FOOD PRESERVATION QUARTERLY

Vol. 24 No. 2 June 1964

REGISTERED IN AUSTRALIA FOR TRANSMISSION BY POST AS A PERIODICAL

Composting Trials with Pear Canning Wastes

By J. F. Kefford

Division of Food Preservation, CSIRO, North Ryde, N.S.W.

Solid wastes from pear canning operations present a special problem in waste disposal to Australian canners, particularly in the Goulburn Valley, Victoria, the principal area of pear production. This article describes some trials which indicate that a composting method developed in the U.S.A. to deal with a similar problem may provide a satisfactory solution in Australia at low cost.

WASTES from apricots and peaches consist of pits, but pear canning produces large amounts of soft, wet, intractable waste material consisting of cores, peels, stems, ends, trimmings, and rejected whole pears. In the Goulburn Valley during the season of about three months the total accumulation of pear wastes is of the order of 10,000 tons and the maximum daily output of wastes is about 200 tons. American canners are faced with the same problem on a very much larger scale and have examined numerous possibilities for the utilization of pear wastes. Having found no profitable outlets (Kefford 1963), they are now looking for cheap and convenient ways of disposal that will not pollute either the atmosphere or natural waters, or create a nuisance in other ways.

During a visit to America in 1962, the writer was impressed with the work being done on the disposal of solid fruit wastes by the National Canners' Association at their Western Regional Laboratory in Berkeley, California. After a series of small-scale trials in bins, NCA workers had concluded that aerobic composting was a feasible and acceptable method for disposal of fruit and vegetable solid wastes (Mercer 1962). In the 1963 season similar trials were conducted by the CSIRO Division of Food Preservation at its North Ryde laboratories, using the procedures recommended by NCA, and the conclusions of the American workers were substantially confirmed.

In the raw state pear waste is too wet for successful composting, and it must be brought to an initial moisture content in the range 65–70% by the addition of suitable dry material. Accordingly, rice hulls, chaff, and recycled compost were examined for suitability for this purpose. The pH of the compost was adjusted by the addition of agricultural lime at the rate of approximately 0·5% of the weight of the pear waste, to encourage rapid microbial growth.

Procedures for Local Trials

Raw Wastes.—Pear wastes from a Sydney cannery were brought to the laboratory in 44-gal drums. The wastes consisted of peels, cores, skins, ends, and some rejected whole pears. In the first trial the wastes were not comminuted, though whole pears were broken up as far as possible with shovels during loading of the bins and turning of the material. In later trials the wastes were put through a Fitzmill, provided with a $\frac{3}{4}$-in. screen to give a coarse puree. Experience now suggests that an intermediate comminution sufficient to break up the whole pears (e.g. by means of a rough hammer mill) would have given results better than either of the procedures followed.

Dry Fillers.—The three dry ingredients used for adjusting the moisture content of the compost were: rice hulls from the rice mills at Leeton, N.S.W.; chopped straw (as

Ingredients and Yields in Compost Trials on Pear Waste

	Trial No. 1		Trial No. 2		Trial No. 3		Trial No. 4	
	Weight (lb)	Moisture (%)	Weight (lb)	Moisture (%)	Weight (lb)	Moisture (%)	Weight (lb)	Moisture (%)
Pear waste	800	88	774	86·5	800	88	875	86·5
Filler	320*	11·5	516†	40	320‡	8·5	320§	12
Lime	4		3		4		3·5	
Initial compost	1124	66	1293	68	1124	64	1198·5	67
Final compost	516	40	420	23	—	—	390	22

* Rice hulls. † Rice hull compost from Trial No. 1. ‡ 4-in. chopped straw. § ½-in chaff.

used for mushroom compost) consisting of wheat straw chopped into 4-in. lengths; and chaff, consisting of wheat straw chopped into ½-in. lengths. The relative proportions of waste and filler in each trial were calculated to give an initial moisture content within the range 65–70%, which NCA workers had shown to be optimal. Agricultural lime was added to all batches for adjustment of pH.

Bins.—Two bins, 4 ft square and 5½ ft high, were constructed from hardboard on timber frames, and had open tops and one side removable for access to the compost. The bins rested on the concrete floor of an open basement beneath one of the laboratory buildings. Provision of cover was necessary because of the likelihood of rain. The dry filler and pear waste were loaded into the bins in six to eight alternate layers and lime was sprinkled on each layer of waste.

Aeration.—On each of the first five days after the day of loading, the compost was shovelled out of the bin, turned with shovels on the concrete floor, and then replaced in the bin. Thereafter the compost was turned on each alternate day until the trial terminated.

Measurements.—The total weight of each ingredient was recorded at the time of loading of the bins. Each day the temperature of the compost was measured with a thermocouple probe at five points 1 ft below the upper surface. The probe was inserted at the centre and at four points on the diagonals, 1 ft from each corner. The compost was sampled for analysis after each turning by taking several shovelfuls at different points and quartering down to a sample of approximately 2 lb, which was placed in a screw-top jar. This sample was examined for moisture content by oven drying at 100°C, and its pH was determined after blending it with an equal weight of distilled water.

Some details of the four trials carried out are given in the table above and further information and observations are given below.

Trial No. 1.—The filler material in this trial was rice hulls, used in the proportion of 1 part by weight to 2½ parts of pear waste. The compost mass was compact (50 cu ft), friable, homogeneous, and easily turned. Microbial activity commenced immediately, as indicated by the temperature and pH readings shown in Figure 1(*a*). Maximum temperature was reached around 7 days, and the cycle was complete in about 14 days.

Trial No. 2.—The compost formed in the first trial was used as filler in the second trial. Since its moisture content was still above 50% after 14 days' composting, it was spread on the concrete floor in a thin layer (2 in. deep) to dry. After 2 days, during which the material was turned occasionally, its moisture content had fallen to 40%. Because of this relatively high water content the proportion needed to bring the moisture content of the pear waste mixture within the optimum range of 65–70% was higher than previously, i.e. 1 part to 1½ parts of pear waste.

The compost mass in this trial was also compact, friable, and easily turned. Microbial activity again occurred rapidly, and the cycle was complete after about 10 days. Maximum temperatures, pH values, and changes in moisture content are shown in Figure 1(*b*). At 21 days the compost was spread out on the concrete floor to dry, and after a further 14 days the moisture content had fallen to 23%.

After two cycles this rice hull compost had retained its physical form apparently unchanged and could probably be recycled many times before breaking down in structure. In the two trials a total of 1550 lb of wet pear waste and 320 lb of rice hulls (at 11·5% moisture) had been reduced to 420 lb (at 23% moisture), as indicated in the weight data in the table.

Trial No. 3.—The filler in this trial was chopped wheat straw cut into 4-in. lengths. The compost mass was very voluminous (75 cu ft) and was difficult to handle when mixing and turning. Maximum temperatures, pH values, and moisture contents are shown in Figure 1(*c*). Microbial activity evidently proceeded satisfactorily although temperatures were generally lower than in other trials, probably because of the voluminous nature of the compost. There appeared to be two "bursts" of activity and the cycle was complete in about 18 days. Because it was inconveniently voluminous the compost was not recycled.

