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The author of this article, who is Head of the Department of Poultry Husbandry in the University of California, has recently spent nine months in the C.S.I.R.O. Division of Food Preservation and Transport as a Senior Research Scholar under the Fulbright Programme. Professor Stewart is an acknowledged authority on eggs and egg products.

Factors Influencing the

THE egg dehydration industry is a very important segment of today's poultry industry in the United States. This is true despite the prediction made that it would collapse or at least shrink to very small dimensions after World War II. The healthy state of the industry is due to the fact that its leaders have devoted themselves to producing some reasonably priced, high-quality products which are superior, in one way or another, to shell eggs or egg pulp.

Fortunately, a good deal of research has been done on egg solids over the past 15 years. The results of this work have made it possible to produce several high-quality products at reasonable cost. However, there is need for additional research and development before it will be possible for egg solids to compete fully with egg pulp.

In this article we will critically review the research and development work which has been done on egg solids. From this we can ascertain the problems of producing and marketing high-quality products, as well as how far research has progressed in obtaining satisfactory answers to these problems. Finally we will indicate some remaining problems requiring additional research, and suggest methods for their solution.

QUALITY CRITERIA

Food technologists define the quality of a food in terms of a number of attributes. The table below lists these for egg solids. Thus, by these criteria egg solids should be palatable and safe to consume, and should supply essential nutrients for human needs, perform essential functions in the preparation of certain dishes, and have sufficient storage life for economic distribution to users. While all of these attributes of quality are important, the most critical ones in the case of egg solids are: palatability, functional properties, and storage life. This is because the dehydration of eggs creates special problems not encountered in the handling of shell eggs or pulp. Therefore, in the discussion to follow we will restrict ourselves to the problems involved in producing egg solids of good palatability with excellent functional properties and adequate storage stability.

Quality Criteria for Egg Solids

Quality	Remarks
1. Palatability	Includes appearance (including colour), odour and flavour, and texture (in cooked form)
2. Safety	Depends on freedom from toxic principles and disease-producing organisms
3. Nutritive value	Depends on nutrient composition, digestibility, and availability of nutrients
4. Functional properties	
(*a*) Beating and leavening powers	Tested in meringues and confectionery, angel and sponge cakes, and in butter cakes
(*b*) Coagulation	Tested in custards, cakes, and confectionery
(*c*) Anti-staling power	Tested in cakes and doughnuts
(*d*) Emulsification	Tested in salad dressings and cakes
5. Storage life	Depends on retention of palatability, nutritive value, and functional properties

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Quality of Dried Egg Products

EFFECTS OF DEHYDRATION

Albumen

The most obvious factor which must be controlled in drying egg-white is temperature. Even before visible coagulation occurs, damage to the beating and leavening properties is observed (Slosberg *et al.* 1948). In practice liquid temperatures during drying are kept well below 130°F. Although the dried product itself is definitely more tolerant to heat, temperatures should be kept reasonably low (usually below 180°F).

The heating and leavening powers of egg-white are very sensitive to the presence of yolk (particularly the free egg oil). Every attempt is made in the commercial separation of yolk and white to avoid contamination of the latter. Bergquist and Wells (1956) have devised a very sensitive method which is widely used in the United States for determining the extent of yolk contamination.

Tolerance to yolk contamination can be increased somewhat by the incorporation into the liquid egg-white of certain surface-active compounds. At the moment only triethyl citrate is approved for this purpose in the United States (Kathe 1953).

In the United States albumen solids are produced commercially by pan drying, foam drying, and spray drying. While the first two of these methods produce products of good functional powers, spray drying frequently results in products which do not whip or produce satisfactory angel cakes.* Bergquist and Stewart (1952*a*, 1952*b*) have shown that the rate and extent of surface formation, and shear (i.e. the cutting action encountered as the egg passes through the small orifice of the atomizing nozzle) are important factors in producing satisfactory products by spray drying. To date the only way to exercise satisfactory control over these factors is by the use of two-fluid atomizers, or the single-fluid pressure atomization system with lower pressures.

* A very popular American cake made from egg-white, sugar, and flour, with cream of tartar and flavouring. The volume of the cake is entirely dependent on the air incorporated by beating the egg-white prior to adding flour.

Yolk and Yolk-Albumen Mixtures

As with albumen close attention must be paid to temperatures in drying yolk and yolk-albumen mixtures (Hanson, Lowed, and Stewart 1947). However, liquid yolk and yolk-white mixtures are more tolerant to heat than is egg-white, and temperatures up to 158–160°F are frequently used. As with albumen, dried yolk is more tolerant to heat than the liquid. In the dryer the product is usually kept below 140°F and after drying is promptly cooled to below 90°F before packaging.

Yolk and yolk-albumen mixtures are usually produced by spray drying in the United States. While the products so produced perform very well in cakes containing butter or shortening and in doughnuts, they are definitely inferior to pulp for salad dressings and sponge cakes. The work of Joslin and Proctor (1954) showed that it is the breaking of the natural oil-in-water emulsion in the yolk which is responsible for the loss in the beating, leavening, and emulsification properties of these products.

Apparently Brooks and Hawthorne (1943) were the first to discover that certain sugars (particularly sucrose and lactose), added to whole-egg pulp prior to spray drying, prevent the loss of these properties. Bergquist (personal communication 1956) has shown that the same is true of yolk. Thus, when

10–15 per cent. of sucrose or lactose is added to liquid whole-egg or yolk, all of the functional properties of these products are retained during drying.

Unfortunately, these "sugar-dried" products are not stable during storage and develop a very characteristic off-odour and flavour (Conrad *et al.* 1948). In fact this off-odour and flavour is sometimes apparent in the powder as it is removed from the spray dryer. This defect will be discussed further under Storage Life Problems.

It is interesting to note that no other method of preventing the above-mentioned losses in functional properties of yolk and yolk-albumen mixtures has been discovered. The manner of drying (including freeze-drying) apparently does not affect the result, nor do drying conditions have any effect. Apparently, something must be added to the liquid egg before drying which will replace water in the emulsion after drying. Certain sugars and polyhydroxy alcohols seem to be the only compounds capable of performing this task.

In passing it is worth noting that the beating and leavening power of plain whole-egg solids may be substantially restored by heating the reconstituted product at an elevated temperature (Hawthorne and Bennion 1942). While this means of restoring the lost functional powers is exceedingly interesting, it is not considered to be of commercial importance. Bakers and other users would rather use frozen pulp than bother to provide a means for "hot-beating" the reconstituted egg.

STORAGE LIFE PROBLEMS

Albumen

Plain egg-white solids are very unstable. Even at room temperatures they quickly turn brown and within a matter of months become almost completely insoluble (Stewart and Kline 1941); obviously, as a result of these extensive changes, albumen loses most of its functional properties (beating and leavening powers and coagulation).

It has been shown by Stewart and Kline (1941) that these changes are entirely due to a reaction between glucose and the proteins of egg-white. Complete control of the reaction can be obtained by simply removing the glucose. This is accomplished by fermentation with bacteria (Stewart and Kline 1941), yeast (Ayres and Stewart 1947), or by the use of the enzyme glucose oxidase (Kline *et al.* 1951). All three methods have been adopted commercially in the United States.

