CSIRO Food Research Quarterly

Microbiology of canned foods*

By W. G. Murrell

Formerly CSIRO Division of Food Research, North Ryde, New South Wales, 2113
(Present address: Department of Microbiology, University of Sydney, New South Wales, 2006)

Introduction

Canning basically involves filling a food product into a can or container, hermetically sealing the container, then heat processing the product at a suitable retort temperature for sufficient time to inactivate the microorganisms in the product and the container. Most products before processing will contain a wide variety of organisms and most, if not all, of these will be killed by the process, hence most canned products are probably free of viable organisms (sterile). Certain products, however, are only processed sufficiently to give a safe storage life under defined storage conditions so may contain survivors (viable microorganisms). Many low-acid products receive a process that is adequate to kill spores of *Clostridium botulinum*, the bacterium which produces toxin and causes botulism, but not necessarily sufficient to kill all of the more heat-resistant spores of thermophiles. These may be present but normally do not grow in the product during storage and so do not cause spoilage. These cans are described as 'commercially sterile'. Acid products (pH < 4.6) also are not processed sufficiently to inactivate all spores since most species of spores will not germinate, outgrow and cause spoilage at low pH. Some foods cannot be processed sufficiently to make them microbiologically stable without adversely affecting their organoleptic properties. These products receive a less severe process and the resulting semi-preserved products must be stored under refrigeration and should be so labelled. Some cured meats especially ham are semi-preserved and must be stored under refrigeration. Canned meats can thus be classified into shelf-stable, cured or uncured and perishable, non shelf-stable or 'semi-preserved' canned cured meats.

The above variations in processing therefore

present opportunities for different microorganisms before and after canning to grow and cause spoilage and to select different types of spoilage organisms according to the conditions. When cans leak at the seams and suffer post-process contamination and spoilage a wide variety of organisms may also grow. This chapter examines the factors affecting the microbial content of food before processing, the types of spoilage that can occur, the growth of survivors, the chief spoilage organisms, can integrity, methods to minimize post-process spoilage, botulism and other considerations regarding the safety of canned foods.

Microbial content of food before processing

Any type of microorganism may be present in or on foods at harvest or after slaughter and dressing of animals, but in practice there tends to be a selection of types on each product depending on the chemical nature of the product and the environment from which the product comes. Many of these organisms will be removed or killed by washing or hot preparation treatments such as blanching. In fact from the processing requirement viewpoint the organisms of most importance will be the bacterial spores in the case of low-acid foods and yeasts and lactobacilli for hot-fill processed acid foods. In practice the microbial content of ingredients and the cannery environment are often of major importance. Sugar, flour, starch and spices may add too many spores or enough of a very heat-resistant type to render the process inadequate. Likewise a specific spoilage type may build up in the plant, e.g. *acetobutylicum-butyricum* types of clostridia in flumes conveying peach and pear pieces, or flat sour thermophilic spores on heated surfaces of equipment, in contact with food, that are not cleaned and sanitized adequately or sufficiently frequently. The contamination level may be significant only in some seasons, e.g. in dry dusty years the skin of peaches or pears may carry a much greater load of spores, or the pH of the ripe fruit (tomatoes, pears) may be 0.1-0.2 higher with the result that surviving spores have a greater chance to outgrow.

Empty cans that have been stored for a long time may carry a significant spore load and if this is critical to the safety of the process it is essential that the cans be washed and sterilized.

Microbial spoilage of canned foods

Microbial spoilage is indicated by off-odours, macroscopic changes in the product and usually large numbers of microorganisms in smears of the product on microscopic examination. The culture of many viable spoilage organisms from the product confirms that there is a microbial spoilage problem.

Microbial spoilage can occur as a result of four circumstances:
- underprocessing
- post-process leakage of cans
- the failure to retort or process cans
- spoilage in the product or food while held in the can before retorting.

The first two causes are of major importance.

Underprocessing

A canned product is said to be underprocessed when it receives a process insufficient to kill or inactivate the organisms likely to spoil it. The relative heat resistance of the various food-poisoning and food spoilage organisms is given in Table 1. The spoilage organisms may be bacterial spores in low-acid foods or yeasts and vegetative bacteria in hot-filled processes. Underprocessing can result from:
- incorrect process calculation, retort operation or an error in process timing
- an excess spore load (low-acid products) or excess contamination with yeasts, lactobacilli and other bacteria (acid products)
- contamination of the food with an unusually heat-resistant spore type.

The commonly recommended processes are designed for products produced under conditions of good canning practice and having average bacterial loads. If there are errors in retorting practice, or the rate of heat penetration has been reduced by changes in the pack, or the ingredients are overloaded with spores then the ordinary process may be inadequate.

Cereals, sugar, spices and salt may contain high counts of spores. These ingredients should be monitored routinely for spores and only those batches with low counts should be used in low-acid canned foods.

Processing equipment, especially that in contact with warm-hot product should be monitored regularly for spore contamination and to check the necessary frequency of and

method of sanitation. Redesign of equipment may be needed to prevent build-up of heat resistant spores.

TABLE 1

Relative heat resistance of spores of the more important food spoilage and poisoning organisms

Food spoilage and poisoning organisms	Range in $D_{100°C}$ values[A]
Clostridium botulinum Type A	10-28
B	7-14
E	0.01
F	0.01-0.04
G	1.2-1.5[B]
Clostridium sporogenes	80->100
Clostridium thermosaccharolyticum	400
Clostridium perfringens	0.3-18
Desulfotomaculum nigrificans	<480
Clostridium butyricum	0.4-0.8
Bacillus stearothermophilus	100-1600
Bacillus coagulans	20-300
Bacillus coagulans var. thermoacidurans	2-3
Bacillus subtilus	7-70
Bacillus licheniformis	13.5
Bacillus cereus	3-200
Byssochlamys fulva[C]	4

[A]Decimal reduction time: Time in minutes at 100°C required to destroy 90% of the cells of the test organism for various strains in water or neutral phosphate buffer.
[B]Lynt *et al.* (1984) for the more heat-resistant spores.
[C]Calculated from data of Splittstoesser and Splittstoesser (1977).
From Russell (1982).

Post-process leakage

This is the commonest form of spoilage. In practically all cases it is indicated, on microscopic examination, by the presence of heat labile organisms, present singly or in mixture. These may be cocci, yeasts, coccobacilli and rods of non-sporing types. Non-sporing rods (rods of non-sporulating species) can generally be differentiated from rods of spore formers: the latter are usually larger, more than 2μm in length, have parallel sides, occur in short chains and are usually Gram positive. Some spore-forming species are Gram negative, and old cultures of Gram positive species may be negative.

Leakages of cans at high temperature may occur, and may be indicated by the presence of one or more types of a spore-forming organism of not very high heat resistance.

Microbiological evidence of leaker spoilage is usually conclusive. Processing should be

stopped immediately until the faults are remedied.

Cans should be examined for obvious faults and leaks and tested for leaks by a recommended method. The can seams should also be stripped or 'pulled down' by an expert on seam examination.

Can leakage may occur at either or both double seams, at the side seam especially at the double seam junction, or the tinplate may have pinholes or be cracked or perforated by embossing dies or other mechanical handling equipment.

Most cans are soundly made and very satisfactory but seams may open momentarily during cooling stresses or during rough handling after processing (Put *et al.* 1972, Segner 1979) and allow microbes to be sucked in. This is particularly dangerous when the cans are wet and they contact contaminated equipment such as wet conveyor belts, operatives, or their clothing, e.g. *C. botulinum* contaminated overalls in the 1978 botulism problem in Alaskan canneries (Anon. 1978). Therefore all aspects of can handling after processing should be carefully examined to minimize these dangers (Segner 1979).

Failure to process

If a retort load misses retorting then a high proportion of the cans can be expected to spoil and show a similar microscopic picture to that of post-process leakage, but probably no seam leaks.

Pre-process spoilage or incipient spoilage (Segner 1979)

This is often caused by holding a product too long at temperatures favourable to growth before canning and processing. A hold-up in the processing operations of 1 or more hours may occur after closing. This could result in incipient spoilage and gas production that could show as vacuum loss and soft swells. Microscopic examination should reveal many organisms of mixed types but on culture no viable organisms. A highly contaminated ingredient may be another cause of incipient spoilage.

In products including meats, vegetables, poultry, soups, fish, dairy-based foods and pet food in spoiled foods analysed over 18 (Segner 1979) and 27 (Murrell 1978) year periods in the USA and Australia, respectively, the most common cause of spoilage was diagnosed as post-process leakage (Table 2). Segner (1979) believes if all the field spoilage figures were included in his study the leaker type spoilage would be as high as 90% of all spoilage incidents.

TABLE 2

Type of spoilage (%) in a variety of canned products presented for microbiological analysis

	CSIRO[A] 1950-1977	Continental Can Co.[B] 1960-1977
Incipient	1.8	4
Gross underprocessing		2
Leakage	31.2	60
Thermophilic		14
Underprocessing	25.7	20
Non-microbial	40.4	

[A]Murrell (1978)
[B]Segner (1979)

Microbial growth in canned foods

Of the wide spectrum of microorganisms present in food, many will grow if the conditions are appropriate. Some may have very specific growth requirements.

Immediately after canning, even though a vacuum closing process may have been used, not all the air is exhausted from canned foods. The residual oxygen usually disappears within a few weeks of storage by ongoing chemical changes. The initial presence of some oxygen may assist outgrowth of surviving spores of facultative anaerobes, and on the other hand inhibit some strict anaerobes. As the oxygen disappears the conditions (e.g. E_h) may become more favourable to the outgrowth of heat-damaged spores of anaerobes.

Organisms entering the can by post-process leaks will not normally be sub-lethally injured or damaged, but this will commonly be the case for small numbers of spores surviving the heat process. Sub-lethal damage may be very important in sterility tests and spoilage. Sub-lethally damaged spores are often very sensitive to pH and E_h conditions, amino acid and glucose levels, and to inhibitors (see reviews by Adams 1978, Foegeding and Busta 1981). The inhibitors may be unsaturated fatty acids, peroxides, preservatives and metal ions, e.g. Sn. The presence of absorbents of inhibitors, e.g. starch and albumin, is also very important (Murrell, Olsen and Scott 1950, Olsen and Scott 1950). However, once the cans are spoiled these factors are not important in obtaining growth of the spoilage organism.

Types of microorganisms important in the spoilage of canned foods

It is probably best to consider or classify these in two ways, firstly, according to the growth characteristics of the organisms and secondly as the organisms of importance in each acidity

group of canned foods. The heat resistance of the more important microorganisms and their spores is tabulated in Table 1.