Trial No. 4.—The compost mass obtained when the filler used was chaff, i.e. wheat

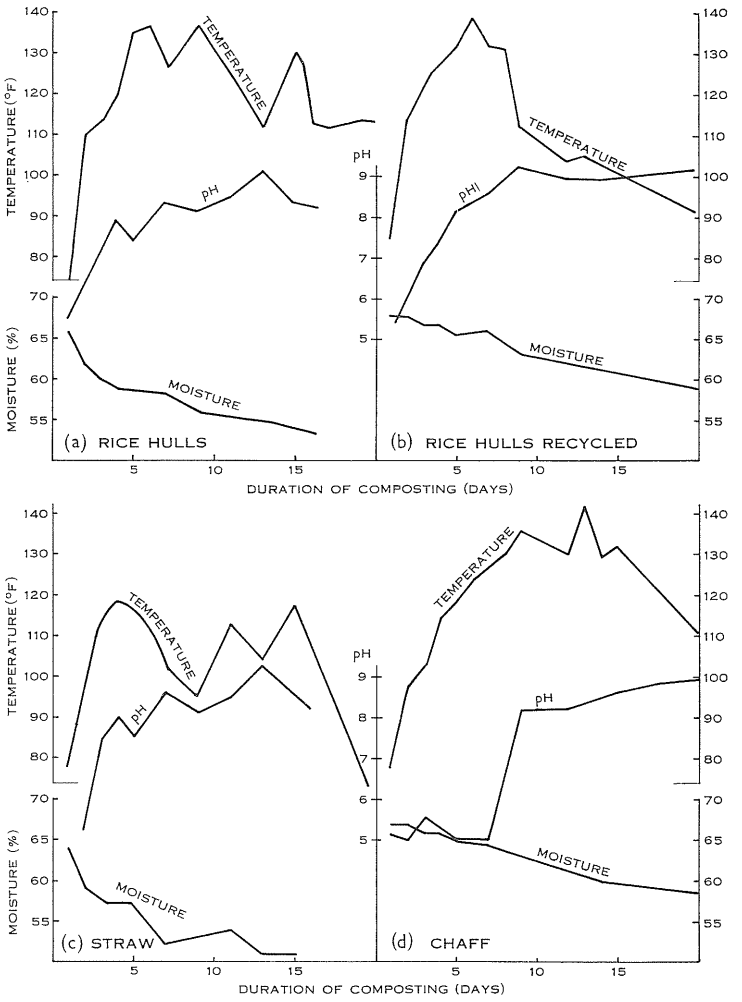


Fig. 1.—Daily changes in maximum temperatures at the hottest point, moisture content, and pH in four types of compost.

straw cut into ½-in. lengths, was very compact (33 cu ft) and easily turned. It was not as friable as the rice hull compost and the waste tended to "ball up" as aggregates. Maximum temperatures, pH values, and moisture contents are shown in Figure 1(*d*). Microbial activity commenced more slowly than in the other trials; maximum temperatures were reached around 13 days and the cycle was complete in about 18 days.

At 21 days the compost was spread out on the concrete floor to dry, and after a further 14 days its moisture content had fallen to 22%. The chaff compost was suitable for recycling in further composting operations but appeared likely to break down in structure earlier than rice hull compost.

General Observations

Odour.—Observations on odour in the vicinity of the compost bins indicated that on the second day there was a marked odour of alcoholic fermentation. By the next day the odour was "vinegary" and this persisted for 2–4 days. From then on only a slight "earthy" odour was apparent. At no stage were objectionable odours detected.

Seepage.—Some seepage from the compost mass occurred shortly after loading the bins, apparently because the dry fillers were not readily wetted and did not immediately take up free liquid draining from the waste.

Flies.—Some infestation with vinegar flies (*Drosophila*) occurred but they were readily controlled by spraying occasionally.

Drying of Compost.—The only notable difference between NCA experience and that reported here was the slower drying of the compost. Generally in the Berkeley trials the moisture content fell to about 35% in 20 days whereas in the Australian trials it remained above 50%. The explanation lies no doubt in climatic conditions, since the NCA bins were open to wind and sun with atmospheric humidities low, while the Ryde trials were conducted in an unusually humid period during which rainfall exceeded 12 in. In the inland irrigation areas where composting of wastes is most likely to be practised, the hot, dry summer climate should favour more rapid drying of the compost. It is important to lose as much moisture as possible in order to permit high ratios of waste to compost during recycling.

Conclusions

Bin trials have shown that pear cannery wastes can be successfully composted according to procedures laid down by the NCA Western Laboratory. A period of approximately 2 weeks was required for each composting cycle.

Rice hulls provided a very satisfactory filler and wheat chaff was also suitable. These fillers were used initially in the proportions 1 part to 2½ parts by weight of waste. It so happens that rice hulls present a waste disposal problem to the rice milling industry and are available at the mills at Echuca and Leeton, which are adjacent to the fruit canning areas of the Goulburn Valley and the Murrumbidgee Irrigation Area, probably for no cost except for cartage. To compost 10,000 tons of pear waste would require at the most 4000 tons of rice hulls, but with recycling of compost on a 14-day cycle only about 1200 tons would be required. The same quantity of pear waste would require 50 tons of lime, which is available in the Goulburn Valley as ground limestone at about £4 per ton delivered.

The compost produced was suitable for recycling as a filler for subsequent batches of waste and might even be carried over from year to year for this purpose. It is not likely to have any commercial value as a fertilizer, because the nitrogen and mineral contents are low, but it may have some application in orchards as a mulch and soil conditioner.

The principal purpose of the composting process is to produce a material that is stable and free from odour and that has been reduced substantially in weight by evaporation and loss of carbon dioxide. If the process is to be useful to canners it must be projected onto a large scale. The NCA has scaled up its operations from bins to windrows, each containing 5–10 tons of compost which is handled and turned by a special vehicle adapted from gravel-loading operations (Rose, personal communication 1963).

References

KEFFORD, J. F. (1963).—Disposal of cannery wastes. Proc. 12th Aust. Canning Convention. pp. 56–65.

MERCER, W. A. (1962).—Composting fruit and vegetable refuse. Part I. Investigation of composting as a means for disposal of fruit waste solids. (National Canners' Association Research Foundation: Washington, D.C.)

LABORATORY EXAMINATION OF CANNED FOODS — XX

New Methods for Examining Headspace Gases

By P. W. Board and R. G. P. Elbourne

Division of Food Preservation, CSIRO, North Ryde, N.S.W.

This article gives details of an improved method for the examination of headspace gases in canned foods, with particular emphasis on the technique of gas chromatography. The method described, besides being rapid and convenient, has the further advantage that headspace volume, pressure, and gas composition may all be determined on the same can.

AN INVESTIGATION involving the examination of headspace gases in large numbers of cans recently demonstrated the need for analytical methods less tedious than those used hitherto in these laboratories. The earlier methods were described in some detail in previous articles of this series by Kefford (1954) and Kefford and Davis (1954) and involved the use of a Campden manometer for the measurement of vacuum or pressure and headspace volume. The technique now described follows the same general principles as before, but utilizes an improved sampling device that allows a sample of headspace gas to be removed for analysis by gas chromatography. Since all the measurements, including the analysis, are carried out on the same can, their mutual relationships are brought out more clearly than where another can has to be sampled to determine the gas composition.

Sampling

The apparatus described by Kefford (1954) corresponds schematically to the left-hand portion only of Figure 1, i.e. a Campden manometer connected by a sampling needle to the can *J* under test. This system allows contamination of the sample of headspace gas by the small amount of air in the capillary tube joining the can to the manometer. It is therefore not possible to use the gas after vacuum determination for analysis of its composition. Displacement of the air from the capillary system with mercury often causes blockage of the needle and contamination of the can and the product. To overcome these problems, the capillary system was modified as shown in Figure 1.

The can *J* is placed on the platform previously used (Kefford 1954) and is raised to make a seal with the collar *I* without the can being punctured by the hypodermic needle. Better seals were obtained when the soft rubber gasket around the hypodermic needle was replaced by the turned polyurethane* collar shown in Figure 2. The mercury in the manometer is raised to about M_1 (the top mark on the tube) and tap *N* is closed; the bulb *G* is filled with mercury and tap *F* closed. A high-vacuum pump is connected to the system through the three-way tap *D* and the whole capillary system enclosed by *A*, the mercury in *G*, the seal at *J*, and the

* Trade name Duralon, Grade 18/40, Shore A. Hardness 65. Obtainable in rod form from A. K. Lever & Company Pty. Ltd., 88 Charlotte Street, Ashfield, N.S.W.

