FOOD PRESERVATION QUARTERLY

Vol. 19 No. 3 September 1959

REGISTERED IN AUSTRALIA FOR TRANSMISSION BY POST AS A PERIODICAL

C.S.I.R.O.

Food Preservation Quarterly

• VOLUME 19
• NUMBER 3
• SEPTEMBER
1959

Published by the Division of Food Preservation and Transport
Commonwealth Scientific and Industrial Research Organization
Sydney, Australia

Fish Smoking

By W. A. Empey

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

INTRODUCTION

Smoke curing of fish has for centuries been used mainly to impart a smoked flavour to fish, and partly to extend its storage life. The preservative effects of a combination of heavy salting, intense smoking, and drying allow products such as "red" herring to be held in edible condition for several months without refrigeration. On the other hand, a mildly salted and smoked product which has been lightly dried will have a storage life only slightly longer than fresh fish. In many parts of the world the present-day demand is largely for lightly cured smoked fish having attractive flavour and appearance, but requiring refrigeration if it is to be held longer than 1 or 2 days.

Until recent years smoke curing has been rather a haphazard procedure, but nowadays some measure of control is obtained by up-to-date techniques.

PREPARATION

For the best results fish to be smoked should be in good condition and free from any signs of spoilage.

Cooling

Unless preparation for smoking can be commenced within a few hours of catching, the fish should be promptly cooled by icing or by immersion in chilled sea water or brine. When flesh temperatures are quickly reduced and held close to 32°F, the fish should remain in good condition for 5 or 6 days. Very oily fish do not remain in acceptable condition for more than 2–3 days at this temperature.

When it is necessary to hold fish for relatively long periods before smoking, low-temperature storage (0°F or lower) should be employed. Additional protection against drying, for example by glazing the fish, will also retard the onset of rancidity. Fish should not be salted before freezing since this promotes the rapid development of rancidity during storage.

Dressing

In some instances smoked products, e.g. bloaters and red herring, are made from whole fish, but most products are produced from fish which are cleaned and gutted before their preparation as split fish with heads on, as kippers, or as fillets or steaks. Sharks of various species are skinned before filleting. All visible blood and tissues such as gills, guts, etc. which decompose rapidly should be removed before the final washing.

Colouring

Artificial colouring of fish before smoking is frequently used nowadays especially for the light smoke cures. Vegetable dyes such as annatto or coal tar dyes such as tartrazine and Orange I have been used to produce shades of colour ranging from yellow to orange or light brown in the smoked fish. If colouring is done before salting the fish are usually dipped for $\frac{1}{2}$–1 min in aqueous solutions containing 1–2 oz of the dyestuff in 10 gallons of water. It has been claimed that a more uniform colour is produced by this method than by adding the dye to the brine in which the fish are salted. Because of the longer exposure of the fish in the brine, a lower concentration of the colouring substance is required to produce a similar intensity of colour. It is possible also to dye the fish after salting, using the same procedure as before salting.

Salting

Salting the fish just before smoking is not necessary for the production of smoky flavour, but it serves a useful purpose in firming the flesh, and it is essential for the development of surface gloss or "pellicle" during subsequent drying. The salt also contributes to the overall flavour of the finished products.

For the production of mild smoke-cured products the preliminary salting is carried

out so that the uptake of salt by the fish is between 2 and 2½ per cent. of its weight. Fish which are to be prepared as red herring or similar products are allowed to take up between 10 and 12 per cent. of salt to ensure that the completely processed products will contain between 14 and 16 per cent. salt, or sufficient to produce saturated solutions of salt in the water remaining in the tissues. If the salt content prior to drying is allowed to exceed this level, an unwanted crystallization of salt will occur on the surface during subsequent drying of the fish. Products having salt concentrations at intermediate levels may be prepared—the salt will exert a pronounced preservative effect against moulds and bacteria at a level of 8–10 per cent. in the fish.

When the raw material is fish previously preserved by salting, some of the salt must be removed before smoking to produce mild smoke-cured products with an attractive gloss. This is done by soaking the fish in tanks of running cold water for periods as long as 6–48 hr depending on the thickness of the fish and the degree of salting. Prolonged storage of fish with high salt content will cause some denaturation of the flesh proteins and make it more difficult to obtain a uniform and attractive gloss in the finished products. Because of this and also on account of the difficulty of effectively removing excess salt to a uniformly low level, it is not a common commercial practice to use heavily salted raw material to produce mild cured products.

Fish to be salted prior to smoking may be packed in dry salt or immersed in a strong brine ranging between 60 and 80 per cent. saturation. Dry salting is often used for the more highly salted products, whereas immersion in brine is the usual practice for the milder cures.

When fish are packed in dry salt, water is extracted from them and some of this flows away unless the fish are salted in a vat. By using about 30 lb of salt per 100 lb of fish a saturated brine, which eventually covers most of the fish, will be formed. The loss of weight in fish salted in this manner will vary with the thickness of the flesh. With small fish up to 1 in. thick the loss of weight may reach 15 per cent. within 12 hr. Dry salting, with its accompanying extraction of water from the flesh, is preferable for producing bloaters from herring. This product usually receives a very light smoking, and most of the drying (which is necessary to ensure reasonable keeping quality) should take place before smoking.

A faster and more uniform salting is obtained by immersing the fish in brine. The periods of immersion required to salt the fish to a particular concentration will depend on the thickness and shape of the fish, the strength and rate of movement of the brine, and the density of packing of the fish. Salt penetration will be retarded by the fat in fatty fish, but increased in fish which have previously been frozen. Taking all these factors into consideration, the brining times to enable an uptake of 2–3 per cent. salt in the fish will range from 10 min in brine of 80 per cent. saturation (80° salinometer) for thin non-fatty fillets to about 90 min in brine of 60 per cent. saturation (60° salinometer) for thick fatty fillets up to 1½ in. in thickness. The maximum thickness of material from large fish such as tuna should be limited to about 2 in. by cutting.

When large quantities of fish are immersed in brine there is great difficulty in maintaining uniform conditions throughout the material. While this may be partly overcome by gentle agitation of the brine one or more times during brining, a mechanical brining process would prove more satisfactory. During immersion for these relatively short periods there is very little change of weight in the fish, but the strength of the brine will fall owing to uptake of salt by the fish. If further lots of fish are to be treated in the same liquid the strength of the brine should be restored by adding and thoroughly dissolving more salt or by the addition of saturated brine.

The brine should be discarded at the first signs of spoilage and replaced by fresh brine after thorough cleaning and disinfection of the vats.

Good-quality salt should be used both for dry salting and for brining. Fish will tend to float in brines of 60° salinometer strength or higher, and a light weight will be required on the uppermost layer to keep the fish submerged.

Draining and Drying

Fish which have been dry salted are rinsed in water to remove visible salt. To obtain

the best results in smoking, the prior formation of a surface pellicle is important. This is formed by the fish muscle proteins partially dissolving in the salt solution (in both dry salting and brining) followed by drying and concentration at the surface of the fish. A well-formed pellicle promotes an even uptake of smoke, may retard drying of the deeper layers of the fish, and reduces the tendency of the fish to crack during exposure to elevated temperatures in hot smoking. Experience in fish smoking has shown that predrying of the surface of the fish to a distinct sticky or "tacky" condition will enable the production of a good pellicle during subsequent smoking.

The time taken to reach the tacky condition should preferably be as short as possible to reduce the likelihood of spoilage before smoking. At the same time the lowest possible moisture loss is desirable. Under different climatic conditions drying times may range from 30 min to 12 hr or longer. During drying, the flesh temperatures should not be allowed to rise above 75°F (24°C), otherwise there is a tendency to partial cooking during prolonged exposure. Cooper and Linton (1936) working with drying tunnels found that drying times of 35–40 min for pre-brined fillets could be obtained with air velocities between 125 and 400 cm/sec, a wet-bulb temperature between 15 and 23°C, and a relative humidity below 70 per cent.