Spoilage organisms classified on growth characteristics

Thermophilic organisms: These include facultative and obligate thermophiles that usually produce acid and have a growth range of about 40°-75°C. There are four major groups:

- *Flat sour organisms* – These are the bacteria that cause 'flat sour' spoilage because they produce acids but none or very little gas as a metabolic product, so the containers remain flat.

    Bacillus coagulans often referred to as *B. thermoacidurans* or *B. coagulans* var. *thermoacidurans* in early literature, has been a common problem in tomatoes. The spores will germinate at pH 4.2 or above causing off taste or odour. Spores of this organism are not usually as resistant to heat as other flat sour organisms.

    B. stearothermophilus is a facultative anaerobe with very resistant spores. These acid producing organisms are very important in food spoilage. In fact Jansen and Aschehoug (1951) consider them more important than the putrefactive anaerobes. This conclusion was based on the examination of 10 000 cans of different packs (Aschehoug and Jansen 1950, Jansen and Aschehoug 1951).

- *Facultative thermophiles, facultative anaerobes,* e.g. *B. subtilis* – produce gas and sometimes acid causing soft swells.
- *Anaerobes not producing H₂S,* e.g. *Clostridium thermosaccharolyticum* – these are strict anaerobes which produce hard swells (thermophilic anaerobic spoilage). They grow best at 55°C or higher.
- *Anaerobes producing H₂S,* e.g. *Desulfotomaculum nigrificans* (formerly *C. nigrificans*) which produces much H₂S and blackening. Spoilage of this type ('sulphide stinker') is not common but serious when it does occur.

    Mesophilic organisms: – These include acid and gas producers, facultative and strict anaerobes. They are widely distributed, but usually not of as great heat resistance as the thermophiles.

- *Facultative anaerobic spore formers: B. coagulans, B. circulans, B. laterosporus, B. brevis, B. macerans, B. pumilus, B. polymyxa, B. betanigrificans* (causes black beets). These species usually hydrolyse starch, but do not usually have as much proteolytic activity as the putrefactive anaerobes. Flat sour types – *B. coagulans, B. circulans* and *B. circulans-alvei*

intermediates. Acid and gas forming types – *B. subtilis-pumilus* group and *B. macerans* (Jansen and Aschehoug 1951). This group is considered to be of more significance in canning today for a variety of reasons (Segner 1979). Segner also describes the characteristics of the strains commonly isolated including some catalase-negative sporeformers.

- *Putrefactive anaerobes* – Typical examples are *C. parasporogenes, C. sporogenes* and *C. putrificum.* Strains of *C. sporogenes* can have great heat resistance, e.g. the putrefactive anaerobe PA 3679 commonly used as a test organism instead of *C. botulinum,* which also belongs to this group. Aschehoug and Jansen (1950) found that in many of the blown cans containing the above organisms that facultative anaerobes of the *B. subtilis* type were also present. Segner (1979) made a similar observation.

    Mesophiles in acid foods: –

- *Bacteria* – *C. butyricum* and *Lactobacillus* spp. are common. Clostridia of the *acetobutylicum* group are less common.
- *Moulds* – Practically all fungi cannot grow anaerobically but some do cause spoilage in canned foods. Most fungi also are usually not very heat resistant.
- *Byssochlamys fulva,* which disintegrates fruit even under reduced oxygen pressure, has moderate heat resistance. The ascospores can resist 30 min at 86°-88°C (185°-190°F) in many fruit syrups. The maximum heat resistance occurs at pH 5, and at 3 is more resistant than at pH 7. It can be a problem in canned fruit juices.
- *Yeasts* – These actively attack carbohydrates and spoil tomato products, syrups, fruit packs, honey, etc. They are not very heat resistant and only occur in foods that have not been given a rigorous heat treatment, e.g. hot-fill packs.

Acidity classification of spoilage organisms

Group 1: – Low-acid foods > pH 5, e.g. most meat products, milk, vegetables such as corn, peas, lima beans, asparagus, spinach. These foods must be processed under steam pressure.

Types of spoilage and spoilage organisms:
- Flat sour – *B. stearothermophilus*
- Putrefactive spoilage and swells – *C. sporogenes, C. putrificum*
- Sulphide spoilage *C. nigrificans, C. botulinum* (cause of botulism)
- Black beets – *B. betanigrificans*

Group 2: – Medium acid foods pH 5-4.5, e.g. meats, vegetable mixtures, spaghetti, soups,

sauces. These foods must be processed under pressure.

Types of spoilage and spoilage organisms:

- Similar to Group 1. More susceptible to spoilage by thermophilic anaerobes not producing H_2S.
- Flat sours – organisms of less heat resistance than in Group 1.

Group 3:– Acid foods pH 4.5-3.7, e.g. tomatoes, pears, pineapples, nectarines.

Spoilage organisms – non-spore forming aciduric bacteria, spore forming anaerobes ('butyric anaerobes' – *C. butyricum – acetobutylicum* group).

Types of spoilage:

- Hard swell – facultative anaerobes (low heat resistance), small coccobacilli, produce gas in certain fruit juices but not in media;
- Mesophilic – obligate anaerobes, clostridia – saccharolytic with much gas formation, fairly heat resistant (13 min @ 100°C at 10^3/ml), e.g. *C. butyricum.*

Yeasts – 'swells' in some fruits, fruit concentrates.

Tomatoes – 1. Flat sour – 'off' flavour – *B. coagulans (var. thermoacidurans).*
            – 2. Hard swell – yeasts – with some heat resistance – cause hard swell in some cases.

Bacteria – mesophilic: *Lactobacillus lycopersici, L. pentoaceticus, L. plantarum, L. gayoni, L. mannitopoeum, L. pleofructi.*
            – thermophilic: spore forming anaerobe, quite heat resistant, grows at 50°C and forms much gas.

Group 4:– High acid pH 3.7 and below, e.g. kraut, pickles, berries, grapefruit, oranges, citrus juices and rhubarb. These foods must be processed by hot fill or in boiling water.

Spoilage – by Group 3 organisms, mainly yeasts and lactobacilli.

Foods in this group are relatively free from spoilage.

High acidity – 'chemical swells' due to H_2 are possible.

Note: Depending on pH the heat treatment must increase as pH rises. Spores of the more resistant spore-formers are not dead, but the low pH prevents their germination and outgrowth.

Below 4.5	pH 4.5	above 4.5
Use hot fill or boiling water process	Steam process	
Less heat resistant	Heat resistant spores *C. botulinum* risk	

Can integrity, sterility and incubation tests

Cans or other types of containers may leak for a variety of reasons, and lead to post-process spoilage. "Post-processing recontamination of canned products has never been considered a significant potential public health problem by most food scientists, a view that is well documented in the scientific literature" (Anon. 1983a). However, in contrast to this view there is concern by many regulatory officials and food microbiologists. This arises because of the significant problems that have occurred and continue to occur over the years, e.g. staphylococcal food poisoning from canned peas in England (Bashford *et al.* 1960), the Aberdeen typhoid outbreak (Milne 1964), type E *C. botulinum* contamination of canned tuna from contaminated cooling water (Johnson *et al.* 1963; Stersky *et al.* 1980) and the recent deaths from botulism from canned salmon (see references Stersky *et al.* 1980) (Table 3).

Following a Food and Drug Administration (FDA) meeting on 19 July 1982, the US industry set up a voluntary Container Integrity Program. The Container Integrity Task Force is made up of the following four working groups:

- Container defects group
- Microbiological assessment group
- Container leak detection methodology group
  - on-line can manufacturing methods
  - on-line methods for containers
  - can examination laboratory methods
- Quality assurance (QA) group
  - Container integrity QA guidelines for can manufacturing
  - Container integrity QA guidelines for canners.

The detailed findings of group 2 will be published in a report. One of their findings is that in the past 42 years over 1.3×10^{12} cans of low-acid foods were consumed, and during this period, five botulinal incidents occurred from leaking containers, i.e. the probability of botulism from container leakage is 3.8×10^{-12} or about 1 chance in every 260 billion containers.

What is the real situation in regard to leaker spoilage and the tolerable levels of leaky cans, and the significance of leaker spoilage in food poisoning and spoilage?

Leaker spoilage – incidence, distribution and significance

A recent survey (Pflug *et al.* 1981) of swelled cans over a 17 month period from outlets of two supermarket food chains in the USA revealed the information shown in Table 4. The statistics showed that swelling occurred in a wide variety of products and the level varied significantly with the type of product.

Using a vacuum leak test 294 containers (38.5% of 764 containers) were found to leak.

TABLE 3

Human botulism outbreaks involving United States commercially canned foods in metal containers, 1940-1982[A]

Year	Product	Out-breaks	Cases[B]	Death	Toxin type	Cause of Outbreak	Reference
1941	Mushroom sauce (single can)	1	3	1	E	Suspected leakage	Geiger (1941) Meyer & Eddie (1965)
1963	Tuna fish	1	3	2	E	Alleged leakage[C]	Johnson et al. (1963) Stersky et al. (1980)
1971	Vichyssoise soup	1	2	1	A	Under-processing[D]	Anon. (1971)
1974	Beef stew (single can)	1	2	1	A	Unknown – can possibly missed retort	Anon. (1974)
1978	Salmon (single can)	1	4	2	E	Leakage – can damaged after processing	Anon. (1978a,b)
1982	Salmon (single can)	1	2	1	E	Leakage – malfunctioning can reformer	Anon. (1982) Thompson (1982)
1982	Peeled whole tomatoes (single can)	1	1	0	A	Unknown – no evidence of container leakage	Anon. (1982)

[A]No botulism outbreak is recorded from 1926 to 1939 in commercially canned foods in metal containers (see Meyer and Eddie 1965).
[B]Number of persons afflicted.
[C]21 additional cans recovered by FDA reportedly showed *C. botulinum;* container evaluation was not definitive.
[D]4 additional cans (swollen) of the same code showed type A toxin.

Most of the leaks occurred at the canner's end (73.5%). The specific location of the leak was mostly at the lap area at the side seam-double seam junction. Seam examinations indicated that 55% had double seams with a potential to leak and vacuum tests indicated that 26% of the cans had a potential to leak at points other than the double seam, i.e. 81% had the potential to leak (Davidson and Pflug 1981).

The significance of these results is that 154 incidents of food poisoning were associated with post-process leakage (PPL) between 1921 and 1979 (72.7% in Great Britain and 17.5% in Canada), mainly in products from South America, Europe, Africa and Australia (Stersky et al. 1980). The types of can defects, products and cases involved and the etiological agents associated with PPL food poisoning are shown in Tables 5, 6 and 7. Over 100 incidents with well over 433 cases associated with canned meat, fish and vegetables arose from staphylococcal intoxications from PPL between 1942 and 1979.