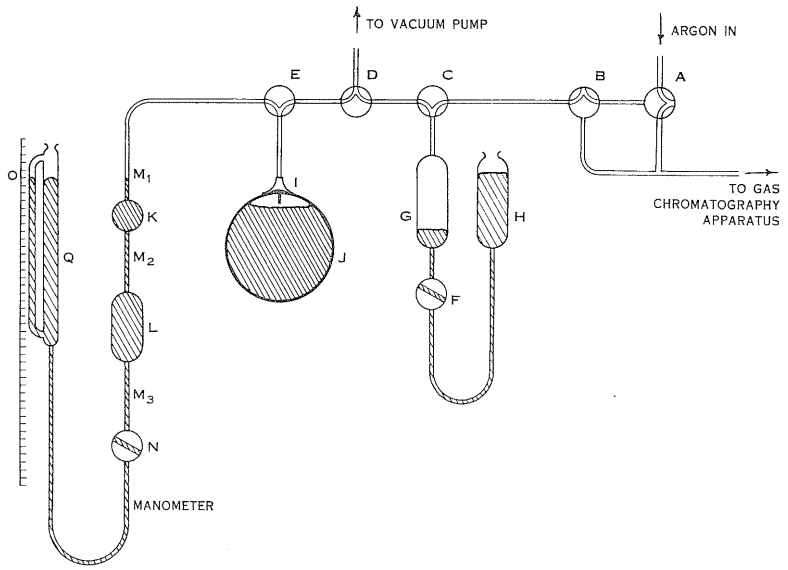


Fig. 1.—Capillary system for sampling headspace gases.

mercury at M_1, is evacuated. Tap D is turned to isolate the vacuum pump, and the pump is disconnected and turned off. The seal at J is tested for leaks by isolating the manometer and the seal from the rest of the system with tap E. Reservoir Q is lowered and tap N opened; a leak at the seal results in a fall in the level of the mercury column at M_1.

Measurement of Pressure and Headspace Volume

If there is no evidence of a leak at the seal, the can is raised further until it is punctured by the hypodermic needle. The reservoir Q is raised until the mercury in the manometer reaches M_1 again, and the pressure difference P_1 between the mercury columns on each side of the manometer is recorded. M_1 has been made level with the zero mark on the manometer scale. By means of reservoir H and taps F, C, E, and B, a sample of the headspace gas is pumped into the tube BA ready for analysis by chromatography.

For the determination of headspace volume the manometer and the can are brought to atmospheric pressure by opening taps D and E. The mercury in the manometer is raised to M_1 once more, and the tap E is turned to connect the can to the manometer. Q is lowered until the mercury is level with M_2, a second arbitrary mark on the manometer x mm below M_1 and between the small bulb K and the large bulb L. The level P_2 of the mercury in Q is again recorded. If very large headspace volumes are being determined, the mercury is lowered to M_3, a third mark on the manometer below the large bulb L.

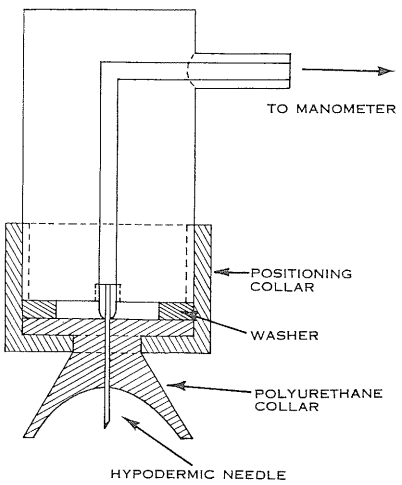


Fig. 2.—Headspace gas sampling device.

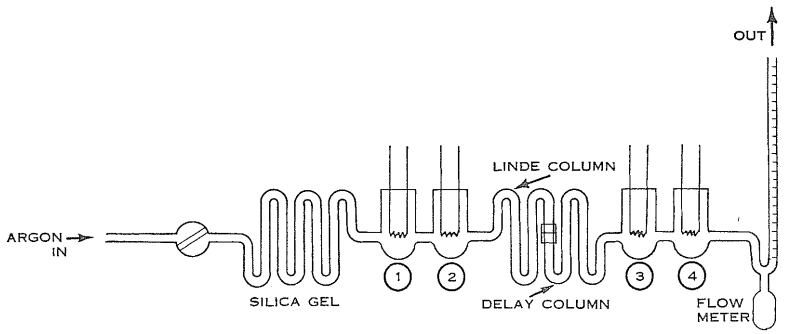


Fig. 3.—Gas flow diagram of gas chromatographic unit.

To calculate the headspace volume (V) and pressure (P) it is necessary to know the volume V_T of the system from M_1 to J, the volume V_B from M_1 to M_2, and the atmospheric pressure (A.P.). Then the headspace volume V is given by

$$V = \frac{V_B\,[\text{A.P.} - (P_2 - x)]}{(P_2 - x)} - V_T \text{ ml.}$$

The pressure P in the can is given by

$$P = \frac{V + V_T}{V}\,(\text{A.P.} - P_1) \text{ cmHg.}$$

Analysis by Gas Chromatography

A gas chromatography unit was built* following the basic design of Vosti, Hernandez, and Strand (1961). A flow diagram of this unit is shown in Figure 3 and a circuit diagram in Figure 4. The argon carrier gas is supplied to the system through a double reduction valve† at the rate of 30 ml per minute. The flow rate is measured with a soap-bubble flow meter constructed from a burette. A diluted detergent is used as a source of bubbles and the rate of flow of argon is measured by determining the rate at which the bubbles rise up the burette.

* This unit was designed and constructed by Mr. B. H. Kennett of the Physical Methods Group of this Division.

† Type T285, available from Commonwealth Industrial Gases Ltd., 138 Bourke Road, Alexandria, N.S.W.

The three chromatography columns were made of $\frac{1}{4}$-in. O.D. copper refrigeration tubing. The first, a column 4 in. in length, is filled with 60–200 mesh silica gel, prepared by grinding and sieving commercial silica gel; the ends of the column are plugged with glass wool. Activation and subsequent regeneration of this column are achieved by passing hot (*c.* 800 °C) argon or oxygen-free nitrogen through the column for 1 hr before the column is fitted into the apparatus. The second column, 9 ft in length, is filled with Linde 5A Molecular Sieve powder* and

* Available from Union Carbide Aust. Ltd., Rothschild Avenue, Rosebery, N.S.W.

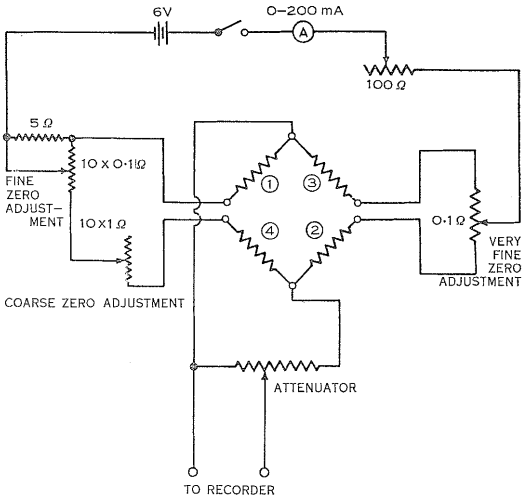


Fig. 4.—Electrical circuit of gas chromatographic unit.

plugged at each end with glass wool. Activation and periodic regeneration of this column are achieved by the slow passage of argon or oxygen-free nitrogen at 150°C through the detached column for 16 hr. The third column, a 9-ft empty tube, is used as a delay column.

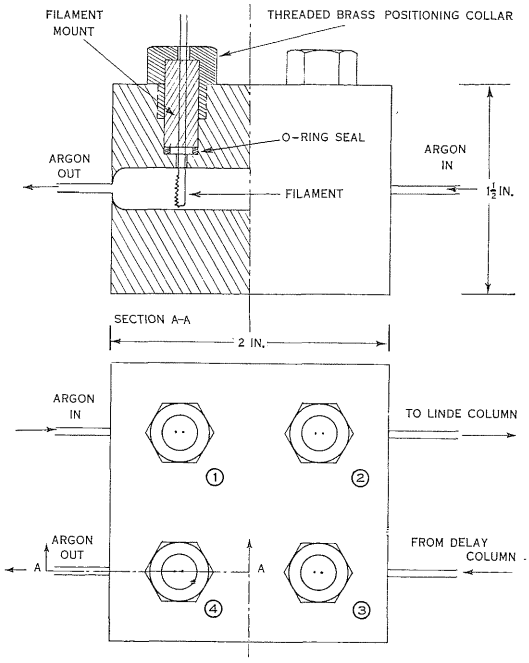


Fig. 5.—Brass block holding thermal conductivity filaments.

