tendons. However, if downward hide pullers are used, the stiffening probes will be ineffective and many broken backs will result. The live electrode can be a probe inserted in and removed from the neck either automatically or manually. The electrodes must be sterilized between use on each carcass. No ES units have been installed in this position in Australia.

Before evisceration

ES in this location can be either fully or semi-automatic, using electrodes which contact the lower back or neck of the carcass rather than the brisket area as practised in the USA. However, the electrodes must be sterilized before contact is made with each successive carcass because inspection is not yet complete. This is the site most commonly selected for HV-ES of carcasses in Australian meatworks.

Before splitting

Similar equipment to that used before evisceration could be used at this location. However, space in this area is generally at a premium, consequently, at present there are no such installations in Australia.

After splitting

This site has two distinct advantages. Firstly, existing works are most likely to have the space necessary to install an ES cabinet, and secondly, if carcass inspection has been completed, the electrodes need only be cleaned regularly, and not sterilized after each application. However, the time from stunning to ES, including normal stoppages must not exceed the maximum recommended. Continuity of electrical contact can also be more difficult because of severe distortion of the side during stimulation.

Safety

High voltage ES is dangerous unless all relevant regulations and recommendations are adhered to. All care must be taken in the design and installation to ensure that personnel are not able to come into contact with a live carcass or electrode (Kerr 1981).

The ES installation must be approved by the local electrical authority and it is strongly recommended that their advice be sought early in the design stage.

All Electrical Authorities in Australia base their safety requirements on the same set of rules (SAA Wiring Rules AS3000 1981). However, an ES system has very particular requirements which may result in differing opinions between the State Authorities.

Case studies

Design parameters for HV-ES were discussed in detail by Kerr (1981). Several arrangements of electrodes for carcasses and sides of beef were suggested. It was stressed that, because none of these suggestions had been implemented at that time, firm guidance on their positioning could not be given.

Since then nine HV systems have been installed in Australia. Five of these installations are located on the slaughter floor before evisceration while the remaining four are side stimulators at various locations between final inspection and the chillers.

In the installations about to be described, the Meat Research Laboratory of CSIRO's Division of Food Research was involved in initial design while the detailed design, construction and installation was done by meatworks' personnel or by contractors.

Carcass stimulation on a continuous chain

This unit is at the Metropolitan Regional Abattoir at Cannon Hill, Qld. It stimulates the carcasses continuously and automatically and is positioned between the hide puller and evisceration station.

Initially, it was proposed to install a side stimulator because ample space was available, but the sides did not reach the proposed site until about 65 minutes after stunning. This is beyond the recommended time after stunning for effective ES. The only other area suitable was the existing brisket sawing station. The brisket saw was therefore relocated to a vacant station closer to the hide pullers, thus creating an area suitable for ES.

The general concept of the system is shown in Fig. 3. Because the carcasses had not been inspected at this stage, two movable electrodes were required, one to be sterilized while the other was in contact with the carcass. The 150 mm OD stainless steel tube electrodes are supported from the wall and extended and retracted by means of pneumatic cylinders. Insulation is provided by nylon bars which form part of the supporting arms. Electrical connection to the electrodes is provided by contacts which the bars physically engage when they are in the extended position. When retracted, contact is broken (Fig. 4). An electrode is retracted for hot water spray sterilization before a carcass reaches a point contacted by the previous carcass. This movement is controlled by a cam, driven by the chain sprocket, which operates the valves controlling the pneumatic cylinders. A timer is provided which delays shut-down of the stimulation system for 60 seconds should the chain stop, completing treatment of carcasses already within the ES enclosure. This ensures that if the chain restarts after a short delay the carcasses still within the ES enclosure do not contract vigorously.