Under some conditions, when natural drying to the tacky stage is likely to exceed an acceptable maximum time of 60–90 min, increasing the rate of air movement over the surfaces of the fish together with the use of slightly higher air temperatures may help. This may be feasible in kilns equipped with heating facilities and forced-air circulation. Under extreme conditions dehumidification of the air by refrigeration will be required.

During drying, whole fish are hung on rods or tenters; fillets are hung over closed metal loops or pairs of wooden strips. Larger fish, either split or as fillets, may be hung by the tails on the tenter hooks. Small fish to be hot-smoked before canning are threaded on thin rods through the eyes. To enable even drying and subsequent even smoking the fish are not allowed to touch each other. Sticks or metal skewers may also be used in some kinds of prepared fish to keep the flesh freely exposed to the air and smoke.

Wire mesh trays are satisfactory for holding fish which are to be dried and smoked in mechanically operated kilns with horizontal flow of air and smoke.

SMOKING

The most common commercial method of smoke curing is by cold smoke in which the air and smoke temperatures in or around the fish are not allowed to rise above 85°F for most of the period. In hot-smoking the fish are simultaneously smoked and cooked at temperatures ranging from 130 to 200°F.

Properties of Smoke

Smoking imparts flavour and colour to the fish, and some of the smoke constituents have bactericidal and bacteriostatic properties. Antioxidants are also present but their protection against rancidity is nullified to some extent by the pro-oxidant effect of salting. The combined effect of the various constituents is to produce the characteristic flavour and colour and to enable the products to be held in good condition slightly longer than is possible with fresh fish.

A wide range of woods is used to produce sawdusts and chips suitable for smoking of fish. Some softwoods, particularly amongst the conifers, are considered to impart undesirable resinous or acrid flavours to the fish, although clear-cut evidence in support of this opinion appears to be lacking. Dolezal (quoted by Foster 1959) found that foods smoked with softwoods tasted slightly better than those smoked with hardwoods. In Poland, Tilgner and Wierzbicka (quoted by Foster 1959) could find very little experimental evidence that softwoods reputed to give poor flavours were significantly inferior to hardwoods such as oak.

The properties of smoke derived from any type of wood are influenced by its rate of combustion. When the rate is too low, a "wet" smoke imparting bitter flavours to the fish is produced. In such smoke, drying of the fish may be unduly restricted. With more complete combustion of the wood, a lighter smoke containing higher proportions of desirable products of combustion is produced. This type of smoke promotes drying of the fish and the formation of a more pronounced pellicle and also gives the fish better colour, flavour, and texture.

Production and Distribution of Smoke

In the simplest types of equipment, smoke and heat are supplied by burning wood underneath the fish which are exposed, usually by hanging, in the natural updraught. Kilns in this category range from modified barrels, packing cases, or cardboard cartons (Rust 1946) to more elaborate buildings up to 25 ft or more in height.

For simple smoking in a barrel the ends are removed and the shell placed over a smoking pit. In some cases, particularly for cold smoking, the pit is at some distance from the barrel, to which it is connected by a large diameter pipe or tunnel. The fish are hung by rods placed across the top of the barrel. After smoking has proceeded for some time, a bag or cloth is placed over the top to allow some control over the concentration and flow of smoke over the fish.

In the commercial types of vertical updraught kilns commonly used throughout the world at the present time, the fires are usually directly underneath the fish which are hung at successively higher levels commencing about 6 ft above the fires. The fire pits are equipped with dampers to control air intake, and adjustable louvres are located near the roof to control removal of surplus smoke and moist air. The construction and operation of such a kiln 17 ft in height has been described by Allan and Empey (1946). In kilns of this type temperature and humidity are controlled to a limited degree by the size of the fire, and by adjustment of the dampers and louvres. For smoking under these conditions fairly dry sawdusts are required (less than 10 per cent. moisture) to ensure smouldering during cold-smoking. Fuel of higher moisture content may be used in the more intense fires for hot-smoking.

Although excellent commercial products have been produced in such kilns there are serious disadvantages which hinder the outturn of uniformly cured and attractive products. The rate of drying and smoking varies considerably from bottom to top of the kiln and this involves moving fish from one level to another during smoking. Prevailing weather conditions also often limit the extent of control of temperature and humidity inside the kilns. High labour costs, excessively long smoking times, and deposition of ash, soot, and partly burnt sawdust on the fish are additional drawbacks.

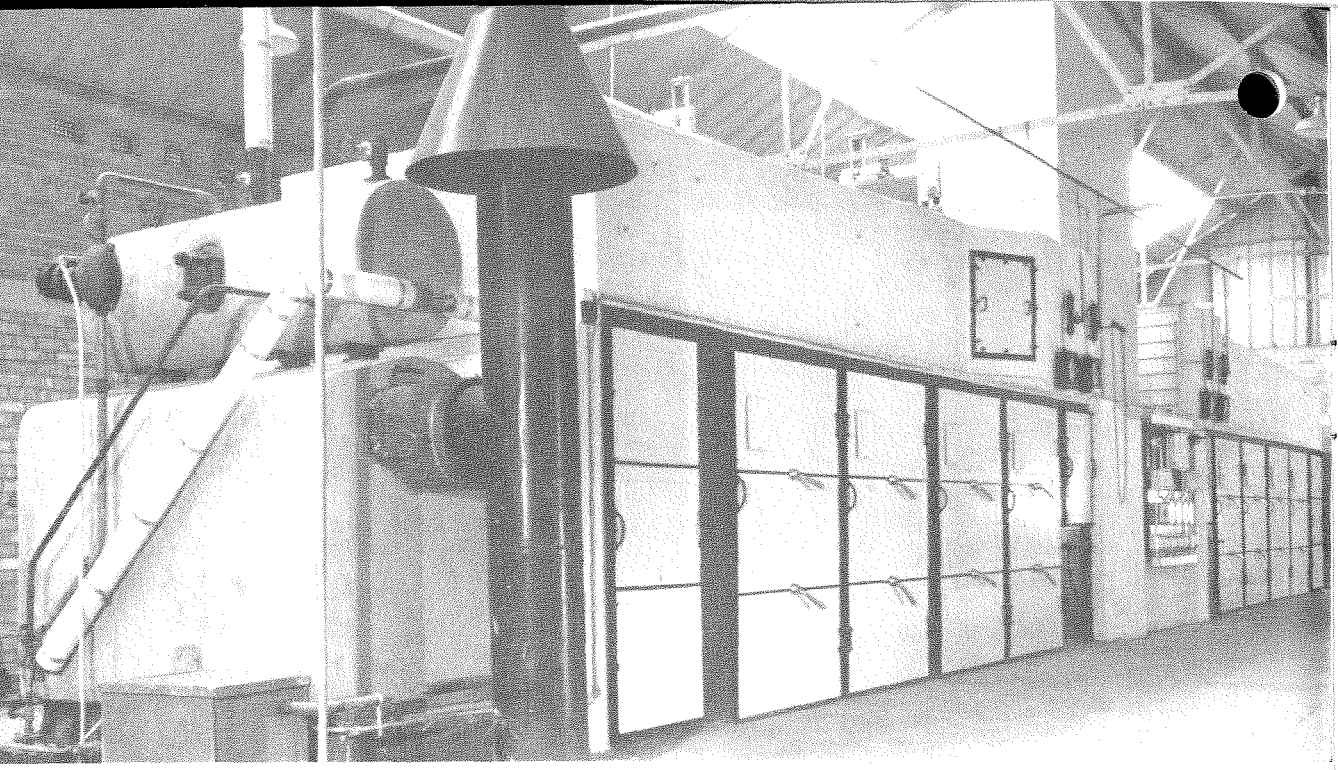
During recent years various kilns have been developed in attempts to overcome all or most of these disadvantages. All the newer designs include means for control of smoke quality and volume, temperature, humidity, air speed, and distribution of air and smoke. The tunnel-type design has been generally adopted, the fish usually being exposed on movable trolleys during smoking. Smoke generators are placed outside the kilns and are equipped with suitable dampers and ventilators to ensure the best conditions for combustion of the wood and control of smoke density. Three such kilns have been developed and have come into commercial use in Great Britain, Canada, and the United States.