A variable current is supplied to the filaments from a 6-volt accumulator through a 100-ohm rheostat, and a current of 100 mA is found to be satisfactory. The filaments used are two pairs of Gow-Mac 9225* tungsten thermal conductivity filaments mounted in a 2 in. by 2 in. by 1½ in. brass block (Fig. 5). The circuit was designed so that each pair of filaments can serve as either a reference or a detector. These filaments are wired into a Wheatstone bridge circuit, and its output, after passing through an attenuating device, is recorded on a suitable potential recorder. A Leeds and Northrup Speedomax Model G recorder,* with a full scale span of 10 mV and a chart speed of 0·4 in/min is used in this laboratory.

The detector block and the columns are mounted in a simple wooden box to protect them from draughts, but no other precautions are taken to operate the apparatus at a constant temperature.

The unit was constructed in the laboratories of the Division of Food Preservation at a cost of approximately £50 for parts (excluding the recorder) and has served for the routine analysis of some thousands of samples.

Operation

The argon supply is turned on and the flow rate adjusted to 30 ml/min. The power supply to the filaments is then turned on and the apparatus allowed to stabilize for about a half-hour, in which time the output potential, as measured by the recorder, becomes constant.

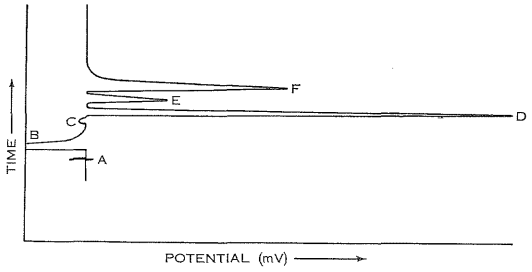


Fig. 6.—Typical chromatogram of headspace gases.

The sample of gas to be analysed in tube *BA* in Figure 1 is swept into the chromatography unit via the glass loop by the simultaneous manipulation of taps *A* and *B*. The recorder usually shows a small pen deflection (Fig. 6, peak *A*) as a result of turning these taps, but immediately recovers.

The silica gel column temporarily absorbs the carbon dioxide, and the other gases pass

* Available from John Morris Pty. Ltd., 167 Pacific Highway, North Sydney, N.S.W.

* Agents in N.S.W. are Alfred Snashall Pty. Ltd., 500 Kent Street, Sydney.

to filaments 1 and 2 to give a large peak (Fig. 6, peak *B*) on the recorder. These gases then enter the Linde column where they are separated and pass one at a time into the delay column. The carbon dioxide, meanwhile, desorbs from the silica gel and is detected by filaments 1 and 2 and recorded as a peak in the negative direction (Fig. 6, peak *C*). It then passes into the Linde column, where it is irreversibly held. Soon after, the other gases leaving the delay column are detected by filaments 3 and 4 to give peaks in a positive direction (Fig. 6, peaks *D*, *E*, and *F*) on the recorder chart.

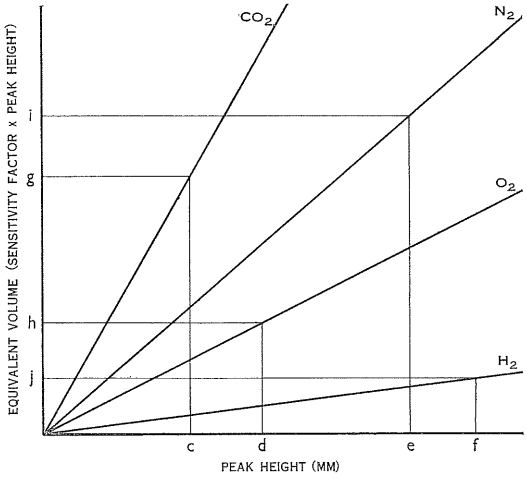


Fig. 7.—Typical calibration curves of headspace gases analysed by gas chromatography.

Calibration

Since the sensitivity of the detectors differs for various gases, the unit must be calibrated for each gas being analysed. Calibration is carried out by measuring the peak height for the individual gases in a number of gas mixtures of known composition. It is not necessary to know the volume of sample which is introduced into the unit for calibration, but in general approximately 2-ml samples are used.

Suppose one mixture of oxygen (20%) and nitrogen (80%) gives peak heights of y mm and z mm respectively, and a second mixture of oxygen (5%) and nitrogen (95%) gives peak heights of p mm and q mm respectively. If the "sensitivity factor" of the detectors for oxygen is a, and for nitrogen is b, the following relationship holds:

$$\frac{b \times z}{a \times y} = \frac{80}{20} \text{ for the first mixture,}$$

$$\frac{b \times q}{a \times p} = \frac{95}{5} \text{ for the second mixture.}$$

Since p, q, y, and z are known, the equations may be solved for a and b.

Graphs of peak height against equivalent volume (i.e. "sensitivity factor" $\times$ peak height) are drawn for each gas, as shown in Figure 7. For a sample of unknown composition, the peak heights for the various gases carbon dioxide, oxygen, nitrogen, and hydrogen may be respectively c, d, e, and f mm (Fig. 7), which correspond to "equivalent volumes" of g, h, i, and j arbitrary units. The percentage composition of the four-component mixtures is then

$$\%\ CO_2 = \frac{g}{g+h+i+j} \times 100;$$

$$\%\ O_2 = \frac{h}{g+h+i+j} \times 100;$$

$$\%\ N_2 = \frac{i}{g+h+i+j} \times 100;$$

$$\%\ H_2 = \frac{j}{g+h+i+j} \times 100.$$

The gas chromatography unit using argon as a carrier gas is most sensitive to hydrogen and is progressively less sensitive to oxygen, nitrogen, and carbon dioxide, in that order. In most routine work the reproducibility of the analyses is about $\pm 0{\cdot}5\%$. The time required for the complete analysis of a headspace gas sample is 5–6 minutes.

References

KEFFORD, J. F. (1954).—Laboratory examination of canned foods. III. Internal vacuum in cans. *CSIRO Food Pres. Quart.* **14**: 8–18.

KEFFORD, J. F., and DAVIS, E. G. (1954).—Laboratory examination of canned foods. V. Headspace gas composition. *CSIRO Food Pres. Quart.* **14**: 46–52.

VOSTI, D. C., HERNANDEZ, H. H., and STRAND, J. B. (1961).—Analysis of headspace gases in canned foods by gas chromatography. *Food Tech., Champaign* **15**: 29–31.

Bacterial Spoilage of Processed Meats*

By L. E. Brownlie

Meat Research Laboratory, Division of Food Preservation, CSIRO, Cannon Hill, Qld.

The most important reason for careful control of bacteria in foodstuffs is to prevent the contamination of the food with organisms pathogenic to man and to prevent the production of material toxic to the consumer. A second reason, scarcely less important, is the need to prevent economic loss through spoilage.

ECONOMIC loss through bacterial spoilage of foodstuffs may result from the return of spoiled goods by the retailer or through loss of product demand due to spoilage at the place of consumption. If a product spoils rapidly even when the consumer has it stored in a refrigerator, it is unlikely that he will be willing to buy it again at a later date. A low degree of bacterial contamination means a product with a potentially long storage life and less loss through spoilage; it is therefore desirable because it enables the manufacturer, the distributor, and the retailer to operate more efficiently and, of course, more profitably.

There is an important distinction between the spoilage and the poisoning of food by microorganisms. A food which is visibly spoiled *may* have few or no food-poisoning organisms in a large spoilage population and be harmless to eat, even though it may be more or less unpalatable. But a food with a large population of spoilage organisms may also at some time have received a massive inoculation with poisoning organisms whose growth has been temporarily arrested by storage conditions. Such a product would be dangerous. A third class of product is one which, while showing no visible signs of spoilage, may be potentially or actually dangerous because it contains organisms capable of causing disease in persons consuming the food, or because it contains toxic metabolic by-products liberated by the organisms.