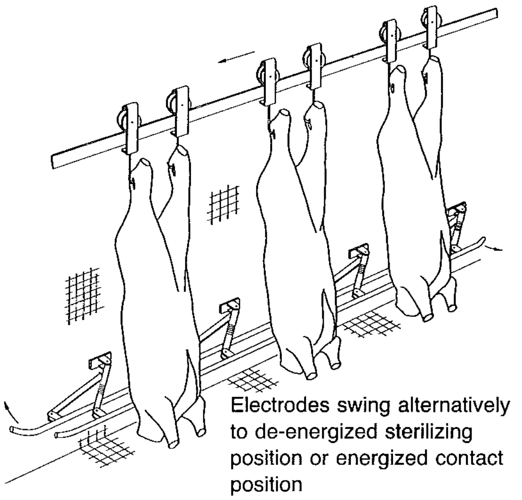

Fig. 3. General concept of a stimulation unit for carcasses on a continuous chain.

While being stimulated, the carcasses are enclosed within a cabinet. If safety footplates at the entry and exit of the ES cabinet are activated the electrodes are de-energized and an alarm sounded. Illuminated signs indicate when power is supplied to the electrodes or when it is safe to enter the cabinet.

Problem encountered. — Initially some difficulty was experienced with the operation of the unit. Some carcasses bounced quite severely when they first contacted the electrode bar, placing severe strain on the equipment and damaging the polypropylene insulators originally used. The bounce was overcome by the abattoir engineers when they fitted a 'leaf spring' (Fig. 4) to the electrode bar, which ensured constant electrical contact with the carcasses. The arms supporting the electrode bars were redesigned to incorporate more robust nylon insulators.

● System details

Kill rate:	Two chain speeds are commonly used, 110 and 140 cattle per hour.
Site:	After the hide puller and before evisceration, 25 and 32 minutes from stunning, dependent on the kill rate.
Electrical parameters:	Alternating half sinusoidal

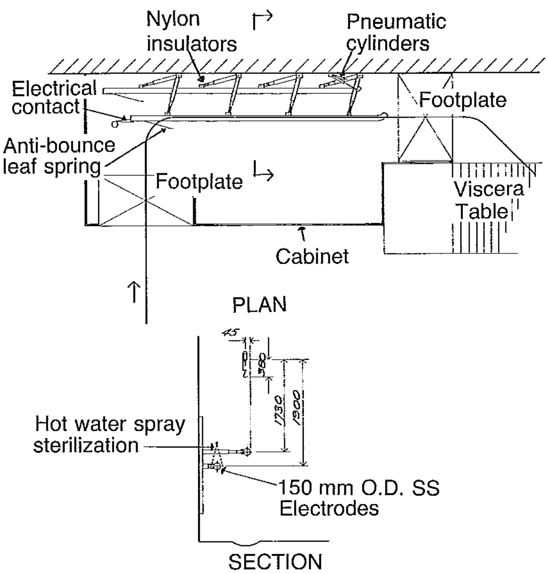

Fig. 4. Plan and section of carcass stimulation unit at Metropolitan Regional Abattoir, Cannon Hill, Qld.

	pulse. 14.3 pulses/s. 10 ms pulse width, 1130V peak derived from 800V RMS 50 Hz transformed mains supply (Fig. 1).
Duration of ES:	53 or 70 seconds, depending on kill rate (i.e. time from stunning to ES).
Number of carcasses on ES at any time:	2-3
Cost of system (1982)	$20 000

Side stimulation on a continuous chain

F. J. Walker (Byron Bay) Ltd have exploited a lowerator as a site for ES. This was ideal because the area could be easily isolated and, depending on the kill rate, beef sides reached this point within 25-45 minutes of stunning.

When a beef side is stimulated, the contracting muscles cause it to curl away from the line of the backbone. This can cause difficulty in the maintenance of electrical contact.

Tests were done with the aim of determining an arrangement of three or four bars which would maintain electrical contact with beef sides of varying sizes. These tests were based on the observation that the neck of the stimulated side would curl around one bar and the arching of the side would allow it to clear the bars above, thus ensuring current will pass, as nearly as is practical, through the entire side.