The kiln developed at the Torry Research Station (Cutting 1950) is now widely used in Great Britain. A factory model of this kiln is shown in the photograph on p 46. Smoke is generated in a battery of hearths outside the kiln, mixed with air in the correct proportion to maintain the desired relative humidity, raised to the required temperature by thermostatically controlled heaters, and blown by a fan so that smoke passes horizontally at a uniform rate over all the fish, which are loaded on trucks. Some of the smoke is recirculated and mixed with a fresh supply of air and smoke.

The chief advantages of this kiln are the high degree of uniformity obtained in smoking and the ability to smoke all the fish at approximately the same rate and in a much shorter time than by the traditional method relying on convection. The increased rate of drying also enables smoking under warm, humid weather conditions which interfere with satisfactory smoking in the older kilns.

The adaptation of the Torry kiln to a smaller size to handle about 140 lb of fish and with all the essential features which provide control, uniformity, and reproducibility of smoking and drying is described by Cutting and Bannerman (1951).

In an improved smoke generator recently developed at the Hull Research Station, means of controlling the quantity and nature of the smoke more accurately than in any previous generator have been provided. In this new type, a fluidized bed of sawdust is



A commercial smoking tunnel for fish, developed at the Torry Research Station, Scotland.

subjected to a stream of hot air at controlled temperatures to produce destructive distillation rather than combustion of the wood. Nicol (1954), under whose name the original British patent and further patent applications are registered, found the shape of the fluidization chamber to be critical. He found the best design to be a truncated cone of a small angle. The generator has recently been converted from batch to continuous operation. Fresh sawdust is brought in by a worm feed, and the decomposed material is carried out with the smoke, from which it is separated by a cyclone or other type of separator. The consumption of sawdust fell to 4 lb/hr as against 28 lb/hr of sawdust and chips with normal fire boxes.

A tunnel-type smokehouse, which has been used successfully in commercial fish smoking in Canada, was developed by Linton and Wood (1946). Metal cone smoke collectors placed over the ordinary mixed sawdust and chip fires allowed a large volume of air to be drawn over the fuel and gave a smoke very similar in odour and flavour to that used in the ordinary trade smoking kilns. A fairly steady and continuous smoke production was maintained by keeping two burners in constant operation, charging and relighting them alternately. Uniform smoke and temperature distribution were obtained by mixing the incoming fresh smoke and air with recirculated smoke by means of the recirculating fan.

Control of the temperature and relative humidity in this smokehouse was secured during the warm humid summer months by admitting a sufficient quantity of dehumidified and cooled air along with the smoke. Cooling and dehumidification were carried out by drawing the fresh air entering the smokehouse through an ice box containing 600 to 700 lb of crushed ice. The cooled air at about 40°F was then heated by a steam heater to give the desired temperature within the smokehouse. Mechanical refrigeration could, when more economical, be substituted for ice cooling. Linton and Wood found that in the Maritime Provinces of Canada in the summer, when the smokehouse was filled with 400 lb of fish, about 1500 cu. ft of cooled air/min were required for mixing with about 300 cu. ft of smoke to maintain temperatures and relative humidities at a sufficiently low level for cold-smoking.

Anderson and Pederson (1948) have designed a smoke-curing kiln which is now widely used in the United States. In this kiln the smoke generator consists of a metal oil

drum placed horizontally on a metal frame, about 20 ft from the smokehouse proper and connected to it by a 5-in. pipe, thus minimizing fire hazards. A drain valve in the pipe about midway between the generator and the smokehouse inlet is provided for removal of the tar and resinous material condensed in the pipeline. Anderson and Pederson describe the use of the kiln for both cold and hot smoking of various fish and shell fish.

In each of the three types of commercial kilns referred to there is provision for automatic control of temperature, but manual control is used for all other adjustments such as air velocity, smoke density, and mixing of air and smoke. Wet- and dry-bulb thermometers are installed to measure the relative humidity inside the kilns.

When mechanical refrigeration is used for cooling air supplied to a kiln, there are possibilities of economy by using hot gases from the compressor for reheating as in the experimental kiln described by Hicks, Taylor, and Wood (1941).

Smoke generation from wood by friction was introduced into the United States in recent years. The application and advantages of this method for smoking of meats have been described (Anon. 1956). Smoked fish have been commercially prepared in Czechoslovakia, using smoke produced by this method. Adam (quoted by Foster 1959) describes a smoke generator consisting of a rotating serrated cylinder, on the outer surface of which a block of wood is pressed. After trial of various types of serrations, a cylinder with narrow longitudinal slits was adopted. The friction surfaces are cooled and cleaned by a blast of air passing through the slits, thus overcoming the hazards of fire and the tarring up of the cylinder. Smoke density is increased with increasing pressure between the wood and the cylinder.

Liquid Smokes

In the past, commercial attempts have been made to impart smoked flavour to foodstuffs by dipping in so-called smoke essences or concentrates. Results have generally been unsatisfactory by comparison with orthodox methods, and bitter flavours were commonly found in the treated foodstuffs. Many of these preparations contained pyroligneous acid which would not be a permissible food additive in some countries. It has been claimed, however (Moldavan 1953) that the undesirable components of these liquid smokes can be removed by subjecting them to the Guinot process, which is described by Moldavan, and that the refined smoke oils, termed fumeol, are suitable for imparting smoked flavours to a variety of foods including fish.

More recently Lapshin (quoted by Foster 1959) described the preparation of a water extract of smoke and its application to fish by dipping or spraying before further treatment to produce smoked fish. In preparing the smoke extracts, wood is burned in a special generator and the smoke is collected in condensers, extracted with water, and concentrated at 130°C. To prepare the dip this solution is diluted with an aqueous salt solution. After brining the fish in the usual manner they are dipped or sprayed with the smoke solution for 1–2 sec. It is claimed that the flavour imparted to the fish is not inferior to that of normally smoked fish.

Application of smoke flavours by the use of liquid smoke must be followed by surface drying to develop the glossy pellicle and to improve the keeping quality of the products. Drying is unnecessary when the fish is to be used for some types of canned fish or fish pastes.

The use of infra-red heaters for drying and for cooking hot-smoked fish has been explored by Lapshin (quoted by Foster 1959). He estimates that processing costs may be reduced by 30 to 50 per cent. by combining liquid smoke and infra-red cooking to produce hot-smoked fish.

Electrostatic Deposition of Smoke

In recent years the electrostatic deposition of highly charged smoke particles on foodstuffs has been explored. The application of this method is discussed by Morse and Pivan (1953). The smoke particles become strongly charged in passing through a charging grid maintained at up to 100,000 volts and deposit readily on the product which is earthed.

The advantages of this technique over the normal method of smoke deposition are that smoke deposition is 95 per cent. faster, more easily controlled, and more uniform, and less smoke is needed, while costs may be

appreciably lowered by allowing a change-over from batch to continuous operation.

The electrostatic smoking of sardines in unsealed cans during an exposure time of about 12 sec is described by Hamm and Rust (1947). In the set-up used by these authors the cans passing through the smoking chamber formed the negative side of an electric field of 14,000–23,000 volts.