Nine outbreaks of salmonellosis involving over 183 cases from eating canned meat, spinach and sardines were identified during 1934-1964. Six outbreaks of typhoid caused 759 cases of typhoid between 1948 and 1964 as a result of PPL. This includes the Aberdeen outbreak of 515 cases. In 33 incidents of food poisoning involving > 126 cases, as a result of PPL, the etiological agent was not identified.

TABLE 5

Types of can defects associated with PPL[A]

(1) During processing, especially cooling
    Temporary microleaks (breaching) in normal cans
    Cracks and defective seams
    Abrasions
    Perforation in lid due to embossing
(2) After processing, particularly after distribution
    Case-cutter damage
    Punctures
    Corrosion
    Dents

[A]Categories (1) and (2) are not mutually exclusive, e.g. temporary microleaks may occur as a result of heating during a fire or from rough handling.

This situation cannot be considered as satisfactory, and there is little evidence that it has improved in recent decades. Allowable levels of leaky cans after processing have not

TABLE 4

Occurrence of swelled cans at the retail stage and the causes of spoilage, state of the seams and types of microorganisms in the containers

	Number of cans	Percentage of cans
Condition of containers		
Swelled cans examined[A]	1104	1.1
Cans with major container defects	314	28.4
Vacuum tests and double seam measurements		
Poor or questionable quality canner's end double seam		51
Leaks at locations other than double seams		26
Poor or questionable quality manufacturer's end double seam		4
Microbiological analysis (790 cans)		
Typical leaker spoilage		86
Typical underprocessing		7
Thermophilic spoilage		1
Non-microbial swells		6
Probable microbial contamination but no viable organisms cultured	425	53.4
Viable microorganisms	368	47
– Typical leaker spoilage organisms		91.6
– Thermophiles		0.5
– Sporeformers		7.9

[A]Incidence of swelled cans was 2.1 to 78.4 per 100 000 units sold over a 17-month period.
From Davidson *et al.* (1981), Pflug *et al.* (1981).

been specified. Recommended levels vary from 0.1% to less than 1 can in 10 000 (0.01%) (Segner 1979).

Microbiological methods to minimize post-process leaker spoilage

The major methods are chlorination of cooling water and prevention of reduction of contamination during post-process handling by cannery sanitation and management. The latter involves a program to avoid or reduce mechanical shock or stress on cans during handling and transport so as to reduce the chances of organisms being sucked into the can. The primary cause of leaker spoilage is filled container abuse while the cans are still wet. Areas of frequent abuse are bar-flight elevators, zig-zag lowerators, unscramblers

and filled can runways, where can-to-can impacts occur (Segner 1979).

Chlorination of cooling water.– This was introduced as a mandatory requirement following the outbreak of type E botulism that occurred as a result of the presence of type E *C. botulinum* spores in the cooling water (Johnson *et al.* 1963). In practice adequate chlorination significantly reduces PPL spoilage levels by reducing the number of viable bacteria in the cooling water (Put *et al.* 1972). Chlorination, however, can have an adverse effect in that it tends to select spores, because of their greater resistance to chlorine than vegetative cells (Odlaug and Pflug 1976), to be the leaker spoilage organism, and in so doing it also reduces the number of competing vegetative bacteria. *C. botulinum* is a poor competitor and many species of bacteria inhibit its growth.

Bacillus spores are more resistant to chlorine than *Clostridium* spores and spores generally are much more resistant than vegetative bacteria (Graves *et al.* 1977; Odlaug and Pflug 1976, 1978). Vegetative bacteria are present in cooling water normally in much greater numbers than *Bacillus* spores, and these are more common than *Clostridium* spores (Graves *et al.* 1977). These authors found very few food-poisoning bacteria such as *Staphylococcus aureus*, coliforms and enterococci in cooling water and failed to detect *C. botulinum*. The frequency of spores, coliforms and enterococci increased as the aerobic plate count (APC) increased. The above authors recommend that the APC should not exceed 100/ml, and found that cooling water commonly exceeded this. Odlaug and Pflug (1978) consider that the anaerobic spore count can be considered a predictor of the public health hazard from *C. botulinum*. They calculate that if 1% of cans have constant leaks of the size used by Put *et al.* (1972), the probability of a can leaking in a *C. botulinum* spore would be less than 2×10^{-6} to 2×10^{-7} when the anaerobic spore counts were at levels of 1 and 0.1/ml of cooling water respectively.

Chlorine is the recommended sanitizer and chlorination should be carried out to give a residual chlorine level of 1-3 mg/l, a level which will effectively reduce the contamination level of vegetative bacteria and spores (Graves *et al.* 1977; Odlaug and Pflug 1976, 1978). Chlorine is more effective the higher the concentration of chlorine, the lower the pH and the higher the temperature. If water in the cannery is recycled it should be filtered to reduce the BOD. A strict program of quality control is needed to monitor the chlorine level and the effectiveness of the chlorination program by making bacterial and spore counts and chlorine measurements at

TABLE 6

Illness from PPL that occurred after processing

Type of defect	Canned food	Etiology	No. of cases	Year	Country where food eaten
Case-cutter damage	Pea soup	Suspect mould	1	1974	Canada
Case-cutter damage	Vegetable soup	n. a.	1	1974	Canada
Case-cutter damage	Tomato soup	n.a.	1	1975	Canada
Case-cutter damage	Tomato juice	n.a.	1	1976	Canada
Case-cutter damage	Cream of chicken soup	Suspect mould	1	1976	Canada
Case-cutter damage	Baked beans	Suspect mould	1	1976	Canada
Case-cutter damage	Salmon	n.a.	2	1976	Canada
Case-cutter damage	Peas	n.a.	1	1976	Canada
Case-cutter damage	Cream style corn	n.a.	1	1976	Canada
Puncture by screwdriver?	Ham	*S. aureus*	3	1972	Canada
Puncture by nail	Shrimp	*S. aureus*	2	1972	Canada
Puncture (unspecified)	Tomato juice	Suspect mould	2	1973	Canada
Puncture (unspecified)	Macaroni and cheese	n.a.	1	1975	Canada
Puncture of unknown origin	Salmon	*C. botulinum* type E	4	1978	England
Corrosion	Evaporated milk	*Strep. faecalis*	74	Mid 1940s	United States
Pin-hole leaks with corrosion	Jugged hare	Streptococci and micrococci	1	1974	Canada
Leaks in can possibly caused by dents	Peas and carrots	*S. aureus*	20	1973	Canada
TOTAL	17 incidents		117	1940-1978	3 countries

n.a. Information not available.
From Stersky *et al.* (1980).

TABLE 7

Etiological agents associated with PPL food poisoning

Agents	Incidents Number	Proportions (%)
Staphylococcus aureus	100	64.9
Salmonella typhi	6	3.9
Other *Salmonella* spp.	9	5.8
Clostridium botulinum	3	2.0
Clostridium perfringens	3	2.0
Coliforms, streptococci, clostridia and/or micrococci	4	2.6
Suspect mould	6	3.9
Undetermined	23	14.9
Total	154	100.0

least once or twice per day.

Cannery sanitation: – Cannery sanitation of all can handling equipment is required after suitable clean-up operations at frequent intervals, and the effectiveness of this on the microbial contamination of surfaces, particularly wet surfaces in contact with cans should be regularly monitored.

An extensive study (1982 – 528 samples from 11 canneries, 1983 – 400 samples from 4 canneries) was carried out at the Alaskan canneries on the effect of in-plant sanitation. This indicated substantial reductions in the surface contamination (Table 8) and the effectiveness of chlorination of natural water supplies (Anon. 1983). Hersom and Hulland (1980) also give data on the effectiveness of chlorination on the bacterial contamination of recirculated water and can spoilage rate.

Sterility and incubation tests of apparently sound containers

A microbiological examination can

TABLE 8

Effect of in-plant sanitation on microbial loads in salmon canneries

	Viable count		
	Before	After clean-up	Reduction
Fish-house	10^4-3×10^9/in^2	10^8-1.5×10^8	
	(Median 7×10^6)	(Median 2.5×10^4)	10^2
Canning area	Similar reductions		10^2
Can closing area	Similar reductions		10^2
One piece of equipment			10^6
Iron chinks			10^4
			(mean $10^{1.5}$)
Clincher (hard to clean piece of equipment)			10^2

Flat open surfaces were more effectively cleaned.
Additional emphasis is necessary on hard to clean areas such as seamer heads and guide rails on clinchers.

From Anon. (1983b)

determine the microbial state of the cans, i.e. whether they are sterile or non-sterile, the type of microorganisms present in them, and whether they will spoil. Sterility testing yields important information on the condition of batches of cans and assesses the possibility of spoilage occurring during storage and distribution. Together with incubation tests, sterility testing measures the effectiveness of processes and plant methods. Both sterility testing and incubation tests should be routine cannery practice.

Can incubation tests in many ways are better than sterility testing because the test is simpler, requires less skill and can provide information on a much larger sample. Incubation tests are the final quality assurance check before release of the product on the market.

Microbiological examinations on the other hand, particularly of cans spoiled during incubation, allow diagnosis of problems in processing, and therefore enable correct remedial measures to be undertaken. A microbiological examination may quickly provide an answer especially if a diagnosis of the cause of spoilage can be made from a microscopic examination of the can contents; this may be done in 1-2 min. Remedial measures can then be taken immediately.

Can incubation tests:– Incubation of samples of cans from each production batch is an essential part of a manufacturer's quality control

procedure and in Australia must be done to comply with export regulations.
● For quality control

Samples of each production batch or retort load should be incubated at appropriate temperatures. The sample should be large enough to give a reasonable chance of detecting abnormalities in the population of cans from which the sample is drawn. Incubation and microbiological tests cannot be relied upon as the sole basis for determining the safety and stability of shelf-stable canned products because of the need to sample and examine an enormous number of cans. Reliance must be placed upon assessing the adequacy of the thermal processes. Incubation of small samples, however, may detect gross faults or abnormalities in the processing of shelf-stable products and semi-preserved canned foods. The International Commission on Microbiological Specifications for Foods (ICMSF) recommends for products processed in still retorts sampling at least two cans from different positions in each retort load, e.g. one from the centre, the other from the top. For products processed in continuous or discontinuous agitating retorts and by aseptic methods, it is recommended that at least one can be obtained from each line every 15 minutes. The can must be identified at the time it is removed.