Glucose-free albumen solids are extremely stable. They may be kept indefinitely at room temperature without loss in quality.

Yolk and Yolk-Albumen Mixtures

Dehydrated plain yolk products are quite unstable. During storage they gradually become insoluble, darken in appearance, and develop strong off-odours and flavours. In addition losses occur in the carotenoid pigments and Vitamin A and B_1 contents (Lightbody and Fevold 1948). Obviously these changes are paralleled by losses in palatability and functional properties (whipping and leavening powers, coagulation, and anti-staling powers). Even after a few months storage at room temperature the products become obviously poorer in quality, particularly for use in such products as custards and butter cakes.

As would be expected it has been shown that the glucose-protein reaction mentioned above is partially responsible for these losses of quality (Stewart, Best, and Lowe 1943). This is particularly true of changes in functional performance and off-colour. The excellent work of Kline, Gegg, and Sonoda (1951) has shown that another browning reaction, involving glucose and cephalin, is largely responsible for the off-odour and flavour of these products, and for some of the brown discoloration noted. Kline and Sonoda (1951) and Kline *et al.* (1951) showed that the removal of glucose from whole-egg pulp before drying tremendously increased storage life of the dried product. Commercial application of this control measure has been achieved using the enzyme glucose oxidase to remove glucose from yolk or yolk-albumen mixture before drying.

Glucose-free yolk and yolk-albumen solids are reasonably stable but still develop off-odours and flavours within a few months at room temperature unless packed in an oxygen-free atmosphere. The precise nature of the responsible reactions is not known. However, the peroxide and aldehyde production, so characteristic of auto-oxidation of ordinary triglycerides *does not occur*. On the other hand, the carotenoid pigments and Vitamin A

are partially destroyed (Kline *et al.* 1951). Kline and co-workers have suggested that phospholipid oxidation might be the cause of the deterioration in odour and flavour.

As indicated earlier it is possible to retain fully the functional properties of yolk and yolk-albumen mixtures *only* by adding certain sugars (or polyhydroxy alcohols) before drying. However, as already stated, when this is done the resulting product has very poor odour and flavour stability. This lack of storage life, apparently, has been overlooked by the English and Canadian workers in their studies on sugared whole-egg. Conrad and his co-workers first made reference to it in 1948. Since that time this defect has been noted by many research workers and more especially by persons in the commercial fields who have attempted to produce and market sugar-dried products. It has been a common experience that yolk-containing solids made with added sugar have little or no odour and flavour stability. While gas or vacuum packing or refrigerated storage alleviates this problem, these methods are not considered to be commercially feasible in the United States.

Little or nothing is known about the chemical nature of the reaction (or reactions) causing this lack of storage life in sugar-dried products. Some sort of oxidation is certainly involved but nothing is known of the reaction pathway. Whether or not the reaction (or reactions) in this case is the same as for plain yolk or yolk-albumen mixtures is also not known. Several research groups are working on the problem but to date very little progress has been made.

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Handling and Care of

WHEN taken from their natural environment edible fish, shellfish, and crustacea are usually exposed to conditions which may adversely affect their quality. The consumer demands fish which will keep for a reasonable time after purchasing, retain its fresh appearance and odour till it is cooked, and be palatable when prepared for the table.

CAUSES OF DETERIORATION

The loss of quality in unfrozen fish, shellfish, and crustacea can be attributed to enzymatic or autolytic activity, oxidative reactions, and bacterial activity.

Enzyme Activity

After death the various parts of the fish are attacked by naturally occurring enzymes which tend to soften the tissues. In some cases, the enzymes derived from small crustacea in the gut are so active that the belly walls are ruptured and the visceral mass converted into a semi-liquid state within a few hours at ordinary air temperatures.

Enzymes derived from bacteria are also capable of breaking down the fish tissues, in this case with the production of well-defined off-odours and flavours. An extremely rapid breakdown of flesh to produce a "milky" condition may be caused by the enzymes of certain protozoan parasites present in live fish.

"Blackhead" in prawns or "blackspot" in shrimp is due to the action of a naturally occurring enzyme which produces brown to black melanins from substances present in the blood of these crustacea.

Oxidative Reactions

The chief form of spoilage due to this cause is rancidity of the fats. The atmospheric oxygen which causes it may also bring about loss of aroma, flavour, and colour.

Bacterial Activity

The flesh of live fish can be regarded as free from living microorganisms. Bacteria occurring in variable numbers on the skin, mouth, gills, and in the intestinal tract are, however, able to multiply and to attack the fish tissues after death, and to form a variety of breakdown products which are largely responsible for the objectionable odours and taste of spoiled fish.

ONSET AND DEVELOPMENT OF SPOILAGE

Soon after catching the flesh of fish is soft and flabby. With the onset of rigor mortis the muscle fibres develop a characteristic stiffness. This is an indication that the fish are in a perfectly fresh condition and that deterioration has not begun. Spoilage, which does not begin until the fish have passed out of rigor mortis, is accompanied by changes in odour, appearance, and texture.

Odour

Changes in odour are usually the first clear indications of deterioration. Fish fresh from the sea usually have a characteristic odour somewhat like seaweed.

Fish which have not been gutted may give off odours suggestive of decomposition long before any spoilage of the flesh has taken place. These odours, including that of hydrogen sulphide, are caused by a rapid decomposition of the material upon which the fish have been feeding, and they can at times be detected in fish no longer than 5–6 hr out of the water. The gills and slime on the skin of the fish generally show earlier and more pronounced odours than the flesh. It can usually be accepted that fish in which

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Fresh Unfrozen Fish

the gills and skin have a fresh odour are in good condition. The development of off-odours on these parts does not necessarily mean that the flesh has begun to spoil, but it is of some value in predicting incipient decomposition. As spoilage advances various off-odours described as stale, "fishy", sour, and putrid will become apparent. In crustacea, and particularly in sharks and rays, strong ammoniacal odours are developed. In fatty fish rancid odours may occur either alone or in conjunction with the more common spoilage odours.

The odour of fish which are gutted while being examined may be affected by volatile substances which have accumulated in the viscera. In this case judgment of the flesh should be postponed to permit some of these substances to dissipate. The intensity of odour is influenced by the temperature of the fish at the time of examination. Consequently off-odours are more readily detected in fish at room temperature than in iced fish.

Appearance and Texture

The eyes of fresh fish have a bright transparent appearance and tend to protrude from the head, but as a fish becomes stale they become sunken and cloudy, particularly in the lens. The bright red colour of the gills gradually fades to a light pink, and changes through yellow to brown. The transparent, almost water-white slime on fresh fish increases in volume as spoilage progresses, and becomes turbid, thick, and frequently yellow in colour.

During dressing of uneviscerated fish, the appearance of the viscera may indicate decomposition. In fish affected by "belly-burn", in which an extremely rapid enzymic breakdown of viscera and of the adjacent belly walls occurs, there may be no clearly discernible off-odours. In less severe cases the flesh of fish handled in the round may gradually soften and be easily separated from the backbone during filleting operations. Later the flesh near the backbone shows signs of reddening and eventually of browning. In fresh fish the texture is firm and it is difficult to express liquid even under heavy pressure. The texture becomes softer as decomposition advances, and fluid may ooze out. The translucent sheen of fresh muscle is lost and the flesh develops a dull lustre.