Generally, spoilage can be used as an index of possible growth of poisoning organisms, and for this reason spoiled food should not be eaten unless exact knowledge of the storage conditions and previous history of the food indicates that it is likely to be free from pathogens or their metabolic products. Such knowledge rarely exists.

There are two factors which may contribute materially towards the production of a product of long storage life, whether the product be in fresh or cured condition. These factors are:

- Reduction of contamination of the product by bacteria.
- Storage of the product in conditions which limit the growth and metabolism of the organisms present within the product.

* Based on a lecture given at a Meat Research Conference held in Brisbane in September 1963.

IMPORTANCE OF HYGIENE

The control of contamination is largely a matter of good housekeeping. If equipment is physically clean and regularly sterilized, bacterial contamination as a result of physical contact can be kept to a minimum. Such a statement is easily made, but carrying out the requirements can be difficult. The equipment used should be designed in such a way that no crevices or corners exist, and all joins should be curved to allow easy cleaning and to prevent a build-up of material. A crevice or corner is difficult to clean and is an ideal site for the accumulation of food particles and moisture, and hence for the growth of contaminating bacteria.

All equipment used in the process should be regularly cleaned and washed, preferably with hot water containing a cleaning compound that has some bactericidal action. The regularity with which equipment should be cleaned will vary with the stage at which the equipment comes into contact with the product. In the case of fresh meat, at slaughter and in subsequent boning-out operations all equipment should be washed down with hot water (180°F) containing detergent, and thoroughly rinsed; this should be done at least once a day. Boning-out operations would benefit greatly by more frequent cleaning of equipment, say twice daily. In processed meat manufacture all equipment should be washed out thoroughly between different products, and with the same regularity as recommended for boning-out operations.

With cooked products a major source of contamination can be the operations of slicing the material and subsequent packaging. The slicing equipment should be thoroughly washed before every break in the working schedule. Such breaks usually occur four times daily, and these could be regarded as minimum cleaning requirements.

Many detergents and cleaning compounds have some bactericidal action, and information on the relative merits of the different types available for use on food processing equipment can be gleaned from commercial literature. They will not be discussed further in this article but have been mentioned in order to indicate the desirability of using such compounds.

INFLUENCE OF ENVIRONMENT

When through the precautions mentioned above the bacterial contamination is kept to a minimum, the length of storage life is determined by the environment to which the product is exposed during storage. Temperature, water activity, and the composition of the environmental atmosphere all have an effect on the growth of bacteria, and control of these factors individually or in combination may be used to extend the storage life.

Temperature

Organisms vary in their ability to grow and metabolize in different temperature ranges. Temperature thus has a selective effect on the type of organism which will predominate as a spoilage organism under any given set of conditions. The psychrophilic or "cold-loving" organisms comprise a small percentage of all bacterial types, their only common characteristic being their ability to grow at low temperatures. At temperatures close to 32°F most organisms are held in "stasis", i.e. their rate of growth is negligible or very slow, but the psychrophiles will continue to multiply, albeit at a slower pace than they would at higher temperatures. The result is that under such conditions the development of these microorganisms is favoured relative to non-psychrophilic types.

Figure 1 shows the general effect of temperature on the growth rates of two typical spoilage organisms, lactobacilli and microbacteria, in laboratory experiments. The former have been implicated in the spoilage of cured cooked sausage material, and microbacteria have been isolated as causal organisms responsible for off-flavour in wet sausages. The different effect of temperature on these two organisms may be noted, particularly the very low growth rate of the lactobacilli at temperatures below 40°F.

Curing

The general effect of the addition of a curing agent, in the form of salt with some nitrate or nitrite, is to reduce the amount of free water within the product, and hence its water activity. Microorganisms vary widely in their ability to thrive under conditions of low water activity, so that this is another factor that can selectively determine the spoilage composition. The curing brine, in

addition to directly affecting the available water, possesses some anti-microbial activity of its own, owing to the presence of nitrate and nitrite. (Nitrate is reduced to nitrite by many microorganisms and modern cures employ nitrite rather than the mixture for this reason.) These compounds also have an effect on the ability of spore-forming bacteria to germinate and grow.

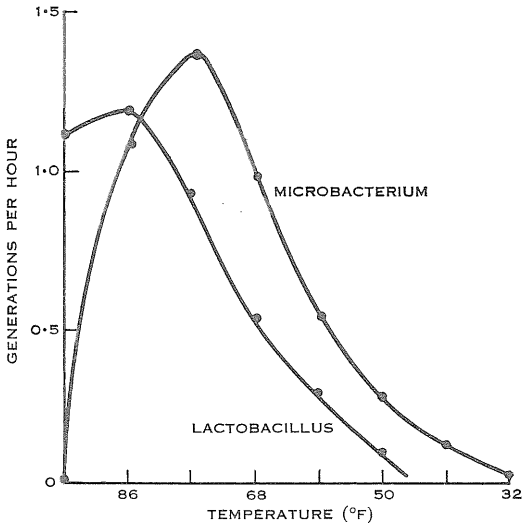


Fig. 1.—Effect of temperature on the growth rate of the spoilage organisms Lactobacillus *sp. and* Microbacterium *sp. in laboratory media.*

Oxygen

The importance of the environmental atmosphere to bacterial growth is governed principally by the oxygen requirements of the organisms. While some microorganisms require oxygen to be present for growth, others can grow in its absence but are able to utilize it if it is present. Another group does not show any growth response to the presence of oxygen, while a fourth group will actually die off if oxygen is present.

Pseudomonads, the spoilage organisms of fresh meat, are of the first type (obligate aerobes) and removal of oxygen removes the spoilage potential of this class. Microbacteria can utilize oxygen if it is available, and grow about twice as fast in air as in its absence. Vacuum packaging can therefore provide a useful means of controlling spoilage induced by these two types, for even if the bacteria are not killed their proliferation may be reduced sufficiently to extend the storage life of the product to a useful extent. However, lactobacilli grow as fast in the absence of air as in its presence, so that vacuum packaging is of little benefit in extending the storage life of products contaminated with this species.

FACTORY PROCESSING

Unless adequate precautions are taken, there are many points during the manufacture of processed meats where excessive bacterial contamination can occur, or where an existing low bacterial population in the food can increase to an undesirable degree. It is convenient, therefore, to consider the various steps in the production sequence of a typical smallgoods factory, with a view to indicating how a product with low bacterial numbers can be obtained.

Raw Material

The raw material used in manufacture can be a major source of contamination of the product, especially if some of it is re-processed. Meat used in manufacture should therefore always be as fresh as can be obtained. This is of particular importance in the manufacture of wet sausages or sausage minces — unlike other smallgoods, these products do not have the benefit of a reduced bacterial population as a consequence of smoking or cooking.

The number of organisms present in the raw material will depend upon the conditions of hygiene and also upon how the material has been stored. Transport of boned-out meat over long distances under so-called "chilling" conditions is a case in point: the temperatures in these vehicles can allow quite rapid growth of contaminating organisms.

Preparation

Material for manufacture should be prepared at as low a temperature and as rapidly as practicable. Sausage material should be stuffed immediately on preparation, wet sausages being taken directly to the cold room and material for cooking heated at once. Delays after commencement of manufacture can result in a rapid increase in the

number of bacteria present, and once this has occurred processing at a later stage may not rectify the situation. Hence if the product is to have a reasonable storage life these delays must be watched closely.

Cooking

One object of cooking material is to reduce the bacterial numbers to a safe level. Heat has an irreversible effect on proteins, causing denaturation and coagulation, and the proteins present in bacteria are no exception. Irreversible effects occur around 155°F, so that raising the temperature of a product to 155°F at all points within the product and maintaining this temperature for 10 minutes should kill most vegetative (i.e. actively reproducing) bacteria.