Adam (quoted by Foster 1959) describes the application of various methods of ionizing and precipitating wood smoke on fish during smoking periods of 4–5 min.

A different technique of electrostatic precipitation of smoke by the space-charge method has been developed by workers at the Torry Research Station (Foster and Jason 1954, Foster 1956). In this system the particles of smoke, charged in a corona field, are passed into the chamber holding the fish. By virtue of their space charge the smoke particles precipitate in the absence of an applied field.

COOLING AND STORAGE

After removal from the kiln the smoked fish are held on cooling racks or on trays until they reach atmospheric temperature. If packed by wrapping or in boxes before cooling is complete, condensation of moisture on the wrapping paper or box may lead to early mould growth.

To allow for loss of weight in cold storage the customary trade practice is to allow approximately 5 per cent. extra weight of fish when packing.

The storage life of smoked fish depends on the storage temperature and on other factors such as concentration of salt, water, and smoke constituents — particularly in the surface layers. The keeping quality is also affected by the freshness of the fish prior to smoking.

The storage life of lightly salted and smoked fish may be only 1–2 days at 70°F, whereas very heavily salted and smoked products such as red herring may be held with safety for several months at this temperature. Since spoilage at temperatures above freezing will be due to bacteria, it may be assumed that the fish could be held at 32°F eight times as long, and at 40°F four times as long, as at 70°F. It is therefore necessary to use frozen storage if the lightly smoke-cured products are to be held longer than about 1 week.

Deterioration in frozen storage is largely due to the rancidity and partly to the development of toughness in the flesh. Both these changes, and also desiccation of the surfaces, may be retarded by the use of low-temperature storage, e.g. 0°F or lower. Additional protection against drying and rancidity may also be obtained by using wrapping materials proofed against water vapour.

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Conference on Control of Food Quality

A CONFERENCE on Control of Food Quality, organized by the C.S.I.R.O. Division of Food Preservation and Transport, will be held in the new Chemistry School, University of Sydney, from November 4 to 6, 1959.

The Conference aims to provide a forum for discussions in food science and technology at a research level, to create a favorable climate for the sharing of knowledge and experience between investigators in universities, in the food industry, and in government research establishments. It also hopes to define fields of investigation which are important for the present or future well-being of the Australian food industries.

Widespread support for the Conference has been indicated and it is expected that about 15 papers will be presented reporting current investigations in food science and technology in university, industrial, and government laboratories. These papers will be arranged in three symposia under the headings: Flavour Stability in Foods, Colour Stability in Foods, and Microbial Stability in Foods.

The conference is open to all persons interested in food science and technology, and those wishing to attend are requested to apply in writing to the Technical Secretary, C.S.I.R.O. Division of Food Preservation and Transport, Private Bag, P.O. Homebush, N.S.W. There is no registration fee. Abstracts of papers will be distributed in advance of the conference to all registered delegates.

A tentative time table for the conference is as follows:

Wednesday, November 4

2 p.m. Opening Session.
5.15 p.m. Inspection of C.S.I.R.O. Physico-Chemical Laboratories and Plant Physiology Unit at Sydney University.
6.15 p.m. Social Gathering, Sydney University Union.

Thursday, November 5

9.30 a.m. Technical Session.
2.15 p.m. Inspection of C.S.I.R.O. Food Preservation Research Laboratories, Homebush.

Friday, November 6

9.30 a.m. Technical Session.
12.30 p.m. Closing of Conference.

A complete program is expected to be available shortly.

BOOK REVIEW

PROTEINS IN FOODS

"PROTEINS IN FOODS," by S. Kuppuswamy, M. Srinavasan, and V. Subrahmanyan. (Indian Council of Medical Research: New Delhi, 1958.) iv +290 pp., 27 tables.

This book summarizes very thoroughly the the available information on nutritive value and amino-acid composition of proteins from a wide range of foodstuffs. The very extensive data brought together were previously scattered through many journals, including some of limited circulation. The value of the work has been greatly enhanced by the fact that the numerical data have, where necessary, been recalculated to a common basis. The book will be warmly welcomed by all working in the field of nutrition; it contains also much information useful to biochemists.

Address to N.S.W. Apples and Pear Growers' Association Conference at Orange, June 1958

The Design and Operation of Cool Stores for Fruit

By E. W. Hicks

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

A COOL STORE is simply an insulated room with a cooling system inside it. A great variety of different designs has been used but all have these two essential components.

INSULATION

The insulation is a very important feature of any cool store. Insulation is used to reduce the amount of heat flow into the store and so to reduce the size and running costs of the machines used to maintain the low temperature. If a store is not well insulated, the running costs are excessive and it is very difficult, or perhaps impossible, to maintain reasonably uniform temperatures in all parts of the stacks. This is likely to lead to high evaporative water loss from the fruit.

There is no such thing as a perfect heat insulator but there is a bewildering variety of fairly efficient insulating materials on the market. It has been said, with almost complete truth, that there is only one heat insulator of any practical importance and that is ordinary air. The various materials which we use are merely devices for keeping the air in small pockets, so preventing flow of air which would increase the transmission of heat. These materials also reduce radiant heat transfer. Thus the theoretical lower limit for the conductivity of ordinary insulating materials is the thermal conductivity of air, or 0·16 B.t.u./ft² hr °F/in. Many materials in common use have thermal conductivities between about 0·22 and 0·33 B.t.u./ft² hr°F/in.

We are sometimes questioned as to the best insulating material to use in cool stores for fruit and we must reply that there is no particular material which is better than all others. The thermal conductivity is important, of course, and must be considered. If a material of relatively high conductivity is chosen it will be necessary to use a greater thickness than with a material of lower conductivity. A low thermal conductivity of the insulation is not the only consideration. A most important aspect is the cost of the completed job—materials plus cost of installation. The mechanical properties of the materials are also important and this often governs the choice of insulation, particularly for floors. The efficiency and useful life of the insulation in a room may depend on the workmanship in its installation. The water vapour barrier on the outer, warm side of the insulation is very important from this point of view. If a good, unbroken water vapour seal is not installed, water will accumulate in the insulation, decreasing its efficiency and reducing its useful life very substantially. With some of the newer insulating materials special adhesives are needed. Care and skill are needed for efficient fixing of most of the materials supplied in the form of blocks or sheets. Skill of a different sort is required to install loose-fill types of insulation to make certain that they are not over compressed and yet not likely to settle seriously, leaving an uninsulated section at the tops of the walls.

It very often happens that after considering all the relevant factors it appears that several insulating materials are about equally attractive. In such circumstances it is reasonable to choose one which the men doing the installation have often used successfully.

There is no need to use the same insulating material for all six faces of a store. It is often desirable to use different materials for the floor and the walls, and it is sometimes

wise to use a different material for the ceiling. In this, as in most insulation questions, the cost of obtaining a specified degree of efficiency will usually be the main factor governing the choice of materials.

COOLING SYSTEMS

The various cooling systems used in fruit stores can be classified into two main types: natural circulation systems which employ no fans; and forced circulation systems in which fans are used to distribute cold air over and through the stacks of fruit.

Natural Circulation

Natural circulation systems are very popular for fruit stores in many parts of Australia and deservedly so. They have the advantages of simplicity and ease of control and it is relatively easy to keep the water loss from the stored fruit at a reasonably low level. They will not cool large stacks of warm fruit quickly and this is sometimes a serious objection. However, most stores for apples and pears can be filled relatively slowly, taking 10 days or so to fill a room. Under these conditions it is easy, by judicious distribution of the incoming warm fruit, to ensure adequate cooling rates.