Shellfish and Crustacea

The determination of freshness in oysters, crayfish, and crabs presents different problems since these are almost invariably delivered to the markets or processing establishments in the live condition. Loose or gaping shells in shellfish is sufficient evidence of death to warrant their rejection. Dryness around the edges of the mantles of oysters usually indicates that they are in poor condition. Off-odours from oysters in the shell may be produced from decaying vegetative matter adhering to the shell, and indicate that the oysters have been out of the water for some time, even though the meats are still in good condition. Oysters, clams, and mussels which are fresh when removed from the shell have a characteristic fresh odour which may become sour as spoilage takes place. In advanced spoilage the liquor in the shell may become turbid and the meats bleached.

Prawns are usually dead on arrival at the market. The presence of black staining in the heads, shell segments, and legs gives some indication that the raw prawns have probably been held on ice for more than two days. Staining is found in cooked prawns

which have not been cooked long enough to destroy the enzyme concerned. Spoilage odours, often ammoniacal in character, may be discernible in the heads and shells, even when the edible flesh shows no definite sign of spoilage. This could be attributed to growth of bacteria in areas where the initial numbers are considerably higher than in the flesh or the intestinal tract. The odour of the meat picked from live crustacea is normally sweetish and very faintly ammoniacal. With the onset of spoilage a strong ammoniacal odour is developed, and is followed by sour, stale, and cheesy odours.

The condition known as "loose-neck" in prawns and other crustacea does not indicate spoilage, but is probably due to the activity of digestive enzymes on the surrounding tissues.

Assessment of Spoilage

Persons engaged in fish handling and processing gain considerable experience in judging by sensory methods the quality of fish and the degree of spoilage. In laboratory testing the use of panels of trained observers and tasters enables the nature of spoilage changes and of the substances responsible for off-odours and abnormal flavours to be fairly well defined. With the aid of chemical and bacteriological methods it is possible to define the types of spoilage and to assess their relative importance. It has been shown that bacterial activity is by far the most important cause of deterioration in fish, shellfish, and crustacea held at temperatures above freezing.

FACTORS INFLUENCING SPOILAGE

The factors which influence the rate of deterioration of fish after catching are, in order of importance: temperature, hygiene, and miscellaneous physical agencies. In this article we will discuss the first only.

Temperature

The flesh temperature of fish when caught is close to that of the surrounding water, but subsequently it approaches that of the surrounding atmosphere. Under Australian conditions temperatures of fish within a few hours of catching may be as low as 40°F or as high as 85°F (unless refrigeration is used).

The activity of bacterial and other enzymes, and the rate of chemical changes such as oxidation decrease with temperature, being halved by a fall of 18°F. Thus at 32°F (the temperature of melting ice) they will be about a quarter of those at 68°F.

On the other hand a fall of 18°F in the temperature of bacteria reduces their rate of growth to approximately one-eighth. Thus bacteria which double their numbers in $1\frac{1}{2}$ hr at 68°F may require 12 hr to do so at 32°F. At 30°F the time for one generation may be extended to 16 hr. Bacteria usually multiply by simple division, and a single organism will increase to approximately 1 million at the end of 20 generations.

In the following table the approximate times taken to reach a spoilage level of 32 million bacteria per gram of flesh are shown in relation to the initial bacterial populations and the temperatures at which the fish are held. The lowest initial population of 100 per gram and the highest of 10,000 per gram represent fish which have received very good and very poor treatment, respectively, prior to storage.

Growth of Bacteria

Initial Bacterial Population per Gram	Number of Generations to Reach 32 Million	Time (approx.) to Reach 32 Million Bacteria per Gram (hr)			
		68°F	40°F	32°F	30°F
100	18	27	90	220	290
1000	15	22	75	180	240
10,000	12	18	60	145	190

In the table no allowance has been made for the possible lag in bacterial growth. If the fish temperatures are quickly reduced to about 32°F immediately after catching, a further 1 or 2 days could safely be added to the storage life at this temperature. The figures in the table are also based on the assumption that the bacterial population consists of organisms all capable of one subdivision every 12 hr. Should the genera-

tion time be 15 hr at 32°F, the storage life at this temperature would be 270 instead of 220 hr.

The table clearly indicates that, while a reduction of the initial bacterial contamination extends the storage life—particularly at the lower temperatures—the overall effect of temperature is of far greater importance. It can be calculated also that prior holding of the fish at 68°F will reduce the subsequent safe holding period at 32°F by 12 hr for each generation which has taken place at the higher temperature.

Use of Ice

Rapid reduction of temperature and subsequent maintenance of the lowest possible temperatures in unfrozen fish are most readily and conveniently obtained by the use of ice. To reach holding temperatures between 30 and 31°F one may use sea-water ice, ice plus salt mixtures, refrigerated brine or sea water, or cold air. During melting, 1 lb ice absorbs 144 B.t.u. of heat from its surroundings. Theoretically this would lower the temperature of 10 lb fish by about 19°F if the cooling effect were confined to the fish. In actual practice heat is absorbed by the ice from other parts of the surroundings.

During manufacture ice is commonly subcooled to 10°F or lower, and stored around this temperature. The crushed ice flows freely, if broken into irregular pieces 1–2 in. across and less. It is easily loaded into trucks, boxes, or sections in the holds on fishing boats. Crushed ice loaded at temperatures of 5–10°F will maintain its free-flowing properties for some time. When loaded close to its melting point the ice tends to form a solid mass, and is more difficult to crush into small pieces. The subcooled ice lasts longer than ice at 32°F and also provides slightly more effective cooling for the fish. Large pieces of ice do not make close contact with the fish, and they may tear the skin and cause bruising of the flesh. Water and fish slime tend to accumulate in layers through the ice when it is too finely crushed.

Irregular flat pieces of flake ice are often used in place of crushed ice. They need not be crushed before delivery, but before storage flake ice should be pre-cooled well below 32°F to reduce its tendency to fuse into a solid mass. The drainage characteristics of flake ice may be better than those of crushed ice. The extra bulk of flake ice may lead to some movement in the hold unless it is properly stacked and protected.

The ratio of ice to fish will depend on the heat to be removed from the fish and its surroundings over the holding period. Under the best conditions there should be a fair proportion of unmelted ice amongst the fish on arrival at the markets. On fishing vessels the ratio of the weight of ice to that of the fish to be carried commonly varies from 1 : 4 to 1 : 1. The consumption of ice can be reduced by insulating the holds; the cost of this should be balanced against the saving of ice and the increased market value of the fish. Refrigerating ceiling grids may be used for pre-cooling empty holds on the way to fishing grounds, particularly if the journeys exceed 3–4 days, and for assisting ice cooling on the return voyage. Fish which have been pre-cooled prior to repacking for transport will require less ice for a given weight of fish. If most of the ice is distributed between the fish and the box, and a good amount placed on top (where conditions are generally warmest), it will effectively cool the fish.