Certain bacteria can exist in a resting form known as a spore. Spores are relatively heat resistant and may germinate and grow in the product at a later stage when conditions are favourable, e.g. if storage conditions are inadequately controlled. Spore-forming organisms fortunately do not occur in large numbers in fresh meat and most of these organisms are poor psychrophiles. Consequently, subsequent storage of the heat-treated product at low temperature (32–40°F) should result in little bacterial growth.

Heat will penetrate slowly towards the centre of a product, the time required to reach the desired internal temperature varying with the geometry of the product, its initial temperature, the temperature of the cooking vat or steam oven, and the ratio of the cold material to the heating medium. Figure 2 shows internal temperature recordings for products of different size, and indicates the variation in times required to reach the desired internal temperature. There is, however, little quantitative information on temperature curves available to plant operators, as few firms have had internal temperatures recorded for smallgoods.

One typical situation leading to variable heat processing is when the load on the cooking department varies from day to day. Thus one day x lb of material may be cooked in y gallons of water for say $1\frac{1}{2}$ hr; the next day there may be a larger cook, $(x + 500)$ lb, which will be cooked in $(y - 50)$ gal for the same period of time. Since on the second day a much larger weight of cold material would have been added to a smaller volume of water it would clearly be impossible to raise the internal temperature to the same level in an identical cooking time, other things being equal.

The example cited indicates one area of operation wherein improvements may be effected. Supervision of cooking schedules and correlation of activities with the despatch department should ensure that the product is adequately processed. This does not mean

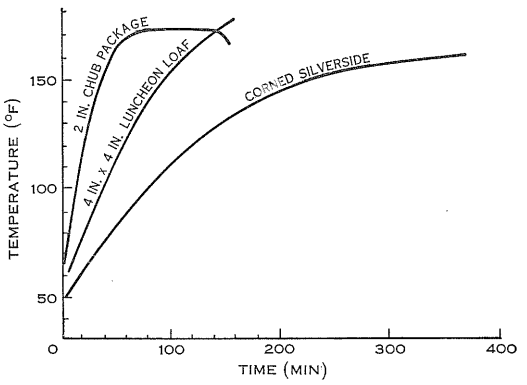


Fig. 2.—Internal temperature recordings of meat during heat processing.

that products are usually undercooked; on the contrary, there is a tendency to overprocess. Nevertheless, during periods of peak production, usually during hot weather, the cooking schedule will become tighter and there may be a risk of underprocessing. Underprocessing during these weather conditions may result in substantial loss of product through returns from the retailer.

Cooking pots should be isolated from other areas of the manufacturing sequence. The heat and steam from the vats substantially raise the temperature in a room, with consequent more rapid bacterial proliferation in and on products in course of preparation, and on the product that has been heat processed.

Cooling

The product should be rapidly cooled after heat processing. This is usually achieved by spraying it with cold water, but since the water supply could be a source of contamination it should always be checked before use in any food manufacturing process.

It is important that the product be removed to a cold room as rapidly as possible after initial cooling. Changes in temperature within the product during cooling will be slow, as with heating, and the speed with which the temperature falls is governed by the same processes which control temperature rise. A rapid fall in temperature is required to ensure that the entire product rapidly attains a temperature at which any remaining organisms will not grow. The product is not "sterile", as canned products are after retorting, and the sporing microorganisms are still capable of germination and growth under appropriate conditions. Should the product have been underprocessed some vegetative organisms may persist, and relatively rapid growth of these types may result if the temperature is elevated.

Packaging

A meat product which is to be sold in prepackaged form should be kept at ordinary ambient temperatures for as short a time as is practicable. To keep product temperature as uniform as possible it is essential that the temperature of the packaging area be as low as it can be, consistent with ease of operation by the staff. The shorter the time that the product is at these relatively elevated temperatures, the less the growth of the contaminating bacteria. Also, the lower the temperature within the packaging room, the slower will be the growth of contaminating bacteria on the machinery used in packaging. Should this machinery be regularly and adequately washed, contamination will be kept to a minimum. Immediately after packaging, the material should be returned to the chiller temperature (32°F).

The choice of packaging material can have an effect on the storage life of the product. American research has indicated that meat adequately cooked within material impermeable to water and oxygen has, under correct refrigeration, a storage life in excess of 100 days. The results indicated that a major source of contamination was in post-processing operations. The experiments were done on small packages (chubs), and local manufacturers have indicated that these packages promote a long storage life of their products. Products of larger diameter should have a similar storage life if they receive adequate heat treatment and storage.

A sliced product is usually packaged in film that has low permeability to oxygen and moisture. Such a system of packaging has a desirable effect in that it reduces the ability of an organism to proliferate within the product. Fresh meat usually suffers from dehydration on the surface tissue during chilling, and this effectively reduces the amount of water available to the bacteria on the surface. If the product is surrounded by a membrane impermeable to moisture the meat and atmosphere within the package come to equilibrium rapidly. The available water or water activity (a_w) within the product is then controlled by the amount of added salt.

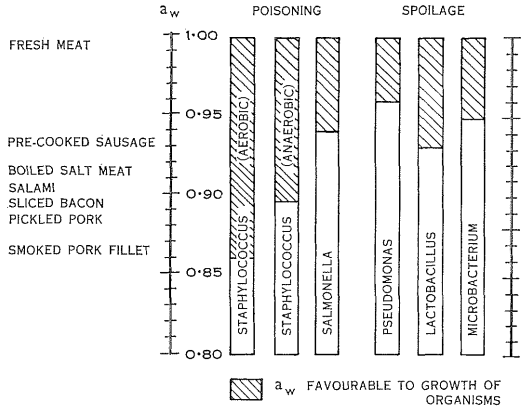


Fig. 3.—Water activity of fresh meat and some typical meat products, and the range of water activity over which food poisoning and spoilage bacteria thrive. (The data of the a_w *of meat products are from European sources, and may not apply to Australian products.)*

Figure 3 indicates the a_w of some common meat products and the a_w response of some selected organisms. The organism capable of growth on these products will be determined largely by the a_w of the product. The

spoilage organisms of fresh meat (pseudomonads) would be quite capable of growth at low temperatures in the a_w of fresh meat, but vacuum packaging removes the oxygen and under such conditions the pseudomonads cannot grow. Food-poisoning organisms such as staphylococci thrive on foods of relatively low a_w, and unless such products have been stored under adequate refrigeration to ensure that staphylococci cannot grow, food poisoning can result from ingestion of the poisoned product. The effect of such an occurrence would be disastrous on the sale of the product.

Storage and Distribution

At all times during storage and distribution the temperature should be kept as close to 32°F as is practicable, and times when the product is at temperatures greater than this should be kept to a minimum. The temperature of the product during distribution is most important, as may be illustrated by temperature recordings from two distribution vans, one refrigerated and the other insulated but unrefrigerated. Temperatures in the unrefrigerated van ranged from 60 to 75°F in the course of a working day which began at 7.00 a.m. and ended in the afternoon, while in the refrigerated vehicle the range was 40 to 60°F. The ambient air temperature was in the range 60–80°F. From the data in Figure 1 it is clear that the growth of spoilage bacteria will be favoured by conditions in the unrefrigerated van, with a corresponding shortening of storage life. However, another factor comes into operation in the retailer's refrigerator, in which the temperature may fluctuate greatly. The manufacturer has, of course, no control over this factor.

CONCLUSION

The foregoing remarks should give the producer adequate information on which to base operations for manufacturing a product having a potentially long storage life with little possibility of food poisoning. Critical stages in production are cooking, cooling, packaging, and distribution. Care at these stages is all-important in the storage life of the product.

To reiterate the important points, and to implicate other factors, the following suggestions are offered in conclusion:

- Educate personnel in hygiene; encourage them to be clean; provide wash basins with disposable paper towels and encourage their use.
- Sectionalize the plant and operation. Do not allow personnel to wander all over the plant. Personnel allowed to handle untreated products should not be allowed to handle treated products without adequate washing-up and changes of clothing.
- Prepare the product with speed, in as cold a temperature as practicable, then heat it immediately if it is a cooked product. Return prepared wet sausages to the cold-room at once.
- Spoiled material should not be re-processed.
- Adequately cook the product to an internal temperature of 155°F for 10 minutes.
- Rapidly cool the product.
- Strictly follow hygienic practices in the packaging room.
- Take care in storage and distribution.