The cooling coils for natural circulation rooms are hung from the ceiling. Direct-expansion ammonia piping is usually used, but brine or other refrigerants could be used. Drip trays below the pipes are necessary—narrow trays serving only a few pipes are preferable to wide trays covering many banks of pipes. It is important to distribute the pipes evenly over the whole ceiling and to design the circuits so that the pipe temperatures are reasonably constant over the whole room.

Bare piping is used in most existing natural circulation rooms but rather widely spaced fins have been used in some recent installations in order to reduce the amount of metal required. This practice may become more common in the future.

Forced Circulation

Forced circulation systems have not been widely favoured in Australia during the past 30 years, but a substantial number have been built fairly recently. They are very popular in some parts of the United States because they are cheaper to build there than natural circulation systems. There have been big improvements in the design and fabrication of components for forced circulation systems, particularly fans and cooling coils. There have also been considerable developments in the overall design of such systems since our older, rather inefficient forced circulation stores were built. Modern, carefully designed forced circulation stores compare favourably in performance with natural circulation stores. They have some advantage in the initial cooling of warm fruit but, generally, this is fairly small unless they have been specially designed as precoolers with very high rates of air flow. It is rather harder to keep the water loss low in a forced circulation store than in a natural circulation one but it can be done by careful design of the cooling system.

In stores for fruit it is usual to design the air circulating system to maintain a blanket of cold air over the top of the stack—achieving much the same condition as in a natural circulation store. There is always some forced circulation around and into the stacks but natural convection still plays a large part in the heat transfer within the stacks of fruit. True forced-circulation through-flow systems in which air cooled in the battery is forced to flow through the stacks, are used in ships with excellent results. However, these systems are rarely used in land stores because in such stores it is usually necessary to leave passageways, and along these, large quantities of air may by-pass the stacks of fruit.

The main weakness of some of the old forced circulation stores in this country is that the air and the fruit near the outlet end or side of the room are consistently several degrees warmer than near the air inlet. This disadvantage is overcome in modern stores by circulating much more air per ton of fruit or by reversing the direction of air flow periodically. Reversal of the direction is particularly helpful in large stores.

It is very important to keep the power consumption of the fans as low as possible. Fan power is, in a sense, paid for twice over, firstly directly and secondly because the power supplied to the fan motors is converted to heat which must be removed by the cooling system. Moreover, the heat input of the fans tends to increase the weight losses from the fruit. Consequently efficient fans

should be used and the resistance of ducts etc. kept as low as possible. Little or no ductwork is used in some modern stores.

The cooling coils may be installed as batteries outside the store or as unit coolers within it. In large stores a single large external battery may serve several rooms. Brine sprays are often used to provide most of the cooling surface in batteries. These can be very efficient but care must be taken to keep the brine concentration very little above that necessary to avoid freezing on the cooling coils. An unduly high average brine concentration can easily double the water loss from the fruit.

Stowage of Cases

Fruit in cool storage is living material, respiring and producing heat. It is essential, therefore, to have a continuous small rate of air flow over the boxes in stacks to carry off the heat, water vapour, and perhaps some other products of the vital processes of the fruit. The temperature gradients within ordinary boxes and the accumulation of carbon dioxide inside them are quite small and do not have any significant effect on the storage behaviour of the fruit. This would not be so if very much larger packages were used. There does not seem to be much interest in the commercial use of packages which are too large in this sense, but it is quite possible to build stacks of regular-shaped boxes which behave like very large packages with partitions which do very little to offset the harmful effects.

Consequently it is essential for successful cool storage to stow the boxes so that there will be enough air flow over them. It is very difficult to measure or specify the minimum degree of openness in stacking which will be sufficient. However, in the course of an extensive survey referred to in the next section, it was found that spaces of $\frac{1}{2}$ in. or more between vertical piles of boxes allowed satisfactory penetration of air. Wider air spaces should be left between the stacks and the walls.

PERFORMANCE OF COOLING SYSTEMS

An extensive survey of the performance of representative cool stores in Australia was carried out by Mr. G. M. Rostos (formerly of the Division) some years ago. It is hoped that a report on this work will be published in the near future.

Mr. Rostos paid particular attention to the variations of the average fruit temperatures between different positions in the stacks. He found greater uniformity of fruit temperatures for boxes inside the stacks than for boxes on the outer faces of the stacks. In most of the stores the average temperatures at particular points within stacks, after the cooling was complete, were within 1°F of the average. This may seem poor performance at first sight, but a little consideration will show that it must be very difficult to achieve absolute uniformity of temperature in a large stack of fruit since the fruit itself is, all the time, liberating heat at an appreciable rate. There were only a few stores in which much greater variations in temperatures within stacks were observed. In one of these the cause was clearly overtight stacking of boxes without bulges so that too little air could penetrate these parts of the stack to carry away the heat produced by the fruit. Most of the other relatively great variations in fruit temperatures inside stacks were observed in old forced circulation stores in which there was too little air flow to avoid a substantial temperature gradient along or across the room.

Temperatures on the outer faces of stacks were almost always more variable than inner temperatures. In a good many stores the overall range in fruit temperatures was within 2°F of the average, and only a very small proportion of the boxes had temperatures differing from the average by more than 1°F. There were, however, a number of stores in which the variations were substantially greater. A few showed a range of 7°F or a little more between highest and lowest average fruit temperatures—the averages being taken over a period of several days.

Variations in fruit temperatures with time were generally quite small and of little practical importance. There were indications of slow drifts in temperature in a number of instances but there was only one store among those studied in which the drift amounted to several degrees over a period of three months. The serious drift in this store seems to have arisen from difficulties in manual control with the compressor which was operated only a few hours a day, its capacity being far too

large for proper balance with the load. Efficient automatic controls should be regarded as essential, particularly for relatively small installations.

As was pointed out in regard to insulation, there is no type of cooling system which is better than all others. There were stores of several quite different designs among the group showing relatively good uniformity of temperature, and stores of most of these types also among the group showing poorer performance. Poor performance was practically always due to faults in details of design, or sometimes of operation, rather than to any fundamental fault in design.

Hobart Branch Laboratory

ON JULY 2, 1959, the food processing plant and cool rooms at the C.S.I.R.O. Tasmanian Regional Laboratory were opened for inspection by about 100 representatives of the food processing industries in Tasmania, the Food Technology Association, the C.S.I.R.O. State Committee, and State and Commonwealth Departments.

The pilot plant and cool rooms, which are housed in an annexe at the rear of the main "Stowell" laboratories, were first used in 1957. The pilot plant occupies about 1200 sq. ft., and a somewhat larger area is devoted to three cool rooms, a freezing room, a constant-temperature room and associated equipment, and to an office and storerooms. The processing space and the freezing room are used by the staff of the Division of Food Preservation, under the supervision of Mr. S. M. Sykes, for investigations on the preservation of apples and berry fruits. The cool rooms and the constant-temperature room are used by the Division of Plant Industry staff, under Dr. D. Martin, for investigations on the storage of apples.

Many of the displays were concerned with the storage and processing of apples, which feature so largely in the economy of Tasmania. The visitors were given the opportunity to taste samples of apple which had been cooked after processing by four different methods: canning, dehydro-canning, dehydration, and freezing. Many of the visitors concerned with the drying of apples were interested in a sample of dehydrated apple prepared by dip-sulphuring and forced-draught drying for 3 hours. Slices of apples at various stages in dehydro-canning also attracted comment. In this process half of the moisture is removed from the apple before canning, thereby reducing the cost of containers and transport. A demonstration was given of methods for determining moisture in dried apples in the laboratory and of a rapid method for use in factories. Equipment for measuring the efficiency of apple drying kilns was also on display.