The effectiveness of ice for fish preservation may be improved by adding chemicals (e.g. nitrites and benzoates), and antibiotics (e.g. chlorotetracycline). Some of these are in commercial use overseas, but not in Australia. The uniform incorporation of these substances is assisted by the inclusion of small amounts of carrageen in the ice-making water. The Fisheries Research Board of Canada recommends that dry carrageen should be mixed with two parts by weight of propylene glycol and after a short time with cold water to give a 5 per cent. concentration of carrageen. This solution is added to the water to be used for ice making so that the final concentration of carrageen is 0·1 per cent.

Fish which are to be held for several days should be stowed with enough ice to bring about rapid cooling and to hold them as close as possible to 32°F for as long as needed. The ice and fish should be arranged so that accumulated water, blood, and slime will drain freely through the stack into the bilge. Excessively high stacking should be

avoided, since the pressure on the lower layers of fish will bring about loss of bloom, physical damage, and appreciable loss of weight. Contamination may be increased by the squeezing out of the intestinal contents, and their distribution by the augmented flow of water near the base of the stack. Ample ice should be applied to keep the fish from contact with wooden surfaces, which are frequently heavily contaminated with bacteria. The layer of ice on the floor of a fish pen in the hold should be 2–8 in. (or more) thick, depending on the anticipated holding period. Similar amounts are recommended for the space between the fish and the sides of the vessel, and on top of the fish. In uninsulated holds additional ice is desirable in areas where heat leakage is known to be high.

After placing ice on the floor, one or two layers of fish, depending on their size, are spread over the ice layer. The gut cavity in eviscerated fish should be filled with ice and turned so that it will drain freely. Alternate layers of fish and ice are arranged in a like manner, and a layer of ice approximately 9 in. deep is placed on top, and piled up in the centre to form a mound.

Use of Refrigeration

Mechanical refrigeration of the hold is used to reduce melting of ice on the outward journey, and on the return journey it is applied in such a way that there is no danger of freezing the fish on top of the stack, or of preventing the ice from melting and so effectively cooling the fish below. If the hold is insulated, and mechanical refrigeration installed, less ice is required and there is more space for fish.

It is difficult to bring about conditions in which most of the fish in the hold are held at or near 32°F. Refrigerated sea water at 32°F is more effective than crushed ice in maintaining uniformly low temperatures and it may be used at temperatures of 30–31°F without freezing, for relatively long periods. Immersion protects the fish from contact with free air and reduces the possibility of oxidation of the surface body oils. It is especially useful for reducing the incidence of black discoloration in prawns and shrimps. Leaching of water-soluble substances may occur if the fish are headed and gutted before immersion, but this effect would not be pronounced in sea water of one-third natural salinity at 31–32°F. The capital cost of refrigerating a hold for storing sea water in tanks is much higher than for ice, and special equipment is needed for discharging and unloading fish. Further, vessels equipped in this manner sometimes need to carry some ice to cope with specially large catches.

Crustacea and Shellfish

Crayfish, lobsters, crabs, and some species of fish are commonly kept alive for several days in sea water circulated at ordinary temperatures. In some boats small holes in the bottom keep the wells filled with fresh sea water. In others the hold may be partly filled with sea water which is renewed from time to time by pumping. Another method is to arrange tanks in the hold in tiers, so that sea water pumped into the top tanks overflows into the lower tanks and thence into the bilge before being pumped overboard. Water which is circulated continuously and aerated may be used for some time. It is advisable to place baffles in large tanks, or use small ones.

Oysters in the shell and some species of clams may be kept alive for several days without icing, but mussels spoil more quickly after removal from the water. After the meat is removed from the shells spoilage is retarded by packing in metal containers in ice.

Marketing

At the markets fish are usually separated from the surrounding ice. When exposed for sale for some hours in hot weather heating of the outer layers of the pre-cooled fish may reduce the storage life during subsequent distribution and retailing.

It is generally inadvisable to rely on air cooling for reducing fish temperature, because the rate of cooling is slow and the surface of the fish is dried, and this may cause a loss of bloom. However, it is often convenient to use cold air storage for boxed fish which have been cooled with ice and contain sufficient ice for their subsequent transport. Cold air rooms at about 30°F will help to maintain the initial temperatures in the fish and prevent undue melting of ice.

When insulated vehicles are not available for iced fish which have been thoroughly cooled before transport, the containers should be closely stacked, and protected from wind and direct sunlight. Insulated blankets are sometimes useful, and tarpaulins or plastic waterproofs afford some protection.

RECOMMENDATIONS

(1) Cool the fish as soon and as rapidly as possible after catching, and maintain them in the chilled condition at the lowest possible temperature.

(2) The most effective and convenient chilling agent is generally ice. It should be:

- initially at a temperature below its melting point,
- in a fairly fine state of subdivision,
- carefully distributed around and amongst the fish, and
- used in sufficient quantities to last throughout the expected holding period.

(3) The storage life of fish may be extended by cooling and holding fish at 30–31°F in sea water or water plus 3 per cent. by weight of salt, or by adding a small proportion of salt to the ice.

(4) Undue rises in the temperature of chilled fish should be prevented by:

- eliminating periods when the fish are not iced or otherwise chilled,
- protecting from direct sunlight and strong air currents,
- stacking containers compactly, and
- using auxiliary chilling by cold air.

Discoloration of Canned Pears

THE DIVISION of Food Preservation and Transport has recently received through the kindness of the author, Mrs. L. Széchényi, a paper* (in Hungarian) on investigations into the prevention of pink discoloration in canned pears, carried out at the Institute for Research in Canning, Meat Packing, and Refrigeration in Hungary.

Since the information in the paper will be inaccessible to many readers, it has been decided to reproduce the main points here.

Mrs. Széchényi found that the discoloration which occurs during the processing and storage of canned pears is due to the presence of colourless leucoanthocyanins which change to red anthocyanin pigments. The colouring of quinces during cooking is due to a similar chemical change. The extent and speed of the change in colour depends on the acid used in the preparation of the syrup, and on the pH of the syrup, the duration of the heat treatment, and the amount of air present. The colourless leucoanthocyanins can be partially removed by preliminary blanching.

* SZECHENYI, L. (1955).—*Élelmez. Ipar.* **9**: 121–4, 130.

Different varieties of pear differ in their susceptibility to discoloration. Some do not change colour, some develop the red pigment only after heat treatments much longer than are necessary to achieve sterilization, and others become coloured well within the normal processing time.

On the basis of these results Mrs. Széchényi recommends the following canning procedure to prevent discoloration:

(1) Immediately after ~~picking~~ peeling hold the pears in a 0·3 per cent. solution of sulphurous acid.

(2) Blanch for 10 min in boiling water to remove residual sulphurous acid and some leucoanthocyanins.

(3) Fill into cans, add hot syrup, and close.

(4) Process for less than 30 min at 212°F.

It would be interesting to learn if canners have ever carried out consumer tests to find out if housewives prefer white canned pears. In the kitchen pears are often stewed until they turn pink, so it is possible that canned pears with a bright uniform pink colour would be welcomed by housewives.