ACKNOWLEDGMENTS

The author wishes to acknowledge his indebtedness to publications by the following: American Meat Institute Foundation, Chicago, U.S.A.; Danish Meat Research Institute, Roskilde, Denmark; Dr. E. M. Foster, University of Wisconsin, Wisconsin, U.S.A.; and Dr. W. J. Scott and Dr. J. H. B. Christian, Division of Food Preservation, CSIRO.

Control of Mould during Degreening of Oranges*

By D. Leggo and J. A. Seberry

N.S.W. Department of Agriculture, Citrus Wastage Research Laboratory, Gosford, N.S.W.

Green mould *(Penicillium digitatum)* can cause severe wastage during the degreening of oranges. Investigations at the Gosford Citrus Wastage Research Laboratory have demonstrated a simple and effective control using ammonia gas, which will reduce mould breakdown and prevent excessive waste before fungicidal dip treatments can be applied.

AT certain times of the year oranges are often degreened by the use of ethylene gas in order to improve fruit colour and to ensure that the appearance of the fruit more closely matches its internal quality and maturity. Such degreening may be applied, for example, to early-season Navel oranges that have reached an acceptable internal maturity but still show patches of green on the skin which suggest immaturity and detract from the market value of the fruit. In the degreening rooms ethylene breaks down the green chlorophyll pigment, and the natural orange pigments present in the rind are revealed. It is sometimes also desirable to use ethylene to degreen late-season Valencia oranges that have matured and then regreened in the orchard over the summer period.

Normal Degreening Conditions

In degreening oranges (Hall 1940) it is usual to introduce ethylene gas into a degreening chamber containing the fruit, and this is done three times each 24 hours at the rate of 1 part in 5000 parts of empty chamber volume, the chamber being ventilated with fresh air prior to each gassing. A fruit temperature of 75–80°F for Navel oranges and 70–75°F for Valencia oranges improves the rate of colour development, and a relative humidity of 90–95% in the chamber helps to reduce fruit shrinkage. These conditions of temperature and humidity also, unfortunately, encourage the development of mould.

SOPP Dip-rinse Treatment

The sodium ortho-phenylphenate (SOPP) dip-rinse treatment (Long and Roberts 1954) is recommended for the control of mould in citrus fruits that require washing to clean them. It is a 2-minute dip in 2·0% SOPP, followed by a rinse with clean water to remove SOPP which, if left on, would injure the rind. For maximum efficiency, fruit should be treated as soon as possible after harvest, and certainly within 24–36 hours of harvest in the warm summer months, and within 3–4 days in cooler conditions.

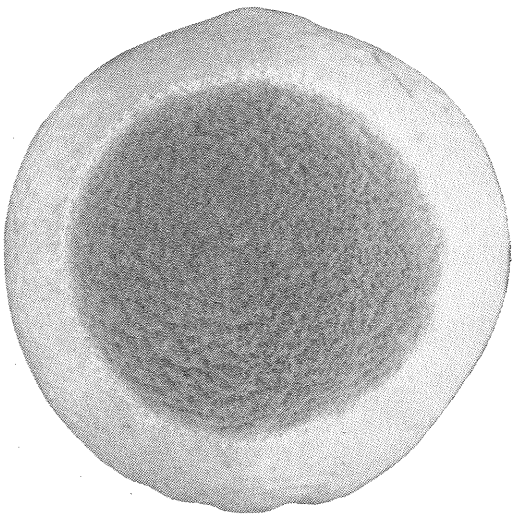
Ethylene degreening should be carried out before the SOPP treatment is applied to the fruit because the washing process for citrus usually includes waxing too, and waxed fruit is not readily degreened. Where ethylene degreening is carried out, however, the resultant delay in applying the SOPP dip can have serious consequences, especially when, as is sometimes necessary, the degreening operation extends to 4 days. In the warm

* These recommendations, which have also appeared in the *Agricultural Gazette of New South Wales*, are the result of investigations carried out at the Citrus Wastage Research Laboratory, Gosford, and are published under the authority of the Citrus Wastage Research Committee. The Committee comprises representatives of the N.S.W. Department of Agriculture and the CSIRO Division of Food Preservation.

moist atmosphere of the degreening chamber moulds naturally present on the fruit can rapidly develop to a stage where subsequent SOPP treatment loses its effectiveness, and wastage of fruit can then be severe. It is therefore necessary that mould growth during degreening be inhibited by some means.

Use of Ammonia during Degreening

Experiments at the Citrus Wastage Research Laboratory, Gosford, on the central coast of New South Wales, have shown that excessive green mould wastage of oranges during ethylene degreening can be prevented by fumigation with ammonia (Leggo and Seberry 1964). The ammonia, conveniently generated by evaporating a measured volume of concentrated ammonium hydroxide from a hotplate in the chamber, is introduced three times every 24 hours, at the same time as the ethylene.



Orange affected with green mould. (Photo: N.S.W. Department of Agriculture.)

The recommended concentration of ammonia gas is 6000 p.p.m., calculated on the empty chamber volume. At this concentration wastage from green mould is substantially reduced and rind injury on treated fruit is most unlikely, provided the fruit load in the chamber is not less than 25% and not more than 50%. This means that in a chamber 10 ft by 10 ft by 9 ft (900 cu ft) the load should not be less than 112 loosely filled bushel field cases, and not more than 225. Concentrations of ammonia higher than 6000 p.p.m. may injure oranges and lower concentrations will give less effective control of wastage.

In a trial with Valencia oranges green mould wastage was reduced from 6·6% to 3·6% immediately following degreening and from 59·5% to 17·6% when the fruit had been held for 11 days without further treatment. The load of fruit in the chambers (that is, the percentage of chamber volume occupied by the fruit and containers) was 25%. In chambers where the fruit load was 50% the corresponding reductions were 8·2% to 4·1% and 64·0% to 27·7%.

It must be emphasized that the application of ammonia during ethylene degreening will control the mould wastage only during this period, and that the usual SOPP dip-rinse treatment should be applied as soon as possible after completion of degreening. Details of the ammonia fumigation are given below.

Requirements

For most efficient use of ammonia the degreening chamber should comply with the following requirements:

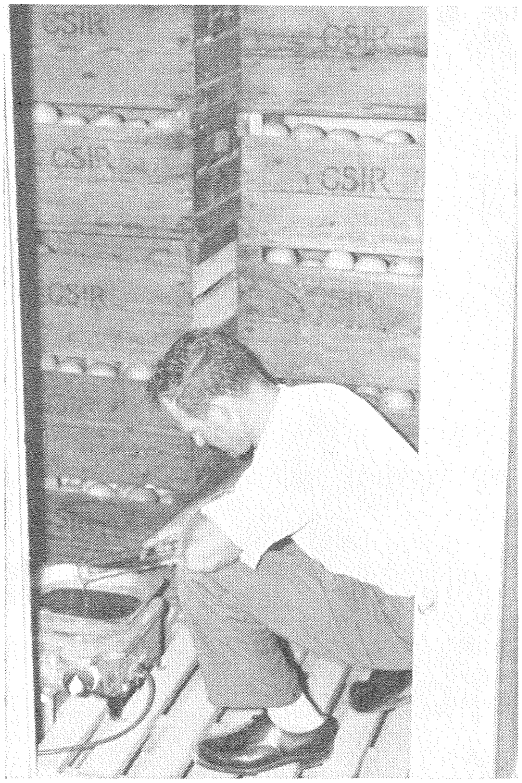
(1) Wiring and electrical fittings must conform with those prescribed for a Class 1, Division 2, Hazardous Area in the Australian Standards Association Wiring Rule CC1.

(2) It must be reasonably gas-tight.

(3) The chamber should be provided with a false floor; alternatively, the fruit should be in cases stacked on pallets, or in bulk bins, to ensure good gas circulation.