Visitors to the Open Day showed considerable interest in the processing equipment, which included a vacuum can closer recently donated to C.S.I.R.O. by J. Gadsden Pty. Ltd., Hobart, an experimental vacuum syruper which was designed and built in Melbourne by Food Machinery (Aust.) Ltd., and a spin cooker which was built by the Food Preservation staff for investigations on the heat processing of canned berries. Among laboratory equipment also on display was a tester developed by the Division of Food Preservation for estimating vacuum in cans, an automatic balance for measuring moisture content of solid materials, and thermocouple equipment for measuring temperatures.

Officers of the Division of Plant Industry demonstrated methods for sampling and analysing the internal atmosphere of apples. They also exhibited photographic slides illustrating aspects of research on apple cell size and on the control of superficial scald with diphenylamine. Many visitors were interested in the two cool rooms which are used for gas storage of apples and in the gas scrubbers which control the carbon dioxide content of the storage atmospheres.

In addition to the displays in the Food Processing Annexe visitors were shown apple waxing equipment, a small forced draught dehydrator, and the automatic oil-fired boiler, all of which are housed in the main buildings of the Tasmanian Regional Laboratory.

Contributions to the Division

IT IS OUR PLEASURE to place on record the financial and other assistance given to the Division during the year ending June 30, 1959. Contributions amounting to over £3600 were made by the following firms:

Barossa Canneries Ltd.
Batlow Packing House Co-operative Ltd.
Berri Co-operative Packing Union Ltd.
Committee of Direction of Fruit Marketing
Containers Ltd.
Cottee's Passiona Ltd.
J. Gadsden Pty. Ltd.
Gordon Edgell & Sons Ltd.
Harry Peck & Co. (Aust.) Ltd.
Holbrooks Pty. Ltd.
Kia-Ora Industries (Vic.) Pty. Ltd.
Kyabram Preserving Company Ltd.
Leeton Co-operative Cannery Ltd.
Matthews Thompson (Trading) Co. Pty. Ltd.
Orange Fruit Growers' Co-operative
Pick-Me-Up Condiment Co. Ltd.
Raleigh Preserving Co. Ltd.
R.B. Manufacturing Co. Pty. Ltd.
Rosella Preserving and Manufacturing Co. Ltd.
Summons & Graham Ltd.

Equipment purchased with the help of the above contributions is now in use in the chemistry and microbiology laboratories in the Division. In addition J. Gadsden Pty. Ltd., Hobart, were good enough to donate a vacuum can-closer which will be used at the C.S.I.R.O. Tasmanian Regional Laboratory for investigations into the canning of apples, berry fruits, and peas.

The Division would also like to warmly acknowledge the assistance, amounting to nearly £16,000 given to research for the following purposes by the Government Departments, and statutory bodies listed below.

Australian Apple and Pear Board.—Studies on the handling and storage of apples and pears.

Australian Egg Board.—Investigations on "pink whites" and other changes in stored eggs.

Australian Meat Board.—Investigations on the technology of meat storage at the Division's Meat Research Laboratory, Cannon Hill, Queensland.

Department of the Army.—Dehydration of meat.

Department of Primary Industry.—Investigations on the removal of spray residues from fruit.

Egg Producers' Council.—Investigations, commencing 1959–60, on the quality of eggs during marketing.

Metropolitan Meat Industry Board, Sydney.—Research on meat, especially on the biochemistry of muscle.

N.S.W. Department of Agriculture.—Storage and freezing of fruit and vegetables.

Queensland Meat Industry Board.—Investigations at the Division's Meat Research Laboratory, Cannon Hill, Queensland.

Funds for investigations on the sterilization of citrus fruit against fruit fly have been received through the Department of Primary Industry. These funds have been made up of contributions from the Commonwealth Government, the State Governments in New South Wales, Victoria, and South Australia, and the Federal Citrus Council.

Curing Ingredients in Cured Meats

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

CANNED CURED MEATS owe some of their characteristic properties of colour and flavour to the presence of curing salts—sodium chloride, potassium nitrate, and sodium nitrite, which are incorporated in the product immediately prior to canning or during a preliminary curing process. Many countries have prescribed limits for the amounts of these curing ingredients in canned meats; for instance in the N.S.W. Pure Food Act (1908–1958) the maximum contents permitted are: 3 per cent. sodium chloride; and 0·2 per cent. nitrates, calculated as potassium nitrate, or 0·2 per cent. combined nitrates and nitrites, provided the nitrite content calculated as potassium nitrite is not greater than 0·014 per cent.

Control of the salt content of canned meats is important for palatability and, in addition, the curing ingredients may influence microbiological stability. Both chloride and nitrite may usefully inhibit microbial growth, whereas nitrate may encourage the growth of aerobes (Silliker, Greenberg, and Schack 1958). Sugar, which is included in some cures, appears to be essential for the production of gas in spoiled canned bacon and the appearance of swelled cans. Excessive amounts of nitrite may also cause swelled cans by the production of nitrogen and oxides of nitrogen during heat processing (Empey 1951).

* 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; Vol. 17 (1957), pp. 11–14, 30–5, 42–7; Vol. 18 (1958), pp. 15–19, 25–9; and Vol. 19 (1959), pp. 22–7.

ANALYTICAL PROCEDURES

Preparation of the Extract

The entire contents of the can are passed through a mincer, preferably with a $\frac{1}{8}$-in. plate, three times, mixing thoroughly after each mincing. A sample of 25 g is comminuted in a high-speed blender with 350 ml of hot water, for 3 min. The suspension is boiled 5 min to coagulate protein, cooled, made up to a volume of 500 ml, and allowed to settle, preferably in a refrigerator to solidify fat. Centrifuging or filtration may be necessary to obtain a clear extract.

Chloride Content

In the classical chemical methods for determination of chloride by reaction with silver nitrate, protein interferes. Protein may be removed from the extract by digestion with nitric acid, as in the method of the Association of Official Agricultural Chemists (A.O.A.C.) (1955*a*), by the addition of protein precipitants (Gerritsma, Van der Kamer, and Willems 1950), or by ashing, as in the following method.

Procedure: Pipette 25 ml of the extract into an evaporating basin and make alkaline to phenolphthalein with sodium carbonate. Evaporate and ash at low heat (about 400° C). Extract with distilled water, make acid to phenolphthalein with acetic acid, and titrate with 0·1N silver nitrate, using 2 drops of 5 per cent. potassium chromate as an indicator.

Similar procedures are prescribed by the Royal Australian Chemical Institute (1952) and the South African Bureau of Standards (1950).

Satisfactory determinations of chloride without complete removal of protein have been claimed by some workers. Thus Anderson

(1956) applied directly to extracts from canned fish and meats the method of Samson (1953) which involves a simple potentiometric titration using two silver/silver chloride electrodes, leading to a "dead-stop" end-point. Good agreement with results by ashing and Mohr titration was obtained. Schonherz (1955) successfully determined chloride in salted meats by titration of water extracts with mercuric nitrate using diphenylcarbazone as an indicator (cf. Ungar 1954).

For the rapid determination of salt in homogeneous foods such as soups and strained foods, the conductimetric tester of De Alcuaz (1955) is very suitable since it records the salt content with a precision of 0·05 per cent. in ½ min. However, conductimetric measurements on solid packs such as canned corned beef are likely to be much less accurate (cf. Rose and Grant 1952).

Nitrate Content

The Royal Australian Chemical Institute prescribes for the determination of nitrate in canned meats the gasometric method of the A.O.A.C. (1955*b*) in which nitrate is reduced to nitric oxide by ferrous chloride. This method, however, is tedious and time-consuming, and most analysts will prefer the alternative colorimetric procedure (A.O.A.C. 1955*c*) based upon the incomplete but reproducible nitration of 2,4-xylenol to nitroxylenol, which is intensely yellow in alkaline solution. Nitrite is first oxidized with potassium permanganate and is determined as nitrate. Interfering proteins and chloride are removed with phosphotungstic acid and silver ammonium hydroxide. To avoid interference by other organic compounds giving yellow or brown colors with sulphuric acid, the nitroxylenol is steam-distilled into alkali and the color is measured spectrophotometrically. An alternative procedure to steam distillation is extraction with toluene (Buckett, Duffield, and Milton 1955).