Food research in C.S.I.R.O. is carried out chiefly by the Organization's Division of Food Preservation and Transport, but problems in the manufacture of dairy products are investigated by the Dairy Research Section, which is located at Highett, Victoria.

The C.S.I.R.O. Dairy Research

By A. K. Klingender

Dairy Research Section, C.S.I.R.O., Highett, Vic.

C.S.I.R.O. first became interested in dairy research in 1929, when a travelling scholarship was granted to enable an Australian scientist to undertake work at the National Institute for Research in Dairying at Reading, England. There was little further activity till 1938 when a start was made to build up a Dairy Research Section. In 1940 a group was formed in the C.S.I.R.O. Division of Industrial Chemistry to work on the chemical engineering aspects of dairy manufacture. During World War II the two groups, which were housed in the laboratories of the C.S.I.R.O. Division of Industrial Chemistry at Fishermen's Bend, Melbourne, worked closely together under the direction of Dr. W. J. Wiley, the former holder of the 1929 scholarship. Near the end of the war the groups were amalgamated into one Section.

In 1946 Dr. Wiley resigned to become Commonwealth Dairy Expert in the Commonwealth Department of Commerce and Agriculture, and was succeeded as Officer-in-Charge by Mr. G. Loftus Hills. By this time the Section had six research officers on its staff, and three more were recruited from overseas between 1948 and 1951.

Accommodation at Fishermen's Bend was limited, and some officers were accommodated temporarily in a prefabricated laboratory on a C.S.I.R.O. site at Highett, a south-eastern suburb of Melbourne. Encouraged by a grant from the Australian Dairy Produce Board, the Section made plans for the erection of permanent laboratories at Highett. These were completed in 1955. The main building (illustrated) is about 9000 sq. ft. in area, and houses most of the research laboratories, the library, administrative offices, and store-rooms. A plant and services building has an area of about 6000 sq. ft. and contains plant rooms, workshops, cold-storage and cheese-maturing rooms, two small laboratories, and a processing bay with pilot plant and experimental machinery. The prefabricated laboratory, referred to above, is occupied by two research teams. The buildings at Highett accommodate the staff of 35 quite comfortably but allow for little expansion of numbers.

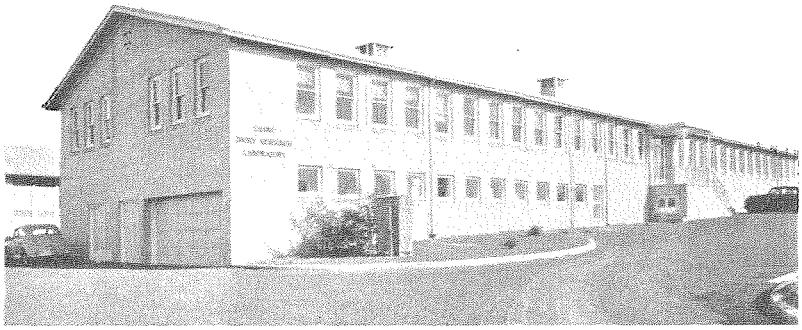
ACTIVITIES OF SECTION

The Section deals with problems arising in the manufacture of dairy products, beginning at the farm and extending to the consumer, but they often extend beyond, to the grass roots or the soil on the one hand and to studies of consumer reaction on the other. The Section maintains a balance between applied and fundamental work, taking into account the activities of State Departments of Agriculture on the applied side, but it leans towards creative work in the development of new products and processes more than to work on the improvement of existing methods.

Flavour Research

Any off-flavour in milk or butter is easily detected against the delicate background taste of the product. Dairy products are quite susceptible to off-flavours, which can be

Laboratory



Main building at Highett.

caused by absorption of taints, bacterial activity, or enzymatic or chemical change. One of the first investigations undertaken was the study of a major flavour problem in the industry—the prevention in butter of taint absorption from butter boxes made from Australian woods. A method was developed in which the inside surfaces of the boxes were sprayed with casein-formaldehyde solution. Tens of millions of butter boxes have since been treated in this way. Another early flavour investigation concerned the notorious "rabbito" flavour in butter, a defect which is of bacterial origin. Causative organisms were isolated, traced to their source in butter factories, and factors leading to their growth in butter were defined.

Since 1938, when Dr. Wiley studied the nature of chemical deterioration in cold-stored butter, oxidative changes in dairy products have been given much attention. Techniques of measuring oxidation were developed and refined, and the catalytic effects of copper and of sunlight in promoting fat oxidation were studied. Oxidation defects in canned "butter concentrate" were found to be due to catalysis by very small amounts of magnesium salts associated with the common salt used.

In recent years a more fundamental approach has been made to flavour problems. Modern techniques greatly facilitate the isolation and identification of the compounds responsible for flavours. These techniques, particularly chromatography, were used in a study of compounds responsible for cardboard flavour in skim milk. The technique of gas chromatography is being used to study various flavour problems, and efforts are being made to elucidate the role of phospholipids in the development of oxidized flavours.

New Products

The Dairy Research Section was formed during war-time, and one of its first tasks was to devise a butterfat product which would not deteriorate under tropical conditions. A "butter concentrate", containing a small amount of hard fat and no water or oxygen, was developed, and manufactured by the Queensland Butter Board. It met war-time requirements well, and it is still produced in quantity for export to tropical regions.

In more recent years, attention has been turned to finding new uses for skim milk powder, because large quantities of skim milk solids are wasted in Australia. In the United States the major outlet for skim milk solids is in bread, but their addition to bread produced in accordance with Australian formulae and methods causes a marked deterioration in the volume and texture of the loaf. A specially modified powder, containing a small amount of plastic fat (such as glycerol monostearate) has been developed, and this improves the nutritive value, palatability, and keeping quality of the loaf. Over 1000 tons per annum of this product is currently being distributed by one Victorian wholesaler alone.

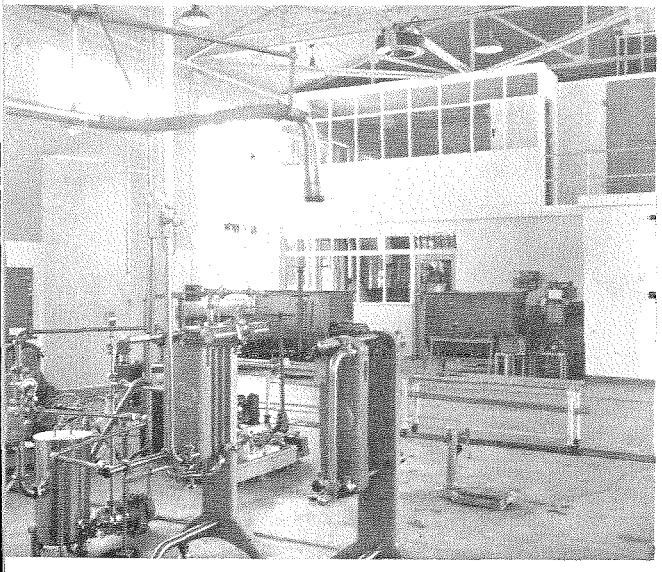
Another line of research is aimed at altering the foaming, froth stability, and other physical properties of milk proteins to make special milk powders suitable for incorporation in baked goods. So far, two modified milk powders have been produced. One of these may be used as a substitute for egg albumen in meringues and sugar confections. The second, which is likely to have wider commercial application, will replace 90 per cent. of whole-egg in cakes, biscuits, and flour confectionery. Many interesting problems of fundamental interest to protein chemists have arisen in this developmental programme, and an understanding of the chemical reactions involved is being sought.