Half of the cans should be incubated at 30°-37°C for 14 days to detect mesophilic spoilage and half at 50°-55°C for 10-14 days to test for thermophilic spoilage. Thermophilic spoilage is not a problem in acid foods so there is little point in incubating these products at 50°-55°C. Thermophilic spoilage does occur in meat products so they should be incubated at both temperature ranges.

Following incubation, all cans should be inspected for swells, then at least 10% should be opened for thorough inspection of the container and contents. If no swells occur, and if the contents of all opened cans show no evidence of spoilage or pH change, the lot may be considered satisfactory.

Changes in pH and swelling of the cans after more than 2 days' incubation at 30°-37°C usually indicate under-processing. Mesophiles and facultative thermophiles will grow at these temperatures. Spoilage by organisms entering the can after processing (leaker spoilage) is usually rapid, occurring within 1-2 days.

Incubation at 50°-55°C should demonstrate obligate and facultative thermophiles, both flat sour and gas-forming types. Spoilage at these temperatures indicates that the cans may have been slowly cooled after processing. On opening, the pH should be measured to test for flat sours, and the contents examined for dark

discolorations resulting from thermophilic sulphide producers, e.g. in corn, peas, or meat packs with cereals.

Spoilage only at 37°C or above may require a recommendation for storage at temperatures well below 37°C. Spoilage at 50°-55°C but not at 37°C requires a recommendation for storage below 37°C, and indicates that the batch is unsuitable for shipping through or to the tropics.

Incubation of the first and last cans packed each day, i.e. probably the worst and best samples of the day's pack with regard to microbiological status may reveal spoilage problems within a few days of the beginning of operations.

The occurrence of swells or flat sours in a particular batch of cans from a retort or day's production of apparently sound cans suggest that under-processing occurred as a result of an error in the process or an unusually heavy contamination of spores in some ingredients. Spoiled cans distributed randomly throughout a season's pack may result from faulty double seaming, defective cans or under-sterilization from the use of a borderline process.
• For compliance with regulations

In making incubation tests to determine whether batches of canned products comply with regulations a distinction should be made between freshly processed cans and those which have been held at ambient temperatures above 20°C for four weeks or longer. Cans in the latter category may be considered to have been incubated and defective cans have probably undergone changes which could be detected without resort to microbiological culture methods. Often a whole batch may be inspected visually for swells and gross can seam defects, i.e. leaking cans or weepers. This is frequently done when bright-stacked, i.e. unlabelled, processed cans are being labelled and packed into cartons at the end of the holding period in the warehouse.

Cans that are labelled straight off the processing line may be checked in a similar manner provided the containers were held on pallets before being packed into cartons, or provided the cartons are not immediately sealed.

Sterility tests:– Sterility tests may be conducted by the cannery staff or regulatory authorities (government importing and exporting agencies). Importing and exporting countries and some government bodies may frequently check consignments of canned foods for sterility, perhaps after a fixed or standard incubation period. The cannery may conduct sterility tests to determine the possibility of

spoilage occurring in a batch of cans during storage and distribution, which may be a routine procedure or arise from the investigation of an outbreak of spoilage, or to determine the effectiveness of manufacturing processes as a guide to future processing requirements. Spoilage from all causes should not exceed 0.1%.

Sterility tests may be made in a number of ways. The cans may be opened under stringent aseptic conditions and a large sample (10-15 g) of product transferred to a suitable enrichment medium, or the can may be pierced aseptically and the product enriched with a suitable bacteriological medium, the can is then sealed and incubated.

Both these methods require good aseptic techniques and the operations should preferably be performed in a special sterile room or in a laminar flow cabinet. By transferring five or more samples in the first method, the results will indicate whether the product is consistently non-sterile and whether the contaminating organisms are similar throughout. An occasional non-sterile culture among sterile multiple samples is usually taken as an indication of contamination resulting from faulty technique.

A third method is to incubate the unopened cans and this was considered earlier. It does not strictly test for sterility if the product is unsuitable for growing heat-damaged spores but it gives the best indication of 'commercial' sterility as the exact conditions are those under which the surviving organisms have to grow.

Microbiological status of apparently sound cans

Hersom and Hulland (1980) have collated the results of several large surveys on this subject, and provide an interesting discussion of the data. The results are summarised in Table 9. The results of these surveys are disquieting to say the least, as we are not here concerned with cans that would be normally categorized as 'commercially sterile'. Commercially sterile cans are defined as cans that 'have been so processed that the food, under ordinary storage conditions will neither spoil nor endanger the health of the consumer' (Hersom and Hulland 1980).

Ruyle and Tanner (1935) (quoted in Hersom and Hulland 1980) concluded from their study and the literature that:
• canned meats show an appreciable incidence of viable bacteria
• viable bacteria frequently fail to cause spoilage even though the cans are stored under conditions favourable to spoilage
• non-heat resistant forms such as cocci have

TABLE 9

Microbiological state of apparently sound cans[A]

Survey	No. of cans in survey	Product	Non-sterile %	Type of organism	Seams
Vaillard (1900)			70-80	Cocci, sporing and non-sporing rods, moulds	
Deichstetter (1901)			0		
Weinzirl (1919)	782	Fruit, vegetables, meat, milk	23	Mainly spore formers	35.9% suspect (air-pressure test)
				Spores only (19.2% cans)	Sound
Cheyney (1919)	725	Meat, fish, vegetables, fruit incubated 37° for 10 days	8	Resistant spore forming rods, staphylococci (2 cans), mould spores (in fruit)	
Savage (1923)		Unsweetened condensed milk	18.2	Yeasts, sporing anaerobes, thermophiles, micrococci	
		Crab	100		
Savage and Hunwicke (1923)	44	Evaporated milk	18.2	Sporing rods, diplococci, thermophiles	
Nichols (1939)	315	Evaporated milk			
		Factory 1	0	Mainly spore forming aerobes	
		Factory 2	6	and anaerobes	
		Factory 3	7		
	253	Cream			
		Factory 1	0	Mainly spore forming aerobes	
		Factory 2	15	and anaerobes, cocci	
		Factory 3	24		
Candy and Nichols (1956)		Sterilized milk		Mainly *B. subtilis*, *C. thermosaccharolyticum*	
Ridgway (1958)				frequently	
Fellers (1926)	5276	Salmon	3.4	Sporing aerobes[B]($< 10/g$), obligate sporing anaerobes, non-sporing rods, cocci, moulds	
Ruyle and Tanner (1935)	559	Meats and meat products	5.5	Obligate anaerobes, sporing aerobes, facultative thermophiles, non-sporing rods, micrococci (mostly sausage and potted meat)	
Crossley (1938)	14 365	Potted meats	12.1	Spore-forming aerobes or anaerobes, non-spore formers only associated with defective samples	
Anonymous (1944)	5000	Meat and meat products	90	*B. subtilis* group	
Grosskopf and Harper (1974)		Sterilized aseptically packaged milk		Psychrotrophic *Bacillus* spp. including *B. cereus*	
Galicz (1969)	6300	Fish products	2.3 to 5.0	*Micrococcus albus, Streptococcus faecalis,* Gram-positive cocci	

[A]Adapted from Hersom and Hulland (1980).
[B]Over 50% grew in canned salmon under nearly perfect anaerobic conditions.

83

been found in cans which have been processed under conditions which would normally be expected to destroy such types
- few investigators who have examined meat products have given adequate attention to the condition of the seams of containers.

Ruyle and Tanner (1935) (quoted in Hersom and Hulland 1980) offered such explanations as: cocci may have been a stage in the life cycle of an organism more resistant than spores, the organisms are protected by fat, or cocci represent a stage in the life cycle of an organism which at other times appeared as a rod.

Hersom and Hulland (1980), after considering the rather inadequate scientific data on the fat protection theory and the air-borne contamination theory, decided that it is difficult to reach a definite conclusion concerning the bacteriological condition of sound canned foods in general. They considered the following a reasonable summary of the present position:

- Spore-forming bacteria of a heat-resistant nature are not infrequently found in commercially sound canned foods. Provided that cool storage conditions prevail, these organisms do not cause spoilage and their presence is no reflection on the heat processing conditions to which the food has been subjected.
- In fat-free canned products such as fruits and vegetables the presence of viable non-spore forming rods or cocci is an indication of under-processing or leakage of the container.
- Experimentally at least, it has been demonstrated that cocci heated in fat may survive temperatures sufficient to destroy resistant spore-forming spoilage organisms heated in aqueous media. Whether or not fat-entrapped cocci survive the pressure-processing of canned foods, the available evidence indicates that they have little or no practical significance since they remain trapped in the fat and are unable to develop.
- When viable cocci or other relative non-heat resistant forms are found in large numbers in the aqueous phase and throughout any pressure-processed canned product, their presence is the result of under-processing or container leakage.

Microbial content and status of canned cured meats

The microbiological status of sound cans of cured meat products such as hams and chopped luncheon meats requires special consideration. The pH of these products is above 5.0, but they receive a relatively low level of heat processing (F_o 0.1 to 0.6 min) to avoid excessive liberation of juices and general loss of quality. The low

process is possible because heating in the presence of curing salts reduces heat resistance and prevents outgrowth of heat-treated spores and because refrigerated storage is used in addition when necessary. The residual microflora after processing therefore differs from that found in other sound non-acid canned foods and may include cocci capable of resisting the process (Brown, Vinton and Gross 1960). It may, therefore, be difficult to differentiate between the bacterial flora associated with sound and unsound cans (see Hersom and Hulland 1980). However, the common experience in Europe and the USA is that canned hams are free of non-sporing organisms, and if not sterile, contain only relatively few (1 to 10/g) organisms, usually spores of the *Bacillus* group and *Lactobacillaceae (Strep. faecalis* and *Strep. thermophilus*). *Clostridium* spores are rarely present.

Some brands are reported to contain less than 100 bacteria per gram on the surface and in the centre (aerobic spore-formers ony) while other brands of canned hams gave counts up to 100 000 per gram at the centre, mainly cocci.

Since *B. cereus* is a food poisoning bacterium one study identified 50 strains of aerobic spore formers isolated from canned ham. The majority were *B. licheniformis, 7 B. coagulans*, 7 were similar to *B. pantothenticus* but did not produce acetyl methyl carbinol, 5 were *B. stearothermophilus*, 5 *B. laterosporus* and 3 *B. subtilis*.

The above and other such results support the view that there is an urgent need for clearly defined bacteriological standards against which the safety and stability of canned hams can be judged or assessed. Hobbs' (1955) opinion is that canned ham should be free from non-sporing organisms and have a viable count (sporing organisms only) less than 1000/g.