Nitrite Content

Nitrite is commonly determined by methods based on the highly sensitive test originated by Griess, in which the nitrite is used to couple two suitable reagents to form a diazo-dye. The pairs of reagents generally used are sulphanilic acid and 1-naphthylamine, or sulphanilamide and *N*-(1-naphthyl)-ethylenediamine dihydrochloride, the latter pair giving more rapid colour development (Shinn 1941).

Rose and Peterson (1953) found that soluble extractives in aqueous extracts from meat interfered with the estimation of nitrite.

In the method of the A.O.A.C. (1955*d*) the extract is cleared with mercuric chloride and the colour is developed with a mixed reagent containing sulphanilic acid and 1-naphthylamine in dilute acetic acid. A similar method is prescribed by the South African Bureau of Standards (1950), but the two reagents are added separately. Barnes and Folkard (1951) examined critically a number of procedures for the determination of nitrites and obtained best results by the method of Rider and Mellor (1946), using either pair of reagents, added separately, in hydrochloric acid solution. Accordingly the following procedure is suggested.

Reagents:

Sulphanilic acid (or sulphanilamide): 0·5 per cent. solution in 20 per cent. v/v hydrochloric acid.

1-Naphthylamine (or *N*-(1-naphthyl)-ethylenediamine hydrochloride): 0·3 per cent. solution in 1 per cent. v/v hydrochloric acid.

Sodium nitrite: 0·01 per cent. standard solution.

Mercuric chloride: saturated solution.

Procedure: Pipette a 50-ml aliquot of the extract into a 100-ml volumetric flask, add 2·5 ml saturated mercuric chloride solution, mix well, make to volume, and filter. Take an aliquot of the filtrate containing 0·01–0·1 mg nitrite in a 100-ml volumetric flask and add 2 ml of the sulphanilic acid reagent. Allow to stand 5 min to complete diazotization, add 2 ml 1-naphthylamine reagent and make up to 100 ml. Allow to stand 30 min (or 10 min with the alternative reagents) to complete colour development.

Measure the absorption in a photoelectric colorimeter at 520 mμ and determine the nitrite content by reference to a calibration curve prepared by applying the same procedure to standard nitrite solutions. Determine also a "reagent blank" and correct the result accordingly. If the colour measurements are delayed, keep the solutions in the dark to avoid fading.

Fermentable Sugar Content

In relation to the effect of sugar on gas production in canned cured meats, the significant quantity is the content of sugars available to microorganisms. This "fermentable sugar content" has been determined in this laboratory by a procedure developed by Huelin (1946).

The extract is cleared with zinc hydroxide. Reducing substances are oxidized with alkaline ferricyanide and the excess ferricyanide is determined by adding potassium iodide and titrating the liberated iodine. Zinc sulphate is present to precipitate the ferricyanide formed so as to prevent its reoxidation. The extract is then fermented with yeast, the non-fermentable reducing substances are determined by the same procedure, and the fermentable sugar content is obtained by difference.

Reagents:

Sodium hydroxide: N solution.

Zinc sulphate: 150 g $ZnSO_4.7H_2O$ in 1 litre water.

Alkaline ferricyanide reagent: 3·2 g $K_3Fe_2(CN)_6$ and 10 g Na_2CO_3 dissolved in 1 litre water.

Zinc sulphate-iodide reagent: 25 g KI, 50 g $ZnSO_4.7H_2O$, and 250 g NaCl dissolved in 1 litre of water. Prepare this reagent in small quantities and store away from light.

Acetic acid: 8% solution by volume.

Sodium thiosulphate: 0·005N, diluted as required from 0·1N stock solution.

Phenolphthalein indicator: 0·05% in 95% alcohol.

Starch indicator: 1% starch in 20% NaCl solution.

Procedure: Pipette 40 ml of the extract into a 50-ml volumetric flask, add 1 ml of zinc sulphate solution, and mix well. Then add 1 ml of N sodium hydroxide and shake. Make up to 50 ml and filter. Take 25 ml of the filtrate, add 0·25 ml (5 drops) of concentrated hydrochloric acid, and boil for 3 min to invert the sucrose. Cool, then neutralize exactly with N sodium hydroxide using 1 drop of phenolphthalein indicator. Make up to 50 ml. Pipette 10 ml of the solution into a large Pyrex test tube (7 by 1 in.) or if the extract is high in reducing substances take a smaller aliquot and make it up to 10 ml with distilled water. Add 5 ml of the alkaline ferricyanide reagent and heat in a boiling water bath for 15 min. Cool and add 2 ml of zinc sulphate-iodide reagent, followed by 2 ml of acetic acid. Titrate with 0·005N sodium thiosulphate using a few drops of starch indicator. Carry out a blank reduction in the same way on 10 ml of distilled water instead of the sugar solution. Calculate the content of total reducing substances according to the relation:

Total Reducing Substances (as mg of invert sugar) = (Blank–Titre) × 0·17.

To determine non-fermentable reducing substances, take 40 ml of the extract and evaporate it rapidly to small volume. Wash it into a test tube so that the final volume is about 10 ml. Cool, add 1 ml of a washed yeast suspension, and incubate for 24 hr at 25°C. Wash into a 50-ml volumetric flask and proceed as for the estimation of total reducing substances.

To prepare the yeast suspension, disperse 1 g of pressed bakers' yeast or 0·5 g of dried yeast in 100 ml of distilled water. If dried yeast is used allow the suspension to stand for 1 hr. Centrifuge at 2000 r.p.m. and decant the liquid. Repeat these operations twice and finally suspend the washed yeast in 100 ml of distilled water.

The difference between the amounts of total reducing material and non-fermentable reducing material gives the fermentable sugar content. The procedure outlined will estimate 0·1–1·4 mg of reducing material expressed as invert sugar. It is advisable to take an aliquot representing 0·5–0·8 mg of invert sugar, and after reduction the titre should not be less than 1 ml of 0·005N sodium thiosulphate. The blank is about 10 ml on freshly prepared alkaline ferricyanide reagent, but it slowly decreases and it is preferable to prepare fresh reagent each week.

Curing Ingredients in the Aqueous Phase

When interpreting the results of curing ingredient analyses in terms of probable effects on microbial growth, it is important to realize that such effects are determined by the concentrations in the aqueous phase of the product rather than in the whole product. The aqueous phase is assumed to consist largely of water and salt:

Aqueous phase (A%) = Moisture% + NaCl%.

The concentrations of curing ingredients in the product are then converted to concentrations in the aqueous phase by multiplying by the factor 100/A.

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NEWS FROM THE DIVISION OF FOOD PRESERVATION AND TRANSPORT

NEW LABORATORIES

Work has begun on the erection of the new central laboratories for the Division at North Ryde, a suburb of Sydney about 6 miles north-west of the city. It is expected that the buildings, which will provide 71,000 sq. ft. of floor space, will be ready for occupation in about 2 years. There will be two large laboratory blocks each of two storeys, the smaller being devoted to research on the processing of foods. A block of constant-temperature rooms, providing temperatures from 20 to 100°F, will be integrated with the larger block. Separate single-storey buildings will house administrative staff and library, meeting room, dining and taste-test room, boiler house, workshops and stores, and factory space for food processing.