Another line of study involving skim milk powder has been concerned with the Vitamin A fortification of this product. Vitamin A, when added to skim milk powder, is rapidly destroyed by oxidative processes. Accordingly, a systematic study has been made of the effect of various stabilizers and antioxidants on Vitamin A stability, and a procedure has been worked out which ensures that 90 per cent. of the vitamin survives storage at a high temperature for 6 months.

Cheesemaking

Since 1951, a team of workers has sought to find ways of improving manufacturing techniques in the cheese industry. As a first step, a collection of different cheese starter organisms was built up, and their bacteriophage relationships were studied. All these strains are now freeze-dried in the Section and distributed to the industry. By suitable rotation of cultures, cheesemakers may now avoid any build-up of bacteriophage concentration in their factories. Another problem in the regular and rapid production of acid in the cheese vat is the occurrence of inhibitory substances in the milk, and the nature and possible means of destruction of these is being investigated.

A corner of the pilot-plant room.



Cheesemaking by traditional methods is a laborious manual process. As a first step in mechanizing the process a more rapid method of making cheese, employing thermoduric "starters" was developed. In this the curd-fusing or cheddaring stage takes place rapidly, in 30 minutes as against 90 in the old process, and this greatly simplifies the construction of machines to handle the curd. Mechanization of this cheddaring stage had been accomplished by 1956, and in November 1957 design and installation of further machinery enabled cheddar cheese to be made for the first time by an entirely mechanized process.

Microstructure

The eating characteristics of foods, as well as many of their storage properties, are controlled as much by their physical microstructure as by their chemical composition. Special attention is therefore paid to elucidating the microstructure of all dairy foods. In this field the Section has recently developed a differential fluorescent staining procedure which is proving most useful in the differentiation of the fat, protein, lactose, etc. in such products as milk powder and cheese.

Equipment

Besides its newly developed processing machinery, the Section is well equipped with a wide range of pilot-plant equipment for the pasteurization, homogenization, and sterilization of milk and cream, the manufacture of butter, casein, and spray-dried milk powder, and the manufacture and maturing of cheese. Some of the equipment, including a low-temperature evaporator, has been designed and built in the Section's workshop, which is particularly well equipped for the fabrication of stainless steel plant.

Dissolved Metals: Tin and Iron

By J. F. Kefford

Division of Food Preservation and Transport, C.S.I.R.O., Homebush, N.S.W.

DETERMINATIONS of the amounts of contaminating metals in canned foods are frequently useful in the investigation of "trouble-shooting" problems, especially those involving corrosion or discoloration. The metals likely to occur in cans in greatest amounts are those derived from the can itself, namely, tin and iron. In plain cans dissolution of tin predominates. In lacquered cans, following attack on both the tin coating and the baseplate at discontinuities in the lacquer, the iron content of the product may be as high as, or higher than, the tin content (Davis 1957).

It is interesting to calculate that if the tin was completely stripped from the internal surface of a 301 × 411 can made from plate having a nominal tin coating weight of 1·25 lb per base box, the tin content of the canned product would be about 1000 p.p.m. In practice, tin contents exceeding 100–150 p.p.m. are unusual, except in some products such as asparagus, silver beet, and rhubarb. These have specific accelerating effects on the corrosion of tin plate and are known to build up high tin contents, of the order of 200 p.p.m., during storage periods of 6–12 months (Adam and Horner 1937; Lynch and Kefford 1939). The iron content of canned foods seldom exceeds 100 p.p.m. (Dickinson and Goose 1955*a*; Davis 1957).

There is no evidence that the tin in canned foods is physiologically harmful; it is probably completely excreted (McKenzie 1945*a*; Monier-Williams 1949*a*; Tanner and Tanner 1953). In most countries, however, legal limits are laid down for the maximum tin content in canned foods, e.g. 286 p.p.m. (2 grains per lb) in Australia and Great Britain, and 300 p.p.m. in the United States.

Dissolved tin adversely affects the colour of foods containing anthocyanin pigments, e.g. cherries, berries, plums, and beetroot, changing the desirable red colours to blue or purple shades.

Metallic taints due to the presence of dissolved metals may become apparent in some canned foods. The off-flavour is commonly described as "tinny", but in one product, canned herring, it has been attributed to dissolved iron (Hollett 1947).

Tin has a specific inhibiting effect on the growth of *Clostridium botulinum* (Scott and Stewart 1944–45). In some canned foods inhibiting concentrations are reached in a few days after canning, so that no growth occurs in cans inoculated with *C. botulinum*. This effect has little practical significance in canning technology but it should not be overlooked in the interpretation of the results of inoculated test packs in plain cans.

Iron is not a toxic metal but is in fact an essential element in human nutrition. Iron contamination in processed foods may, however, lead to discoloration problems following the formation of black iron sulphide or iron "tannate" (Monier-Williams 1949*b*; Davis and Kefford 1955).

ANALYTICAL PROCEDURES

Sampling

A sample of 50 g of a canned food is usually sufficient for a determination of dissolved metals. The whole contents of a can may be macerated into a homogeneous puree in an electric blender, or the drained

* Earlier articles in this series appeared in *C.S.I.R.O. Food Preservation Quarterly*, Vol. 13 (1953), pp. 3–8, 21–31; Vol. 14 (1954), pp. 8–18, 26–31, 46–52, 74–6; Vol. 15 (1955), pp. 28–32, 52–7, 72–7; Vol. 16 (1956), pp. 7–10; and Vol. 17 (1957), pp. 11–14, 30–5, 42–7.

solids and the liquor may be analysed separately in which case the solids should be macerated in a blender.

The product must be removed from the can immediately after opening to avoid rapid pick-up of tin and iron in the presence of atmospheric oxygen. During sampling operations contamination with any of the metals to be determined must be avoided, for instance, by using glass or porcelain vessels and stainless steel or aluminium screens. Lamden (1950) has drawn attention to the danger of copper contamination from exposed brass parts of electric blenders.

Reagents conforming to high standards of purity must be used in estimating metals present in minute amounts, and blank determinations on the reagents should always be made.

Preparation of Digest

Before determining metals in foods it is generally necessary to destroy the organic matter in the sample. In fruit and vegetable products the organic matter is mainly carbohydrate in nature and is relatively easy to eliminate by combustion or wet oxidation. But destruction of the proteins and fats present in meats, fish, and dairy products may be a difficult and tedious operation.

Dry ashing is not recommended because of the possibility of loss of metals by volatilization or by combination in compounds that resist solution. Middleton and Stuckey (1953–54) have made a comprehensive review of methods for the destruction of organic matter prior to the determination of trace metals and they advocate a method of wet ashing using nitric acid alone. Smith (1953) recommends digestion with hot concentrated perchloric acid with or without nitric acid and a vanadium catalyst. Perchloric acid is, however, not a popular reagent because of explosion hazards.