Based on the results obtained, the stimulator was set up with three electrode bars parallel to the conveyor rail and 450 mm apart. The bars were made adjustable both horizontally and vertically. After several months operation and various adjustments, a satisfactory arrangement of the electrode bars was obtained (Fig. 5).

The electrode bars of 38 mm diameter stainless steel are supported from the wall by galvanized steel tubing (providing sliding adjustment) and insulators machined from acetal (trade name Delrin*)s Lead-in bars and bounce restraining bars of 38 mm diameter nylon are provided. An earthed, 4 m long lead-in bar of galvanized steel tube is provided to reduce the chance of electrical conduction to the structure and/or sides of beef outside the system.

Stimulation of beef after carcass has been split requires every side to be specifically oriented so that the outer (not cavity) side contacts the electrode. In practice the last operator on the floor turns the side (if required) onto a guide bar which directs it into the cabinet. The guide bar is positioned in such a way that the side is gradually moved or tilted away from the vertical. When the side makes contact with the live electrode bar(s) the bounce associated with the vigorous contraction of the beef side is almost completely eliminated. However, bounce-restraining bars of 38 mm diameter nylon are provided for the initial 1 m of the live section.

A timer is provided which delays shut-down of the stimulation system for 60 seconds should the chain stop, thus completing the treatment of carcasses already within the ES enclosure. This ensures that if the chain restarts after a short delay the sides still within the ES zone do not contract vigorously.

Hinged footplates are provided at the entry to and the exit from the ES enclosure. If depressed, they disconnect the power to the stimulator and sound an alarm. Two sets of plastic doors which are opened by the progress of the sides are also provided at the entry to the ES system to prevent hosing

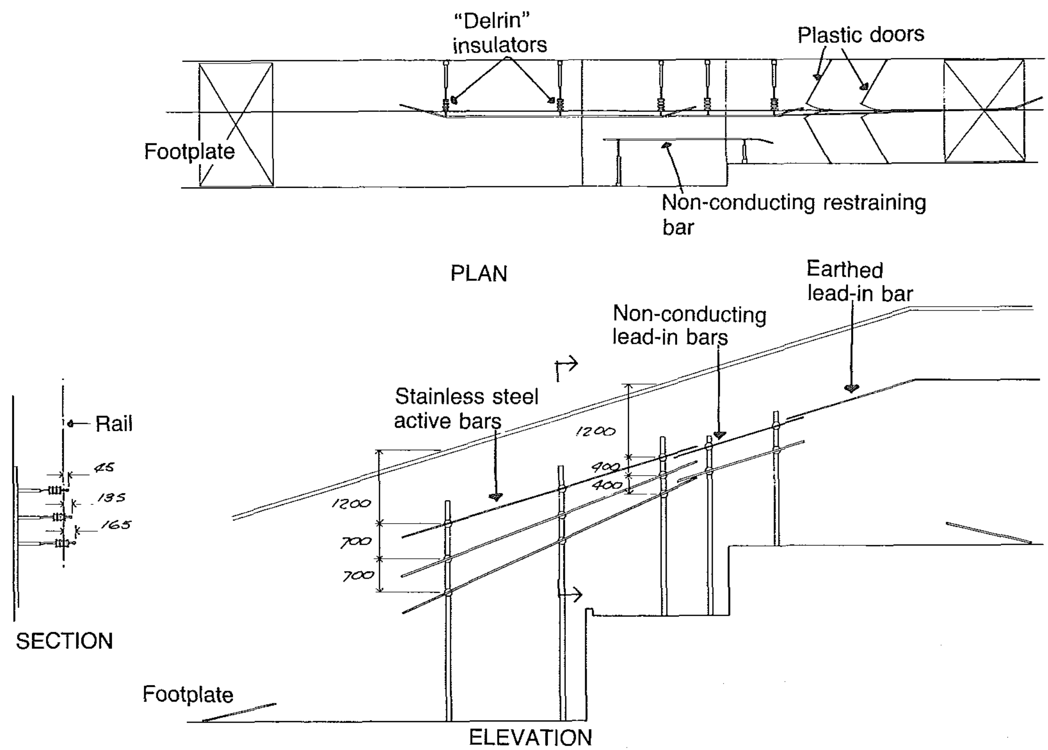

Fig. 5. Plan and elevation of the beef side stimulation unit at F. J. Walker (Byron Bay) Ltd

inside the ES enclosure. Illuminated warning signs which indicate STIMULATOR ON or STIMULATOR OFF are provided at the entry and exit, along with emergency stop buttons.