SULPHURING FRUIT

It has long been customary in the dried tree fruits industry to treat the fresh fruit with sulphur dioxide to retard darkening of the fruit during the drying process, and while the dried fruit is in store. The usual method of sulphuring is to expose the fruit to fumes from burning sulphur in an enclosed space into which enough air can enter to support

combustion of the sulphur. This procedure results in the dried product containing sulphur dioxide at many different levels, which often depart greatly from the Australian permissible upper limit of 21 grains per pound or 3000 parts per million.

Over recent years, a study has been made at Homebush of factors affecting the absorption of sulphur dioxide by fruit tissue and its retention during subsequent drying. Basic information has been obtained by using a small recirculatory tunnel in which dry-bulb temperature, air speed and sulphur dioxide concentration could be varied. The thermal conductivity of the circulating air stream varied with its sulphur dioxide content, and this was used to control the concentration of the latter. Materials used in the construction of the tunnel were waterproof plywood coated with sulphur-resisting lacquer and stainless steel, or plastic-coated mild steel.

The basic information obtained from the tunnel experiments has been applied to pilot-scale operation, and the results suggest that the method can be used commercially. The pilot-scale equipment consists of a box in which two tiers of trays are fitted on wooden runners. Leakage at the door is prevented by Neoprene gasketting. Sulphur dioxide from a cylinder of the compressed gas is introduced into the box through a simple flowmeter and exposure continues for a fixed time. During a run, the air and sulphur dioxide in the box are well mixed by means of a stainless steel fan. The concentration of sulphur dioxide in the box falls during a run because it is absorbed by the fruit but, by using fixed loadings of fruit and introducing the gas at fixed rates, the absorption levels in fruit can be kept within a narrow range. The interior of the box is protected with a plastic finish, and metal parts exposed to sulphur dioxide are made of stainless steel.

PERSONAL

DR. R. N. ROBERTSON, Assistant Chief of the Division, completed his academic year as Visiting Professor of Horticulture at the University of California, Los Angeles, in June 1959. After visiting other research laboratories in the United States, Dr. Robertson left for Cambridge, where he spent about 2 months in collaborative work with Professor G. E. Briggs. In August, Dr. Robertson attended the International Botanical Congress at Montreal, Canada. Shortly after his return to Sydney in September, Dr. Robertson will join the Executive of C.S.I.R.O.

DR. G. KAESS, Senior Research Officer at the Division's Meat Research Laboratory, Cannon Hill, Queensland, left for Europe on July 31 to attend the Tenth International Congress of Refrigeration at Copenhagen from August 19 to 26, 1959, and a meeting of workers from meat research institutes in Paris during September. He will take the opportunity of visiting centres of meat research in the United Kingdom, Sweden, Denmark, Germany, Switzerland, and Holland. He will return via Canada and the United States, reaching Australia early in November.

DR. M. D. HATCH, Research Officer in the Division's Plant Physiology Unit has been awarded a Research Fellowship in the Department of Agricultural Biochemistry at the University of California, Davis. He left Sydney at the beginning of August and will spend a year working on biochemical problems of lipid metabolism under the direction of Dr. P. K. Stumpf.

MR. E. G. DAVIS, Senior Research Officer in the Canning Section returned in July from the Massachusetts Institute of Technology, where he carried out research on packing of foods in flexible films, with special reference to heat processing. He returned via Europe to study the packaging of cheese in film containers in Copenhagen, the production of electrolytic tinplate in Wales and its performance, and other container problems.

PUBLICATIONS BY STAFF

Effects of Oxygen on Quality and Ascorbic Acid Retention in Canned and Frozen Orange Juices. J. F. Kefford, H. A. McKenzie, and P. C. O. Thompson. *J. Sci. Fd. Agric.* **10**: 51–63 (1959).

Canned orange juice has a short storage life due to rapid development of off-flavours and a slow loss of ascorbic acid (vitamin C). Oxygen may be present in the headspace or dissolved in the juice, and de-aeration to remove it has been considered an essential step in processing orange juice if it is to retain its quality for a reasonable time. In the experiments described in this paper juices were canned with initial oxygen contents ranging from about 3·5 per cent. to less than

0·002 per cent., by means of a gas-saturation procedure, and a quantitative study was made of changes in oxygen content, ascorbic acid content, flavour, and colour during processing and storage of both pasteurized and frozen orange juice.

In frozen juices stored at 0°F the presence of free oxygen in the cans for at least 1 year permitted slow oxidative loss of ascorbic acid.

In pasteurized juices stored at 86°F, oxidative destruction of ascorbic acid occurred only during the first few days, since free oxygen rapidly disappeared from the cans. Throughout subsequent storage anaerobic loss of ascorbic acid continued at a rate about one-tenth of that in the early period.

Anaerobic reactions also contributed to flavour changes in pasteurized orange juices since complete removal of oxygen failed to retard the development of stale flavour at 86°F.

It was concluded that the importance of de-aeration for canned pasteurized citrus juices has been over-emphasized, since pasteurization causes a decrease in oxygen content, and the consumption of oxygen in the can continues rapidly in storage. With frozen juices, on the other hand, oxygen does not disappear rapidly from the container, and efficient de-aeration may lead to improved retention of flavour and ascorbic acid.

Effects of Residual Oxygen on Storage Life of Dehydrated Mutton Mince. A. R. Prater and A. G. L. Elliott. *C.S.I.R.O. Aust. Div. Food Pres. Transp. Tech. Pap.* No. 10.

Previous work has shown that exclusion of oxygen from dried meat packs gives a much longer storage life, but, as the cost of excluding all oxygen under commercial conditions may be too high, a study was made to compare the storage life of dried mutton mince containing different amounts of oxygen. Samples were packed in air, carbon dioxide, nitrogen, and three atmospheres of nitrogen containing 1·4, 2·5, and 4·3 per cent. oxygen. For each gas there were two sizes of free space and storage temperatures of 77 and 86°F.

In general, acceptability decreased with increasing amounts of oxygen; the difference between nitrogen with 1·4 and 2·5 per cent. oxygen did not quite reach the 5 per cent. significance level. Variation in oxygen content due to variation in free space had highly significant effects on shelf life. Changes in gas composition have been recorded over the storage period of 30 months.

Chemistry of Non-enzymic Browning. IV. Determination of Amino Acids and Amino Acid-Deoxyfructoses in Browned Freeze-dried Apricots. D. L. Ingles, and T. M. Reynolds. *Aust. J. Chem.* **11**: 575–80 (1958). **V. The Preparation of Aldose-Potassium Bisulphite Addition Compounds and Some Amino Derivates.** D. L. Ingles. *Aust. J. Chem.* **12**: 97–101 (1959).

These two papers give an account of chemical work designed to elucidate the browning of foods, particularly of dried fruits in storage, by following changes in the amino acids and sugars as the browning proceeds. Part V seeks to explain how bisulphites and sulphur dioxide protect foods from browning.

Studies in the Natural Coating of Apples. IV. The Nature of Cutin. F. E. Huelin. *Aust. J. Biol. Sci.* **12**: 175–80 (1959).

The cutin on the surface of the apple restricts the loss of water and exchange of gases through the skin. This paper describes investigations on its chemical composition and mode of formation.

Oxidation of Krebs Cycle Acids by Tissue Slices and Cytoplasmic Particles from Apple Fruit. M. D. Hatch, Judith A. Pearson, Adele Millerd*, and R. N. Robertson. *Aust. J. Biol. Sci.* **12**: 167–74 (1959).

The work described in this paper was designed to give a fuller understanding of the rise in respiration of apples at maturity, and how it is delayed by cold storage and high concentrations of carbon dioxide in the storage atmosphere.

* Biochemistry Department, University of Sydney, now at Waite Agricultural Research Institute, University of Adelaide.

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).