In this laboratory a digestion procedure using sulphuric and nitric acids has been applied successfully to most canned foods. In the final stages hydrogen peroxide is added to complete the digestion and to remove residual nitric acid and reduction products.

Reagents:

Sulphuric acid A.R. : 36N
Nitric acid A.R. : 16N
Hydrogen peroxide B.P.: 30 per cent.

Procedure: To the canned food sample (50 g) contained in a 500 ml Kjeldahl flask, add 20 ml nitric acid and 10 ml sulphuric acid (20 ml with canned meats) and a glass bead to minimize bumping. Heat gently until the early violent reaction subsides, then more strongly until charring commences and white fumes appear. Samples having a high sugar content, such as canned fruits and jams, should not be charred beyond a brown colour at this stage, otherwise troublesome foaming occurs at later stages. Allow the digest to cool until fuming ceases then add 5 ml nitric acid and mix. Heat again until white fumes appear. Continue successive additions of nitric acid until the digest on cooling is a pale yellow or light brown colour. Add 10 ml hydrogen peroxide dropwise and again heat to fuming. Repeat the addition of hydrogen peroxide until the digest is water-white. If a white crystalline deposit of calcium sulphate appears on cooling the digest, redissolve it by adding distilled water and warming. Make up the digest to 50 ml with distilled water.

Digestion of most canned foods is complete in about 2 hr, or in 1 hr with liquid products.

DETERMINATION OF TIN

A volumetric procedure developed by McKenzie (1945*b*) is used for the determination of tin in this laboratory. The tin in an aliquot of the digest is reduced with nascent hydrogen, an atmosphere of carbon dioxide is maintained to exclude oxygen, and the stannous tin is titrated with potassium iodate in the presence of potassium iodide. The method will determine tin in amounts down to 0·5–1 mg with an accuracy of about 3 per cent. There is no significant interference from copper up to 20 p.p.m. or from iron up to 200 p.p.m.

Reagents:

Hydrochloric acid A.R.: 3N solution.

Aluminium foil: purest grade available, in pieces about 1 cm square.

Sodium bicarbonate A.R.: 5 per cent. solution.

Starch indicator: 1 per cent. soluble starch in 20 per cent. sodium chloride solution.

Potassium iodide reagent: Dissolve 0·2 g potassium iodide A.R. with 3 g sodium bicarbonate A.R. in 100 ml boiled-out

water in a reagent bottle. Add a few drops of hydrochloric acid and agitate. When effervescence ceases insert stopper.

Potassium iodate A.R.: 5·3505 g made up to 1 litre with boiled-out water gives 0·1N stock solution. Dilute 10 ml to 200 ml to obtain 0·005N solution and connect to 10 ml burette by siphon.

The potassium iodide and iodate reagents should be freshly prepared or prepared daily when in constant use.

Procedure: Pipette 20 ml of digest into a 150 ml conical flask with a B24 neck. Add 30 ml 3N hydrochloric acid and excess aluminium foil (about 0·3 g). Connect the flask by means of a B24 ground joint and a capillary (2 mm internal diameter) to a "suck-back" test tube containing sodium bicarbonate solution. Sodium bicarbonate drawn back into the flask generates carbon dioxide to maintain the inert atmosphere, and lowers the acidity. Jackson (1953) describes a compact guard valve on the same principle.

A convenient apparatus for conducting a series of tin determinations simultaneously is illustrated below.

Heat the flask gently until evolution of gas commences then withdraw heat. When the aluminium is almost completely dissolved heat again. By careful agitation disperse any metal particles at the liquid surface. Finally boil until liquid is clear. Cool the flask in ice water to below room temperature, while still connected to the guard tube. Disconnect the flask and wash down the sides with about 4 ml of potassium iodide solution run in from a 5 ml pipette. Add a few drops of starch indicator and titrate rapidly with 0·005N potassium iodate solution to a blue end-point stable for several seconds. A blank determination on the reagents should be made at the same time and should not exceed 0·2 ml of 0·005N potassium iodate. The tin content of the test sample is then:

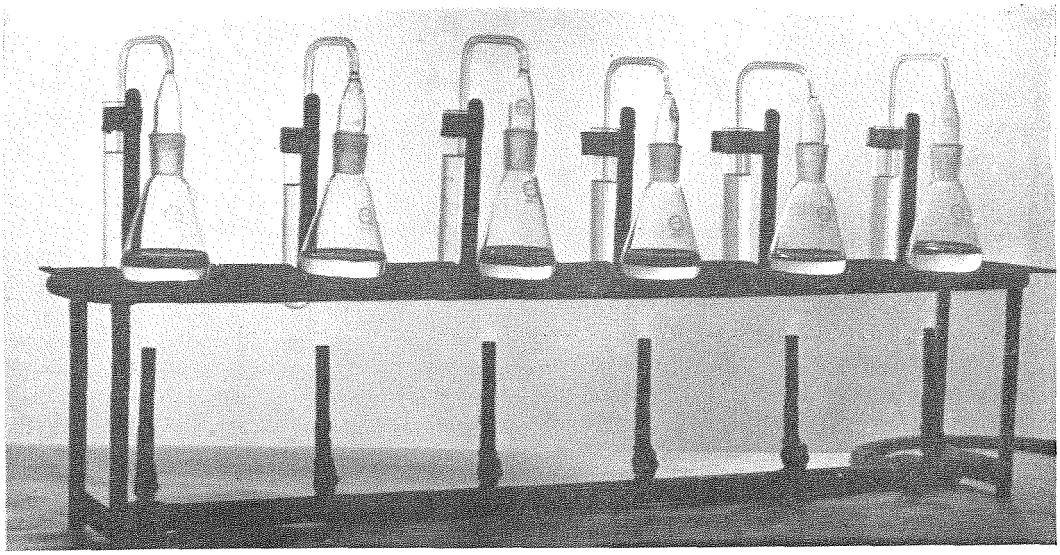
(corrected titre $\times$ 14·8) p.p.m.

Townsend, *et al.* (1954) found some departure from stoichiometric relations in the reaction between potassium iodate and tin at very low concentrations and they recommend that conversion factors for low levels of tin should be calculated by making determinations on standard tin solutions.

Some Alternative Methods

Polarographic Procedures: When equipment is available the polarographic determination of tin is rapid and specific. Markland and Shenton (1957) describe a straightforward procedure for determining tin in foods in 1 mg quantities with an accuracy of about 3 per cent. After wet digestion the acid digest is heated with ammonium oxalate

Apparatus for the determination of tin.



to avoid interference from residual nitric acid. Lead interferes but is not usually present in significant amounts.

Cieleszky and Lindner (1951) have claimed that tin contents may be determined with 10 per cent. accuracy by polarographic measurements on liquors from canned foods and tomato pureés without prior digestion (cf. Deschrieder and van Coillie (n.d.)).