Problems encountered. – Initially, 150 mm diameter ceramic insulators were used but they were unable to withstand the shock loads caused by contraction of large sides. They were replaced by insulators machined from acetal (trade name Delrin*).

A limit switch was provided at the entry to the stimulator area at a height of 1.8 m below the rail. Larger sides trip this switch and power to the top electrode bar is turned off. This ensures that the current does not short circuit from the upper regions of the side – and thus leave the forequarter unstimulated.

Another problem encountered was that as the sides relaxed towards the end of the stimulation period, the neck and front leg of some dropped to the wrong side of the lower electrode bar and fouled the insulator and supports. This was solved by increasing the vertical distance between the bars on the exit end, so that they are no longer parallel (Fig. 5).

● System details

Kill rate:	Two chain speeds are used, 45 and 80 head per hour.
Site:	In lowerator, 25-45 minutes from stunning, dependent on kill rate.
Electrical parameters:	Alternating half sinusoidal pulses. 14.3 pulses/s, 10 ms pulse width, 1130V peak, derived from 800V RMS 50 Hz transformed mains supply (Fig. 1).
Duration of ES:	100 seconds.
Number of sides on ES at any time:	6
Cost of system:	$11 000 (1982)

*Regd Trade Name E.I. du Pont de Nemours & Co.

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News from the Division

'Approved persons' courses

Two courses on the theory and practice of determining heat sterilization processes for low-acid canned foods were presented at FRL in May by Messrs P. W. Board and P. J. Rutledge, and Dr R. J. Steele. The courses were desigfed to train participants to the stage of their being able to determine processing conditions for low-acid canned foods and to determine the sterilizing value of established and non-scheduled processes. The courses were similar to those presented in 1982 and were attended by some twenty-five people from the Australian canning industry and from the associated Commonwealth regulatory authorities. Those who passed the two written examinations at the end of the courses had their names added to the list of approved persons held by the Department of Primary Industry in Canberra.

Food irradiation

A National Symposium on Ionizing Energy Treatment of Foods is to be held on 5-6 October 1983, at the Shore Hotel, Artarmon (Sydney). The meeting is sponsored by the AIFST and the AIAS (Australian Institute of Agricultural Science), with assistance from industry and the public sector. The Division is one of the organizers.

The purpose of the Symposium is to inform Australians of recent advances in irradiation technology and changes in overseas legislation relating to the commercial use of ionizing radiation for food preservation and disinfestation.

Award

The Australian Society of Dairy Technology 1983 Silver Medal — The Loftus Hills Dairy Science Award, was awarded to Mr F. G. Kieseker of DRL, 'for his contribution, through published work and practical application, which has greatly assisted the economic development of the recombined milk products industry. He has dealt with a wide range of dairy products and is recognized as a leading scientific and technical worker in this field'.

Dr R. R. Hull, also of DRL received a commendation from the Australian Journal of Dairy Technology for his paper 'Bacteriophages more active against Cheddar cheese starters in unheated milk'.

Visit

As part of the Division's continuing collaboration with the countries of ASEAN (Malaysia, Indonesia, Singapore, Thailand, Philippines and Australia), a group of eighteen food technologists from the participating countries inspected selected laboratories at FRL on 25 May 1983.

The tour, organized by Dr K. T. H. Farrer, food consultant, and Dr A. Buchanan, Australian Scientific Liaison Officer with ASEAN, included visits to industry, tertiary education establishments and government laboratories, in New South Wales, Victoria and Tasmania.