Goldenberg, Sheppey and Robson (1955) proposed the following specifications:

	Satisfactory	Reasonably Satisfactory
E. coli (faecal) ⎫ C. perfringens ⎬ Faecal streptococci ⎭	Absent 1 g	Absent 1 g
Total count, 37°C	< 10/g	10 to 100/g
Total count, 22°C	< 10/g	10 to 100/g
Spores	< 10/g	< 10/g
Pathogenic bacteria	Not found	Not found

The following standards were proposed at the 1st International Symposium of Food Bacteriology (International Association of Microbiological Societies, 1955).

- Pathogenic bacteria
  1. *C. botulinum* should be absent, or, if present, the conditions in the ham should

be sufficient to prevent toxin formation
2. Toxigenic clostridia such as *C. perfringens* should be absent
3. *Salmonella* and *Shigella* should be absent
4. Toxin-forming *Staphylococcus* and/or its toxin should be absent

- Bacteria indicative of inadequate processing
  1. All members of the *Enterobacteriaceae* should be absent
  2. All members of the genera *Achromobacter, Flavobacter* and *Pseudomonas* should be absent
  3. Fungi should be absent

- Bacteria related to the stability of the pack
  1. Gas-forming clostridia should be absent, except those which cannot develop in canned ham
  2. Gas-forming denitrifying bacilli may be present. If present, the cans may blow up if they are not kept in cool storage
  3. *Micrococcus denitrificans* and *Corynebacterium denitrificans* should be absent
  4. Lactobacilli which can alter the colour, taste, or smell should be absent
  5. Faecal streptococci, of Lancefield group D, should be absent

- Bacteria likely to be present, but not known to affect the quality of the pack if present in reasonable numbers.

The spores of inert clostridia, and of inert bacilli may be present, besides other inert thermoduric bacteria. The viable count of all these bacteria should not exceed 10^4 per gram. (In this context, inert means non-pathogenic and not able to change the quality of canned hams at temperatures below 5°C).

In a pack such as canned ham the possibility of the survival of non-sporing organisms through fat protection must be considered. The fact, however, that some packers consistently produce canned hams free from non-sporing organisms without obvious loss of quality from over-processing suggests that the standard proposed by Hobbs (1955) is not unrealistic.

Non-microbial methods of detection of spoilage

pH changes

Acid and gas production are the commonest non-microbial indicators of spoilage. If the pH of can contents falls during storage or incubation compared with that of control or newly/freshly processed products this is a good indicator of microbiological spoilage. Flat-sour spoilage may result in a fall of 1 pH unit or more.

Gas production

Most organisms during growth will produce gases such as CO_2, CH_4, NH_3 and varying amounts of these with loss of vacuum and swelling of the can. Determination of the headspace gases (see Bean 1976) can be useful in identifying some types of microbial spoilage and in differentiation between microbial and chemical spoilage.

Metabolites

A great variety of volatile and non-volatile metabolites are produced by organisms during growth which will not normally be present in canned foods. Detection of ethanol has long been recognized as an indicator of microbial spoilage. However, with the present availability and performance of g.c., l.c. and h.p.l.c it is possible to analyse rapidly volatile and non-volatile fractions for a wide spectrum of organic acids, esters and alcohols, resulting in a profile that can often indicate the species of the spoilage organism and even perhaps detect the presence of a particular type of *C. botulinum* (Adams *et al.* 1984; Bean 1976). Such analyses can supply very valuable supporting evidence under particular circumstances, e.g. where autosterilization has occurred.

Microcalorimetry

Microcalorimetry and other non-destructive methods such as automated vacuum testing, optical pyrometry or infra-red scanning are discussed by Bean (1976). Bean concludes "that the most practical approach to the problem of spoilage control in canned foods lies in strict control of the cannery operations to avoid spoilage, rather than monitoring the finished product for spoilage levels".

Impedance

Bacterial growth in a food sample after removal from a can or in culture can be detected by monitoring the changes in electrical impedance (Bean 1976). This method requires comparison of the electrical impedance between two cells containing a low conductivity substrate, one of which is sterile. Since many foods contain substances of relatively high conductivity it may be necessary to first separate or dilute the food sample. On the other hand, it may be possible to analyse brine samples without such treatment. Bacterial growth can be detected within a few hours by this method.

Botulism in canned foods

Botulism is the most dangerous type of food poisoning. It is caused by a heat-labile toxin produced by *C. botulinum* of which there are eight types, each producing a serologically distinct toxin. Botulism and *C. botulinum* are of

particular importance to the canning industry for the following reasons:

- *C. botulinum* produces heat-resistant spores, particularly types A, B, F and G (Table 1), and therefore all canned processes of shelf-stable foods must be adequate to inactivate these spores, i.e. the heat resistant and possible spore load of these spores determines the heat-process requirements. For non-shelf stable processes it determines the storage requirements, i.e. less than 4°C.
- The heat process selects spores and kills off competitive vegetative cells, and therefore, because *C. botulinum* is a poor competitor, a slightly inadequate heat process enhances the chance of surviving spores of *C. botulinum* growing and producing toxin.
- Canned foods are often eaten without a further heat treatment so that any toxin present will not normally be inactivated, as may occur in the case of many foods with incipient spoilage by *C. botulinum*. In some foods such as cured, salted or chilled semi-preserves and salmon it is possible for *C. botulinum* to grow and produce toxin without the noticeable normal danger signals, i.e. putrefactive odours and gas (swelling).
- *C. botulinum* is present worldwide, particularly the common heat-resistant types A and B – in the soil, on vegetables and hence in many foods, in water and canneries. Low levels of contamination of meat products occur in some countries. Since the levels in Australian soils (Murrell and Stewart 1983)

TABLE 10

Food-poisoning botulism in Australia

Year	Food	Location	Type	Remarks	Ref.
1942	Canned beetroot	N T		31 cases 8 deaths	Gray (1948)
1957	Home-preserved beetroot	Gunnedah NSW		15 cases 0 deaths	Dept Publ. Hlth NSW (1957)
1963	Home-preserved cantaloup	Garden-vale, Vic.	A	1 case 1 death	Bennett and Stevenson (1964)
1966	Canned tuna	Merri-wagga, NSW	E?	2 cases 0 deaths	Bennett *et al.* (1968)
1983	Canned mushrooms	Griffith, NSW		4 cases 0 deaths	Unpub-lished

appear to be much lower than in countries such as the USA, Scandinavian and mid-European countries, this may be one reason why Australia has had relatively fewer problems of botulism from canned food (Table 10).

The increased significance of botulism from post-process leakage chiefly in California (Johnson *et al.* 1963) and in Alaskan salmon (Table 8) has resulted in the 1984 Canned Salmon Control Plan, a voluntary cooperative agreement between participating salmon packers, the National Food Processors

TABLE 11

Recommended standards for the spore content of ingredients for canned foods

Ingredient	Reference	Flat-sour	Sulphide spoilage (H_2S-producing anaerobes)	Thermophilic anaerobes (non-H_2S-producers)	Thermophilic gas-producers	Total thermophiles (non-acid + acid producers)
			Bacterial spore content (no./g)			
Sugar and starch	A	≯ 7.5 (5 samples) average ≯ 5.0	≯ 2/5 samples positive	≯ 3/5 samples positive		≯ 15 (5 samples) Average ≯ 12.5
			≯ 5 spores/ 10 g in any 1 sample	≯ 4/5 tubes in any 1 sample		
	B	≯ 1	≯ 0.1		0/6 tubes	≯ 10

[A]Clark and Tanner (1937): Heat treatment 100°C for 30 min.
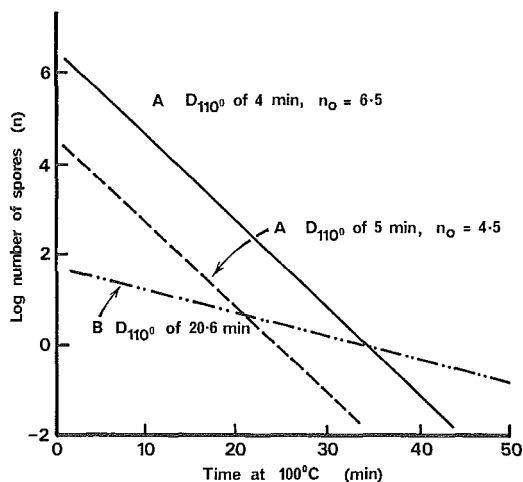[B]South African Bureau of Standards (1952): Heat treatment 110°C for 30 min.

Fig. 1. Survivor curves of spores of organism A and B. A low concentration of B in a product may not be inactivated by a process designed to inactivate a much higher concentration of organism A. A 100-fold increase in concentration of A increases the inactivation time from 24 to 35 min at 110°C.

Association and the Federal Food and Drug Administration. This lays down requirements for compliance with the plan, plant inspections, book-keeping (e.g. lots, codes and units of control), sampling procedures, shipments, warehousing, procedures for reconditioning or destruction, container integrity examinations (use of low-vacuum detectors and check-weighers), procedures for handling post-process deviations, and in-plant conditions.

Quality control programs to prevent botulism are discussed elsewhere (Gordon and Murrell 1967; Murrell 1979).

Raw materials sampling

Since ingredients of canned foods such as spices, sugar, starch, flour and salt may be major contributors to the spore load, and hence reduce the effectiveness of a calculated process (see Fig. 1) it is essential as a QC procedure to monitor the spore load of these ingredients, and preferably only buy batches that comply with the in-house or recommended standards (Table 11).

Methods for making spore counts of the various types of bacteria for several ingredients are given in Hersom and Hulland (1980).

In some products limits on specific species of spores should be adhered to, e.g. *Byssochlamys fulva* spores in pasteurized canned fruit juices, *C. thermosaccharolyticum* in maize products.

Regulations and guidelines

Within Australia the Australian Defence

TABLE 12

International specifications for canned foods[A]

Reference	Product	Stage
Alinorm 85/13	Natural mineral waters	Working group
Code Alimentarius Commission Vol. G	Low acid canned foods, Code of Hygienic Practice	Working group
	Acidified low-acid, canned foods, Code of Hygienic Practice	Working group
CAC/RCP 23-1979 FAO/WHO 1983	Recommended International Code of Practice for low-acid and acidified low-acid canned foods	1st Edition
Alinorm 85/13 Apendix III CX/FH 84/4	Visual and tear-down inspection of cans for defects	Joint FAO/WHO Working group[B]
Alinorm 83/16 Appendix III	Sampling and inspection procedures for microbiological examination of meat products in hermetically sealed containers	Step 6[C]
CX/FH 82/7 83/13 Appendix VII	Code of practice for the salvaging of suspect damaged canned products	Step 4

[A]Joint FAO/WHO Food Standards Program, Codex Alimentarius Commission
[B]Illustrated document in preparation
[C]Recommended Code to be reviewed at next session

Force Food Specifications lay down specifications and guidelines for many canned foods and processors should be familiar with these, as they are accepted generally by the industry. At the international level, guidelines, good manufacturing practice and regulations for several types of product are being developed as shown in Table 12.