Colorimetric Procedures: The reagent dithiol (1-methyl-3,4-dimercaptobenzene) reacts with tin to form a red insoluble complex which may be dispersed, with the aid of dispersing agents such as "Teepol" or "Lorol", to give a clear colloidal suspension suitable for photoelectric absorptiometric measurements (Dickinson and Holt 1954; Dickinson and Goose 1955*b*; Ovenston and Kenyon 1955). It is necessary, however, to extract copper to avoid interference and the dithiol reagent is not very stable.

DETERMINATION OF IRON

In this laboratory a very large number of iron determinations in canned foods has been made by the colorimetric method of McKenzie (1948) using 1,10-phenanthroline as the chromogenic agent. Iron in the digest is reduced by glycine to the ferrous state and reacts with 1,10-phenanthroline to form an orange-red complex ion. Copper, zinc, aluminium, and phosphates in the amounts to be expected in canned foods do not interfere, and interference by tin is overcome by the addition of citrate. The method will determine iron contents in foods down to 2–3 p.p.m. with about 3 per cent. accuracy.

Reagents:

Sodium citrate A.R.: 25 g in 100 ml water.

p-Hydroxyphenylaminoacetic acid (photographic glycin): 0·1 g in 100 ml 0·4N sulphuric acid.

1,10-Phenanthroline: 0·4 g in 100 ml 2 per cent. acetic acid.

Bromophenol blue indicator: Triturate 0·1 g with 1·5 ml 0·1N sodium hydroxide and make up to 100 ml with water.

Ammonium hydroxide A.R.: concentrated.

Ammonium acetate A.R.: 70 g in 1 litre water.

Procedure: Pipette 5 ml of the digest, preferably containing 20–200 μg of iron, into a 50 ml volumetric flask. Add 1 ml sodium citrate solution, 1 ml glycin solution, and 2 ml phenanthroline solution. From a burette add ammonium hydroxide to give a pH of approximately 3·8. Titrate a separate aliquot to the bromophenol blue end-point to determine the amount of ammonium hydroxide required. Make up to 50 ml with ammonium acetate solution. Remove any precipitate by centrifuging. Allow to stand 15 min. Measure the transmittance on a spectrophotometer at 474 mμ. Determine the iron content by reference to a calibration curve prepared by applying the recommended procedure to standard solutions of ferrous ammonium sulphate. A blank determination on the reagents should be made at the same time and should not exceed 2 p.p.m. of iron.

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NEWS from the Division of Food Preservation and Transport

PERSONAL

Dr. J. R. VICKERY, Chief of the Division of Food Preservation and Transport, is at present in the United Kingdom. His services have been made available to the British Government since January 1958 to advise the Ministry of Agriculture, Fisheries, and Food on the establishment of a Meat Research Institute in England. Dr. Vickery left Australia on January 10, and travelled to London by air via the United States. In America he took the opportunity to visit meat research centres at the University of Missouri, in Chicago, and at the University of Ohio.

Dr. W. J. SCOTT, Senior Principal Research Officer, left Australia on February 25, 1958, for a 6 months' visit overseas. Dr. Scott will be visiting centres of microbiological research in North America, the United Kingdom, and the Continent. He will also attend the annual meeting of the Society for General Microbiology in London, and will present a paper to the Seventh International Congress of Microbiology in Stockholm. Dr. Scott is especially interested in research on the physiology of microorganisms, and the freezing of biological material.

PUBLICATIONS BY STAFF

Malvalic Acid and its Structure. J. J. Macfarlane, F. S. Shenstone, and J. R. Vickery. *Nature* **179**: 830–1 (1957).

The name "malvalic acid" is proposed for the C_{18} fatty acid isolated from *Malva verticillata* and *M. parviflora*, which causes pink whites in the eggs when it is ingested by hens. The structures of this acid and of sterculic acid, which also gives the Halphen colour reaction, are discussed.

A Property of Ox Muscle Affecting Bacterial Growth at 0°. A. D. Brown, G. G. Coote, and M. F. Meaney. *J. Appl. Bact.* **20**: 75–85 (1957).

Experiments described in this paper confirm the findings of overseas workers with

pigs that the rate of bacterial spoilage of the flesh of beef cattle is influenced by the history of the animals before slaughter. Acid concentration in the flesh, determined among other things by the concentration of muscle glycogen at the time of death, is the main factor affecting bacterial growth at 0°C on the psoas muscle of steers and the longissimus dorsi of cows. A second factor may be measured by time to the onset of rigor mortis. Its nature has not been established yet. In the l. dorsi of steers this property was the major one affecting bacterial growth, and under these conditions the contribution of pH was not significant.

Apparent Free Space. G. E. Briggs* and R. N. Robertson. *Annu. Rev. Pl. Physiol.* **8**: 11–30 (1957).

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Phosphorylated Compounds in Plants. I. Adenosine and Uridine 5′-Phosphates in Pea Seedlings. K. S. Rowan. *J. Exp. Bot.* **8**: 256–71 (1957).

Physiology of Pea Fruits. IV. Changes in Sugars in the Developing Seed. J. F. Turner, Donella H. Turner, and J. B. Lee. *Aust. J. Biol. Sci.* **10**: 407–13 (1957).

Paper chromatographic methods were developed for the estimation of sugars in plant tissues and were used to follow changes in some individual sugars during the development of the pea seed. Sucrose was the predominant sugar present in the seeds and there were smaller quantities of fructose, glucose, and galactose. The amounts of fructose and glucose were approximately equal at all stages of development. The sucrose, fructose, and glucose contents of the seed increased in the early stages of development but decreased during the phase of rapid starch synthesis. The galactose content increased to a maximum at a later stage than the other sugars estimated. The concentrations of sucrose, fructose, and glucose in the seeds were compared with the concentrations in the leaves, stems and hulls. The possible significance of the changes in sugars in relation to the metabolism of the pea seed is discussed.

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Physiology of Pea Fruits. V. Phosphate Compounds in the Developing Seed. K. S. Rowan and Donella H. Turner. *Aust. J. Biol. Sci.* **10**: 414–25 (1957).

The aim of the experiment reported here was to look for correlations between changes in the concentration of compounds containing phosphorus and (*a*) changes in concentration of starch, sucrose, and protein nitrogen, and (*b*) changes in the rate of respiration.

The decrease in the value of the ratio inorganic phosphate/hexose monophosphate measured in the extracts of the seed preceded by some days the increase in the rate of starch synthesis. The rate of starch synthesis in the seed was not closely related to the ratio inorganic phosphate/glucose *l*-phosphate. The accumulation of starch after 23 days from flowering was accompanied by a decrease in concentration of hexose monophosphate presumably a direct consequence of starch formation. The concentration of phosphorus compounds did not appear to be closely related to the rate of protein synthesis or of respiration.

Apple Storage in Australia. R. N. Robertson and D. Martin. *J. Aust. Inst. Agric. Sci.* **23**: 183–8 (1957).

The authors discuss the practice and problems of storage of apples for the local market, with reference to apple varieties, storage temperatures, the effects of fruit size and maturity, some storage disorders, types of store including gas storage, and the quality of stored fruit.

Copies of papers mentioned above may be obtained from the Librarian, Division of Food Preservation and Transport, Private Bag, P.O., Homebush, N.S.W. (Telephone: UM 8431, UM 6782, UM 8938).