(4) A fan of sufficient capacity to give an internal air circulation at a rate of 40 changes of room volume per hour should be housed in a vertical duct, placed either in the centre of the chamber or against the wall, to draw air from below the false floor, with the duct discharging the air immediately beneath the ceiling in such a way as to provide uniform air distribution throughout the room.

(5) There should be a glass observation panel in the wall or door of the chamber, to permit evaporation of the ammonium hydroxide to be observed.



Pouring ammonium hydroxide into pan on hot-plate in degreening chamber.

(6) A power point inside the chamber controlled by a switch installed outside the room is also required. A light in the chamber is desirable.

Other materials and equipment required are:

- Commercial concentrated ammonium hydroxide (approximately 15N).
- Small electric hot-plate.
- Shallow metal dish (for example, a baking dish).
- Measuring cylinder graduated up to 500 ml.

Fumigation Procedure

On the central coast of New South Wales citrus is degreened by introducing ethylene three times daily. For example, ethylene might be let into a chamber at 7 a.m., and at 1.00 p.m. the room would be opened and ventilated for 30 min before re-gassing; a further ventilation and re-gassing would take place at about 8 p.m.

In this schedule ammonia should be added at each gassing throughout the degreening period. The ammonium hydroxide is used at the rate of 50 ml for every 100 cu ft of chamber volume; for example, a chamber 10 ft by 10 ft by 9 ft (900 cu ft) would require 450 ml.

The required quantity of concentrated ammonium hydroxide is measured accurately, using the graduated cylinder, and poured into the shallow metal dish. The dish is then placed on the hot-plate (or a small electric stove) in the chamber, so positioned that it may be observed through the glass panel. When the chamber is sealed, the circulating fan is switched on and the ethylene introduced, before turning on the hot-plate. (Note: Concentrations of ethylene higher than those recommended can be explosive.) As soon as the ammonium hydroxide has evaporated, the hot-plate should be switched off.

The chamber should be ventilated with fresh air for 30 min prior to each addition of gas, and all normal degreening procedures, such as the control of fruit temperature and humidity in the chamber, carried out.

Cost

The ammonia treatment is not expensive, as can be seen from the following example. Suppose 200 bushels of oranges are to be degreened for 4 days in a room 1000 cu ft in volume. At a dosage of 500 ml thrice daily, a total of 6 litres of ammonium hydroxide will be used altogether. This would cost approximately 16*s*, which corresponds to 1*d* per bushel.

Precautions

Commercial ammonium hydroxide (15N) is a very concentrated solution of ammonia in water and should be handled carefully. Splashing of the solution must be avoided, and any accidentally spilled on the skin must be washed off at once with a copious flow of water. Avoid inhaling the fumes, and when handling the solution use goggles and a respirator fitted with a suitable chemical

cartridge. Do not on any account suck the liquid through a tube by mouth in attempting to siphon it from its container.

Care should be taken to ensure that the ammonium hydroxide container is sealed properly, and stored in a cool place. Under warm conditions ammonia evaporates from the solution, which then becomes ineffective. It is advisable to obtain fresh supplies of ammonium hydroxide at the beginning of each season.

References

HALL, E. G. (1940).—Ethylene gas to colour fruits and hasten the ripening of tomatoes. *Agric. Gaz. N.S.W.* **51**: 98–101, 143–5.

LEGGO, D., and SEBERRY, J. A. (1964).—Ammonia fumigation for reduction of green mould wastage in oranges during ethylene degreening. *Aust. J. Exp. Agric. Anim. Husb.* **4**: 173–7.

LONG, J. K., and ROBERTS, E. A. (1954).—New dip treatment for control of green mould in oranges. *Agric. Gaz. N.S.W.* **65**: 394–5, 412–3.

NEWS FROM THE DIVISION OF FOOD PRESERVATION

JUICE EXTRACTOR

In September 1963 F.M.C. (Aust.) Ltd. made available on loan to the Division of Food Preservation for a virtually unlimited period one of its three-head State Test Model Juice Extractors for use in experimental work on citrus juice quality. The machine accommodates three different-sized fruits — oranges, lemons, and grapefruits — and handles up to 120 fruit per minute with ease; it is the model used in American plants for extraction of test samples of juice. It is particularly suitable for pilot-plant studies involving small quantities of fruit such as are encountered during the Division's juice quality investigations, where juice samples are required from as few as half-a-dozen fruit. There is no doubt that it has already greatly facilitated the Division's research on citrus products.

Although designed for use as a test extractor, the machine incorporates many details of the larger commercial F.M.C. models and can be effectively used to demonstrate their mode of operation. Unlike other extractors, which halve or quarter the fruit, the F.M.C. extractor squeezes the juice from the intact orange. A lower cup holds the fruit centrally over a narrow cutting tube

Oranges being put through the F.M.C. juice extractor.

while an upper cup, which also carries a central cutting tube, moves down onto the fruit. The cutting tubes pass into the fruit, which is subjected to squeezing pressure, and the juice runs down the lower tube and is strained through a sieving system incorporated in the lower tube. In this process the seeds, peel, and membranes are separated from the juice almost instantly after extraction. A wide variety of adjustments can be made to the machine, according to whether the emphasis is on high yields or on good-quality juice and peel recovery. The test model can be adapted for peel-oil recovery by attachments similar to those incorporated in the commercial plant models.

The test extractor is available for demonstration to those interested, who are asked to give several days' notice and to bring their own raw material.

NEW APPOINTMENTS

Dr. W. B. McGlasson has joined the Division of Food Preservation as a Senior Research Officer, to engage in research in the physiology of fruits and vegetables after harvesting. Dr. McGlasson graduated in Agricultural Science at the University of Adelaide in 1951, when he was appointed to the South Australian Department of Agriculture to carry out research on storage and transport of fruit.

He spent from 1959 to 1962 in the Department of Vegetable Crops at the University of California, Davis, U.S.A., where he collaborated with Professor Harlan K. Pratt in a series of researches on growth and maturation in the cantaloupe.

Dr. N. S. Parker has been appointed to the Division of Food Preservation to carry out research on the rheology of foods. Trained as a physicist at the University of Durham, where he took his Ph.D. degree in 1954, Dr. Parker spent three years with the U.K. Atomic Energy Authority, and seven years in the chocolate industry in Great Britain. During the latter period Dr. Parker studied the rheological properties of chocolates and batters, and the factors influencing the texture of confectionery products.

SOME RECENT PUBLICATIONS OF THE DIVISION

Copies of most of these publications may be obtained from the Librarian, Division of Food Preservation, Box 43, P.O., Ryde, N.S.W. (Tel. 88 0233.)

CHRISTIAN, J. H. B. (1963).—Microbiological spoilage problems of dehydrated foods. *In* "Microbiological Quality of Foods". pp. 223–8. (Academic Press: New York.)

CHRISTIAN, J. H. B. (1964).—Microbial selection and adaptation in cured meats. *Food Tech., Aust.* **16**: 208.

COGGIOLA, I. M. (1963).—2,5-dihydro-2-furoic acid: a product of the anaerobic decomposition of ascorbic acid. *Nature* **200**: 954–5.

COGGIOLA, I. M., and HUELIN, F. E. (1964).—Absorption of 1,2-dibromoethane by oranges and by materials used in their fumigation. *J. Agric. Fd. Chem.* **12**: 192–6.

DAVENPORT, J. B. (1964).—Phospholipids of pigeon and ox-skeletal muscle. *Biochem. J.* **90**: 116–22.

INGLES, D. L. (1964).—Cyclic sulphite ester of glucose. *Chem. & Ind.* **1964**: 366–7.

MCBEAN, D. MCG., JOHNSTON, A. A., and PITT, J. I. (1964).—Absorption of sulfur dioxide by fruit tissue. *J. Food Sci.* **29**: 257–65.

REYNOLDS, T. M. (1963).—Chemistry of non-enzymic browning. I. The reaction between aldoses and amines. *Advanc. Food Res.* **12**: 1–52.

SMITH, M. B. (1964).—Studies on ovalbumin. I. Denaturation by heat, and the heterogeneity of ovalbumin. *Aust. J. Biol. Sci.* **17**: 261–70.