The Commonwealth Department of Health has recently discussed problems relating to holding of lots for investigation, recall procedures for suspect lots, and testing. The Council of Australian Food Technology Association (CAFTA) has drafted a recall procedure which has been circulated to all member companies for comment or modification.

References

Adams, D. M. (1978). Heat injury of bacterial spores. *Advances in Applied Microbiology* 23, 245-61.
Adams, R. F., Jones, R. L., and Conway, P. L. (1984). High-

performance liquid chromatography of microbial acid metabolites. *Journal of Chromatography* 336, 125-37.

Anon. (1971). Epidemiological notes and reports. Botulism associated with commercially canned vichyssoise. *Morbidity and Mortality Weekly Report* 20, 242.

Anon. (1974). Type A botulism due to a commercial product – Georgia. *Morbidity and Mortality Weekly Report* 24, 417-8.

Anon. (1978a). FDA theorizes on route of contamination of salmon. *Food Chemical News* August 28, 20, 23-4.

Anon (1978b). NFPA theorizes can of salmon was damaged by a band saw. *Food Chemical News* 20, 40-1.

Anon (1982a). Canned salmon recall industry wide and international implications. Annual Report. NFPA Research Laboratories: Washington D.C.

Anon. (1982b). FDA issues news release on withdrawal of canned tomatoes. *Food Chemical News* 24, 22.

Anon. (1983a) Container integrity: regulatory focus centre in 1983. 1983 Annual Report. NFPA Research Laboratories: Washington D.C.

Anon. (1983b). Effect of in-plant sanitation on microbial loads in salmon canneries. 1983 Annual Report. NFPA Research Laboratories. Washington D.C.

Aschehoug, V., and Jansen, E. (1950). Studies on putrefactive anaerobes as spoilage agents in canned foods. *Food Research* 16, 62-7.

Bashford, T. E., Gillespy, T. G., and Tomlinson, A. J. H. (1960). Staphylococcal food poisoning associated with processed peas. The Fruit and Vegetable Canning and Quick Freezing Res. Assoc. Chipping Campden, Gloucest.

Bean, P. G. (1976). Microbiological techniques in the examination of canned foods. *Laboratory Practice* (May), 303-7.

Bennett, N. M., and Stevenson, W. J. (1964). A case of human botulism due to home-preserved cantaloup. *Medical Journal of Australia* 1, 758-9.

Bennett, N. M., Forbes, J. A., Lucas, C. R., and Kucers, A. (1968). Botulism: a report of two cases. *Medical Journal of Australia* 1, 804-6.

Brown, W. L., Vinton, C. A., and Gross, C. E. (1960). Heat resistance and growth characteristics of microorganisms isolated from semi-perishable canned hams. *Food Research* 25, 345-50.

Clark, F. M., and Dehr, A. (1947). A study of butyric acid producing anaerobes isolated from spoiled canned tomatoes. *Food Research* 12, 122-8.

Clark, F. M., and Tanner, F. W. (1937). Thermophilic canned-food spoilage organisms in sugar and starch. *Food Research* 2, 27-39.

Clark, F. M., and Tanner, F. W. (1939). Thermophilic organisms in starch and sugar. *Food Manufacture* 14, 387-9.

Clark, F. M., and Tanner, F. W. (1940). Thermophilic organisms in starch and sugar. *Food Manufacture* 15, 39-44.

Davidson, P. M., and Pflug, I. J. (1981). Leakage potential of swelled cans of low-acid foods collected from supermarkets. *Journal of Food Protection* 44, 692-5.

Davidson, P. M., Pflug, I. J., and Smith, G. M. (1981).

Microbiological analysis of food product in swelled cans of low-acid foods collected from supermarkets. *Journal of Food Protection* 44, 686-91.

Department of Public Health, NSW (1957). Botulism in New South Wales. Department of Public Health, NSW. *Monthly Bulletin* 3, 1.

Foegeding, P. M., and Busta, F. F. (1981). Bacterial spore injury – an update. *Journal of Food Protection* 44, 776-86.

Geiger, J. C. (1941). An outbreak of botulism. *Journal of American Medical Association* 117, 22.

Goldenburg, N., Sheppey, C. G., and Robson, J. N. (1955). Int. Symp. on Food Bacteriology. *Annales de L'Institut Pasteur de Lille* 7, 240.

Gordon, R. A., and Murrell, W. G. (1967). Botulism. A review of the present situation. *CSIRO Food Preservation Quarterly* 27, 6-18.

Graves, R. R., Lesniewski, R. S., and Lake, D. E. (1977). Bacteriological quality of cannery cooling water. *Journal of Food Science* 42, 1280-5.

Gray, D. F. (1948). Human botulism in Australia. *Medical Journal of Australia* 1, 37.

Hersom, A. C., and Hulland, E. D. (1969). Canned foods: an introduction to their microbiology. 6th ed. (J. and A. Churchill: London).

Hersom, A. C., and Hulland, E. D. (1980). Canned foods: an introduction to their microbiology. 7th ed. (J. and A. Churchill: Edinburgh).

Hobbs, B. C. (1955). The laboratory investigation of non-sterile canned hams. 1st International Symposium on Food Bacteriology, *Annales de l'Institut Pasteur de Lille* 7, 190-202.

International Association of Microbiology Societies (1955). 1st International Symposium on Food Bacteriology. Bacteriology of Semi-preserved Meats. *Annales de l'Institut Pasteur de Lille* Vol. VII (Editions Medicales Flammarion: Paris).

Jansen, E., and Aschehoug, V. (1951). *Bacillus* as spoilage organisms in canned foods. *Food Research* 16, 457-61.

Johnson, R. W., Feldman, J., and Sullivan, R. (1963). Botulism from canned tuna fish. *Public Health Reports* 78, 561-4.

Lynt, R. K., Solomon, H. M., and Kautter, D. A. (1984). Heat resistance of *Clostridium botulinum* type G in phosphate buffer. *Journal of Food Protection* 47, 463-6.

Meyer, K. F., and Eddie, B. (1965). Sixty-five years of human botulism in the United States and Canada. p.78. Univ. of California: Davis.

Milne, D. (1964). The Aberdeen typhoid outbreak. Report of the Dept. Committee of Enquiry, Scottish Home and Health Dept. Cmnd. 2542.

Murrell, W. G. (1978) The spoilage of canned foods. *Food Technology in Australia* 30, 381-4.

Murrell, W. G. (1979) *Clostridium botulinum*. Food-borne microorganisms of public health significance. 3rd Ed. Buckle, K. A., Davey, G. R., Eyles, M. J., Fleet, G. H., and Murrell, W. G., eds Sydney: AIFST-CSIRO-UNSW.

Murrell, W. G., Olsen, A. M., and Scott, W. J. (1950). The enumeration of heated bacterial spores. II. Experiments with *Bacillus* spores. *Australian Journal of Scientific Research*

Series B. **3**, 234-44.

Murrell, W. G., and Stewart, B. J. (1983). Botulism in New South Wales, 1980-1981. *Medical Journal of Australia* **1**, 13.

Odlaug, T. E., and Pflug, I. J. (1976). Sporocidal properties of chlorine compounds: applicability to cooling water for canned foods. *Journal of Milk and Food Technology* **39**, 493-8.

Odlaug, T. E., and Pflug, I. J. (1978). Microbiological and sanitizer analysis of water used for cooling containers of food in commercial canning factories in Minnesota and Wisconsin. *Journal of Food Science* **43**, 954-63.

Olsen, A. M., and Scott, W. J. (1950). The enumeration of heated bacterial spores. I. Experiments with *Clostridium botulinum* and other species of *Clostridium*. *Australian Journal of Scientific Research Series B* **3**, 219-33.

Pflug, I. J., Davidson, P. M. and Holcomb, R. G. (1981). Incidence of canned food spoilage at the retail level. *Journal of Food Protection* **44**, 682-5.

Put, H. M. C., van Doren, H., Warner, W. R., and Kruiswijk, J. T. (1972). The mechanism of microbiological leaker spoilage of canned foods: a review. *Journal of Applied Bacteriology* **35**, 7-27.

Russell, A. D. (1982) The destruction of bacterial spores. (Academic Press: London).

Segner, W. P. (1979). Mesophilic aerobic sporeforming bacteria in the spoilage of low-acid canned foods. *Food Technology* **33**, 55-9, 80.

South African Bureau of Standards (1952). Standard specification for canners' sucrose. SABS 420-1952. (Council of the South African Bureau of Standards: Pretoria).

Splittstoesser, D. F., and Splittstoesser, C. M. (1977). Ascospores of *Byssochlamys fulva* compared with those of a heat resistant *Aspergillus*. *Journal of Food Science* **42**, 685-8.

Stersky, A., Todd, E., and Pivnick H. (1980). Food poisoning associated with post-process leakage (PPL) in canned foods. *Journal of Food Protection* **43**, 465-76.

Thompson, R. C. (1982). The tin of salmon had but a tiny hole. *FDA Consumer* **16**, 7-9.

Appendix

Trade terms to describe types of spoilage and comments

Flat sours

- Flat can, concave ends
- greater acidity than normal
- no gas, decomposition stopped in acid stage (therefore not readily detected from exterior)
- cause – understerilized or leaky cans (unlikely as leaker contaminants not likely to be all non-gas producers)
- thermophiles especially important

Swells

- bulged ends
- causes – biological – gas forming bacteria
        chemical – H_2 – action of contents of can on container
        – chemical decomposition of material in can
    overfilling at low temperatures
    altitude

Breathers

- probably bacteriologically tight but not 'airtight'
- low vacuum
- spoilage point of view probably not important due to filter action on organisms

Springers

- slightly bulged
- potential bacterial or chemical swells
- causes – improper exhausting, cold packing
- organism may be weak gas producer – type of metabolism
- one or several factors may be involved in cause
- usually reduced by methods of canning which ensure good vacuum – proper exhaustion, proper filling, leaving a little headspace

Flippers

- ends driven out by striking against a hard object
- due to insufficient exhaust, loss of vacuum

Springers ⎫
flippers ⎬ relative terms
swells ⎭

flipper → springer → swell
            under
            different
            temp
            conditions

In the trade – "swell" – spoiled can; "flipper" and "springer" – not necessarily spoiled

Buckled can

- rough handling
- insufficient exhaust
- overfilling
- large diameter cans (No. 10) – buckles can scarcely be avoided with heavy process unless the cans are cooled under pressure.

Alternative methods of applying extra low voltage electrical stimulation

By V. H. Powell, P. V. Harris, W. R. Shorthose, N. G. McPhail and R. F. Dickinson

CSIRO Division of Food Research, Cannon Hill, Queensland, 4170

Cattle are slaughtered for the Muslim market by a transverse cut severing the throat. The head hangs lower, making insertion of the extra low voltage electrical stimulation nostril electrode difficult, in some plants. Alternative methods of applying the electrodes were evaluated.

If nostril application is impractical, then equivalent results could be obtained by placing an active electrode into the anus and earthing through a rubbing bar contacting the neck.

With the nostril probe as the active electrode, severing of either the throat (Halal slaughter) or the spinal cord (pithing) had no effect on the efficacy of extra low voltage electrical stimulation.

Introduction

When cattle are slaughtered for the Muslim market the neck is almost completely severed. The head hangs lower, making insertion of the nostril probe of the extra low voltage electrical stimulation (ELV ES) system difficult in some plants. The probe may also contact grating or work platforms, with the possibility of dislodgment or a short circuit.

It was shown previously (Powell *et al.* unpublished data 1983) that incorrect insertion of the nostril probe in either the tip of the nose or the stick wound resulted in ineffective ES. Preliminary experiments also indicated that once the animal's throat was cut for Halal slaughter, nostril to anus or nostril to leg ES was ineffective. Morton and Newbold (1982) demonstrated that a functional nervous system was necessary for ELV ES to be effective.

In some smaller plants the head is removed in the bleeding area, making use of a nostril probe impractical. It was therefore desirable that effective, alternative application point(s) for the electrode be found.

Procedure

Electrical stimulation system

Carcasses were electrically stimulated in two meatworks (plants A and B), one to four minutes (plant A) or four to nine minutes (plant B) after stunning, using a Koch-Britton 150 LV stimulator operating at 45 V for 44 seconds. The ES system was part of the meatworks' normal operations.

Materials and design

The bodies of 175 cattle (carcass dressed weight 96-403 kg, and 0-33 mm fat depth) were assigned to the following treatments:

T1 nostril to anal earth ES
T2 nostril to anal earth ES – pithed
T3 nostril to anal earth ES – Halal slaughter
T4 anus to nostril earth ES
T5 anus to back of neck earth ES
T6 non-ES control

T1:– ES was applied by the normal method of inserting an active hook electrode deep into the nostril and an earthed probe into the anus.

T2:– The electrodes were attached as in T1, but the spinal cord was severed prior to ES by inserting a knife between the skull and the first cervical vertebra.

T3:– The animals were slaughtered by the Halal method of a transverse knife cut, severing the trachea, oesophagus, arteries and veins of the neck. The electrodes were attached as in T1.

T4:– The electrodes were again attached as in T1, but the polarity was reversed so that the anal probe became the active electrode.

T5:– Again the anal probe was the active electrode, but the earthed nostril probe was manually held firmly against the back of the neck.

T6: The carcasses of the control animals were not stimulated, pithed or Halal slaughtered (except in plant B, where control animals were Halal slaughtered).

Muscle sampling

On completion of slaughter and dressing, the carcasses were chilled for approximately 20 hours at an air temperature of 7°-8°C, which reduced the loin centre temperature to below 10°C within 15 hours. After chilling, the sides were quartered between the 12th and 13th ribs, and approximately 50 mm of the striploin
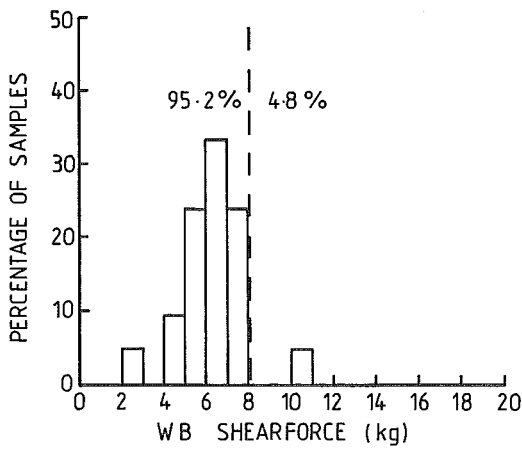
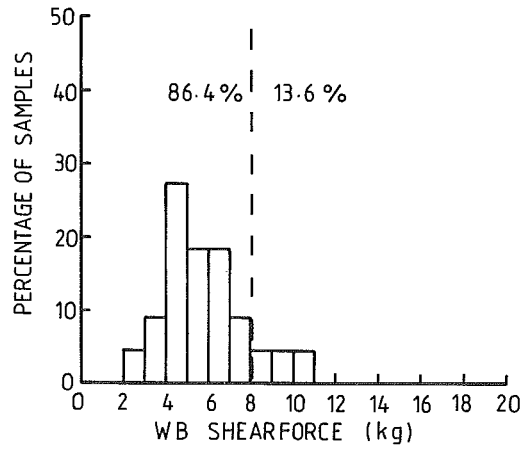Fig. 1. (a) Histogram of WB shear force measurements for treatment T1.

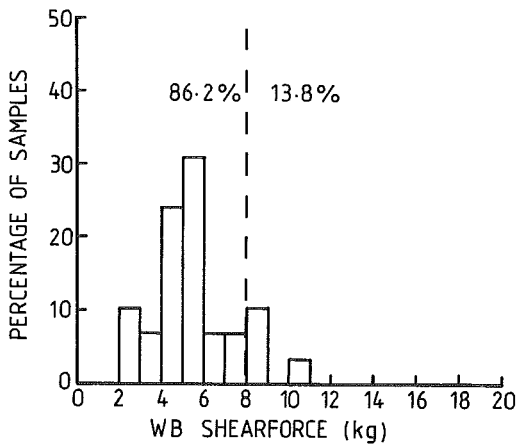Fig. 1 (b). Histogram of WB shear forced measurements for treatment T2.

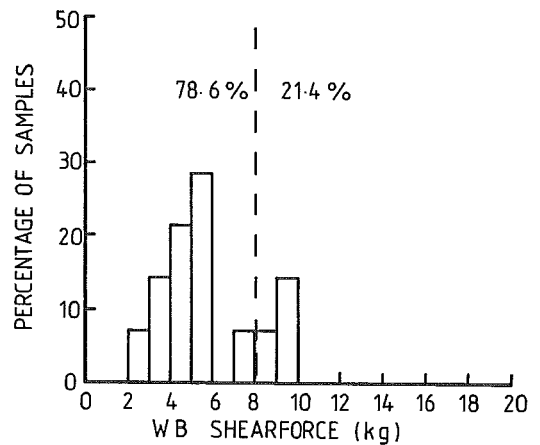Fig. 1 (c). Histogram of WB shear force measurements for treatment T3.

Fig. 1 (d). Histogram of WB shear force measurements for treatment T4.
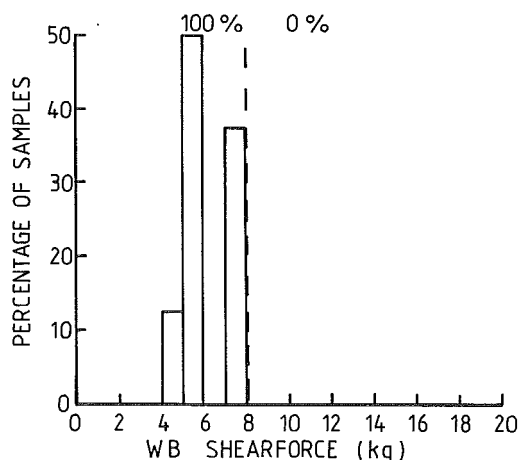
Fig. 1. (e) Histogram of WB shear force measurements for treatment T5.

Fig. 1 (f). Histogram of WB shear force measurements for treatment T6.

(*Longissimus dorsi* – LD) was removed from the hindquarter and transported to the laboratory for tenderness evaluation.

pH measurement and cooking treatment

At the laboratory the muscle pH was measured using a probe type combined glass pH electrode (Philips C63/1) with a digital meter (Watson Victor Model 5004). The results from muscles with pH values ≥ 5.8 were excluded.

A sample weighing 140-160 g was removed from each muscle, placed in a polyethylene bag which was fastened with a metal clip, and cooked totally immersed in water controlled at $80° \pm 0.5°C$ for one hour. After cooking, the samples were cooled in running water for at least 30 minutes before drying and storing overnight in polyethylene bags at $0°$-$1°C$.

Warner Bratzler shear measurement

The WB shear device used and the parameters measured from the shear force deformation curves have been described in detail elsewhere (Bouton *et al.* 1978). The cooked samples were cut to give five to six subsamples, each about 4-6 cm long, of rectangular cross section (15 x 7 mm) with the muscle fibres lying parallel to the greatest length.

Results and discussion

The results of the WB shear force measurements for the six treatment groups are given in Table 1.
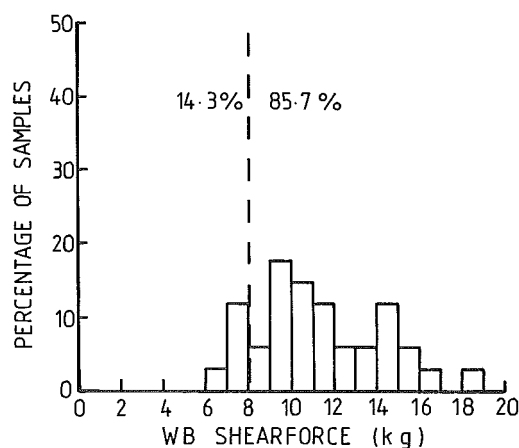
TABLE 1

WB initial yield force measurements (kg) obtained for LD muscle samples

TI (n = 21)[A]	T2 (n = 22)	T3 (n = 29)	T4 (n = 14)	T5 (n = 8)	T6 (n = 34)
6.3	5.8	5.6	5.9	6.0	11.4

[A]Number of animals per group (ultimate pH < 5.8)

The mean shear values for each ES treatment were similar and were significantly lower than the mean of the unstimulated control (T6).

Figs 1(a)-1(f) show histograms of the WB shear force measurements for the six treatments. The histograms show the percentage of samples in each shear force range (i.e. 2-3 kg, 3-4 kg, 4-5 kg, etc.). Samples with a shear force value of < 8 kg are considered acceptably tender (Powell *et al.* 1984). The percentage of samples classified as acceptably tender ranged from 79% for anus to nose ES, to 100% for anus to neck. Only 14% of the control samples were deemed tender.

All ES application methods produced acceptable results. Preliminary results which indicated that after Halal slaughter, nose application of ES was ineffective, were not reproduced in the present experiment. Severing the spinal cord by pithing did not alter the effectiveness of ELV ES when conventional sticking was employed. This demonstrates that pathways other than the spinal cord must exist for transmission of the ELV electrical signals.

If the nostril electrode for nose to leg or anus ES is difficult to apply, the current path may be reversed by inserting the active electrode into the anus and returning through either a rubbing bar contacting the back of the neck or shoulder, or a spear probe in the severed neck area.

Conclusions

Severing the neck (Halal slaughter) or the spinal cord (pithing) failed to reduce the effectiveness of ELV ES in the nostril/leg configuration. If the normal nostril to leg or nostril to anus method of applying ELV is unsuitable, the anal probe may be made active with the current return path *via* either a rubbing bar contacting the neck or shoulder, or a probe inserted in the severed neck area.

References

Bouton, P. E., Ford, A. L., Harris, P. V., and Shaw, F. D. (1978). Effect of low voltage stimulation of beef carcasses on muscle tenderness and pH. *Journal Food Science* 43, 1392

Morton, H. C., and Newbold, R. P. (1982). Pathways of high and low voltage electrical stimulation in sheep carcasses. *Meat Science* 7, 285-97.

Powell, V. H., Dickinson, R. F., McPhail, N. G., Bouton, P. E., and Harris, P. V. (1984). Evaluation of extra low voltage electrical stimulation systems for bovine carcasses. *Journal Food Science* 49, 363.

News from the Division

Review of the Division of Food Research

As reported previously (Vol. 44, No. 1), the research program of the Division was reviewed in March, 1985. A draft of the Review Committee's report was made available to the Division for comment early in October and the report has now been finalized. At the time of writing its findings are being examined by the CSIRO Executive, whose major decisions will be published in the next issue of the Quarterly.

Awards

CSIRO Overseas Study Awards for 1985 were won by Mr R. D. Lipscomb and Mr P. M. Husband giving the Division of Food Research the highest number of such awards since the scheme was established in 1976 as the Jubilee Awards (to mark the 50th year of the Organization). Other winners were Mr I. R. Mc Donald (Divisional Secretary), Mr P. J. Rutledge and Mr D. R. Smith (Extension Officers at FRL and MRL respectively), Ms Sue Collins (DRL Librarian) and Ms Ailsa Hocking and Mr G. R. Chaplin (Experimental Scientists at FRL).

Roger Lipscomb will spend about four months in the United Kingdom, Norway and the Netherlands in 1986, studying a) management methods and styles in research organizations similar to CSIRO, particularly those that have recently undergone changes and b) methods of administration and management of foreign aid and development programs in science and technology.

Peter Husband, MRL's extension officer based in Perth, WA, will go to the US, Canada, the UK and Europe for about four months in mid-1986 to visit research and academic institutions, materials' suppliers and equipment manufacturers specializing in packaging, to add to his expertise in meat and seafood processing.

Dr D. Graham, Leader of FRL's Plant Physiology Group, has been elected to Fellowship of the Institute of Biology (London).

Retirements and transfer

J. R. Vickery

Dr J. R. Vickery, OBE, MSc, PhD, FRACI, FAIFST, FIFST, FTS Foundation Chief of the Division, relinquished his position as Honorary Research Fellow on 22 November 1985. Dr Vickery formally retired from CSIRO in 1967 at the age of 65; Food Research Quarterly Vol. 27, No. 3 (September 1967), the James Richard Vickery Commemorative Issue, recorded some of his achievements until then. To say that Dr Vickery has led a full and active life in his (first) retirement would be a gross understatement. Since 1967 he has published more than 20 scientific papers on lipids and on chemical aspects of plant taxonomy, served on numerous committees and continued to fully participate in scientific meetings – both at FRL and elsewhere.

Dr Vickery's research career spans 61 years, having commenced with studies on the freezing of beef at the University of Melbourne in 1924. In 1931, after returning from work at the Low Temperature Research Station in Cambridge, he took charge of food research in CSIR; the Section became the Division of Food Preservation and Transport in 1940, with Dr Vickery as Chief. His colleagues, past and present, in Australia and overseas, wish him continuing good health and many more years of – this time – real retirement.

L. S. Herbert

Len Herbert loosened his ties with the Meat Research Laboratory in September 1985 by his decision to retire shortly after his 60th birthday. However, his former colleagues will continue to see and hear of and from him as Len establishes himself as an engineering consultant to the meat industry.

As a graduate in chemical engineering from London University, Mr Herbert was a Research Officer in the UK Explosives Research and Development Establishment before his appointment in 1959 to the CSIRO Division of Chemical Engineering. A basic interest in heat and mass transfer, initially directed to problems of desalination, led to his being contracted in 1968 by the Australian

Meat Research Committee to study the batch rendering process. He was thus well placed to become a senior member of staff in the Division of Food Research's rapidly expanding Meat Research Laboratory. In 1970 he joined that Laboratory as Leader of the Physics and Engineering Group.

Mr Herbert made numerous further contributions to the meat industry during the next 15 years. Always practically-orientated, he became the Division's interface with industry on detailed matters concerning rendering, refrigeration, loss of product weight through evaporative loss of moisture, accelerated processing of carcasses, wastewater treatment and energy conservation. His leadership of many wide-ranging research projects was characterized by an enviable capacity for precise organization and the maximization of returns for effort expended.

Len Herbert has left the Division substantially enriched in knowledge and experience in several engineering-related fields. Our appreciation of his professional contributions and his genial conviviality goes with him as he enters retirement.   D.J.W.

G. Moore

At a joint function on 22 November the staff of FRL farewelled Roger Lipscomb and Geoff Moore. Geoff joined the Division in 1962 and has been Driver and Transport Officer and acting Purchasing Officer as well as fulfilling many other and varied functions in the Administration. Geoff is taking early retirement.

Transfer – R. D. Lipscomb

Mr R.D. (Roger) Lipscomb, FRL's Administrative Officer since 1972, has transferred to the new CSIRO Division of Information Technology as its Divisional Secretary. He will be replaced by Ms C. E. Read from CSIRO Headquarters in Canberra. (See also paragraph headed 'Awards'.)

Return to Australia

Dr Alex Buchanan, FTS, formerly of DRL, has returned to Australia after spending 12 years in South East Asia. From 1973-75 he was at the Institute of Food Research and Product Development, Kasetsart University, Bangkok where he successfully developed a weaning food which was produced commercially by four manufacturers in

Thailand. From 1975 to 1985 he was based in Kuala Lumpur as the Australian Scientific Liaison Officer to the ASEAN-Australia Economic Cooperation Program which developed, during this time, into a \$A13m per annum program, including \$A6m per annum on food research and development projects. CSIRO has now extended the secondment of Dr Buchanan as a specialist adviser to the Australian Development Assistance Bureau (ADAB) where his duties include frequent brief
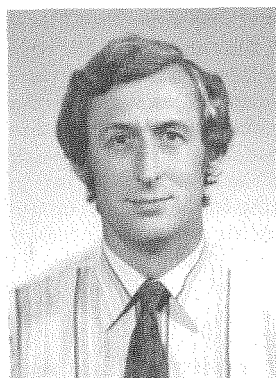
visits overseas from a base in Melbourne. His place in Kuala Lumpur will be taken by Mr Peter Hodge of ADAB. Dr Buchanan's contributions to science and technology were recognized this year by his election as a Fellow of the Australian Academy of Technological Sciences.

Visits to the Division by Federal Parliamentarians

There have been three visits by Federal Members of Parliament to FRL during the last few months; Hon. Russ Gorman (ALP), the Member for Greenway, Hon. Michael Maher (ALP), the Member for Lowe, and Senator Chris Puplick (Lib). These visits were organized by the NSW branch of the CSIRO Officers Association (OA) as part of a national scheme that has as one of its aims the improvement of communications between politicians and CSIRO scientists. The enthusiasm shown for these visits by parliamentarians, OA members and Chiefs of Divisions suggests that they are worthwhile. The OA hopes that by enabling parliamentarians to gain first-hand knowledge of some of CSIRO's research, the image of

science and technology will be enhanced at government level.

Australian aid to Bhutan

In Vol. 40, pp 43-44 and Vol 41, pp 58-59 and 87 of the Quarterly we described the first phase of the project which aimed at improving post-harvest horticulture in Bhutan. Phase two (Vol. 44, p. 24), including the construction of the cool store for horticultural produce, is now complete and the five Bhutanese who were mentioned in the March 1984 issue have returned to their homeland. The project has now entered a new phase: three ex-trainees employed by the Food Corporation of Bhutan to run the refrigeration plant have so impressed their superiors that the Bhutanese have requested similar training in refrigeration technology for three more plant operators. These three arrived in Australia in November 1985 and will receive two months intensive training in the English language before commencing a composite refrigeration course at Sydney Technical College. The trainees are Shyam Chhetri, Tshering Namgay and Purna Tamang. They will return to Bhutan in December 1986.

During their stay in Australia the visitors are attached to FRL and, under the supervision of Mr G. B. Morgan, will gain practical experience at these laboratories, as well as undertaking field trips in New South Wales.

Visiting Scientists

The Division has had two longer-term visiting scientists, Dr R. B. Duckworth and Dr M. Dalla Rosa, working at FRL with Dr R. J. Steele on the effects of pretreatments on sorption properties of foods.

Dr Ron Duckworth is from the Food Science Division of the Department of Bioscience and Biotechnology at the University of Strathclyde. His studies on the properties of water in food are known around the world and the international ISOPOW meetings on properties of water in foods are often referred to as the "Duckworth meetings" in recognition of his contribution to this field of science.

Dr Marco Dalla Rosa is from the Agricultural Institute of the University of Bologna and was granted a scholarship by the Italian Government to work in the Division from August to November 1985. He has a wide range of interests in food technology, such as kiwifruit processing, drying and freeze-drying of foods and milk derivatives, meat and meat products and coffee technology.

His current interests in water activity have led to a survey of several methods for measuring water activity including gas chromatography and electric hygrometry.

He has been working with Dr Steele on the effect of sulphur dioxide pretreatments on the drying rate of apples.

96