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Important developments have taken place recently in the control of apple scald, a serious disorder of apples in cold storage.

Control of

APPLE scald is, perhaps, the most important of the disorders which may afflict apples in cool storage and certainly the one which has been investigated most by research workers. Investigations into disorders of the scald type have been carried out in many places for over 50 years, yet the real cause of storage scald of apples is still unknown. Because of the increasing adoption of gas storage, where scald is of great importance, and because of some recent important developments, interest in the problem of scald has been greatly stimulated. At the present time it is being intensively investigated in Australia and overseas.

The subject was discussed at a Conference of Australian and New Zealand fruit storage investigators in Sydney at the end of July 1956, where an excellent paper on the present position in research on apple scald was delivered by Dr. D. Martin of the C.S.I.R.O. Tasmanian Regional Laboratory, Hobart. The author is indebted to Dr. Martin's paper for much of the information contained in this article.

DESCRIPTION OF SCALD

In its broadest sense scald is a response to storage, and the available evidence points to it being due to the accumulation, at or near the skin, of toxic by-products of the apple's own respiratory life processes. Symptomatically it varies over a wide range; some forms, such as Jonathan Spot or deep (or soft) scald are quite distinctive. This paper will be largely confined to the commonest form of scald, frequently met on the Granny Smith variety, and known as *superficial scald.* Examples of this are shown in the top and centre figures on p. 4. This superficial browning of the skin in the less severe cases appears as a vague brown clouding, affecting the colour but not the texture or level of the surface. In more sharply defined or reticulated types, the colour may vary from grey to dark brown, and the affected areas usually become depressed or rugose. Other forms may appear as spots centred on lenticels, and these spots may either coalesce or remain isolated (see bottom figure, p. 4). Extreme cases of the last-mentioned type may be primarily due to fungal infection or to injury by gases, such as ammonia, from an external source, but in general the whole range is due to substances produced by the fruit itself.

CHANGES IN THE APPLE

It is interesting to know that lenticels, those pin-point natural spots on the skin of the apple which are commonly thought of as the breathing pores of the fruit, only function in that way when the fruit is very small. As it grows on the tree, the lenticels become blocked with debris and are for the most part covered over by the developing natural waxy coating on the skin. Therefore, after harvest, gas exchange and water loss from the apple take place by direct diffusion through this natural coating. This development of a natural waxy coating on top of the cuticle, which is itself a useful protecting barrier, means that an apple, particularly a variety like

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Apple Scald

Based on an address to the Annual General Meeting of the Australian Apple and Pear Growers' Association at Bathurst, N.S.W., August 8-9, 1956.

the Granny Smith, is enclosed in a good natural "package". Work carried out by Mr. E. W. Hicks, of the Division of Food Preservation and Transport, C.S.I.R.O., has shown that the water loss through the skin of a sound Granny Smith apple, which loss is entirely responsible for wilting, is only 1/100 of that from a free water surface of the same area.

It has been stated above that, as a Granny Smith ripens, the development of the natural waxy coating results in an increasing resistance to the diffusion of gases through the skin, so that the atmosphere in the 30 per cent. of air space inside the fruit becomes increasingly different in composition from the air outside the fruit. Furthermore, volatiles from the apple accumulate within the fruit. In a ripe apple there may be three or four per cent. carbon dioxide and only about five per cent. oxygen. When such atmospheres are produced inside apples early in their storage life by artificial means (by controlled-atmosphere techniques, by applying special very thin coatings to the skin, or by keeping them in sealed polythene or similar bags), the life of the fruit can be greatly prolonged. Such changes in the fruit may greatly increase the liability to scald. Natural changes in the internal atmosphere may also be responsible for changing susceptibility to scald with increasing maturity of the fruit.

DEVELOPMENT OF SCALD

Dr. Martin's survey of the literature showed that the disorder termed superficial scald in Australia is well known to investigators overseas, and that its development generally follows the following pattern:

- It occurs mainly on uncoloured varieties.
- It occurs only on fruit which has been cool stored for more than six weeks.
- Its final development is not increased by low storage temperatures and may even be increased by holding at higher temperatures within the range 30–50°F.
- It declines with increasing maturity at picking, but not with ripening during delayed storage unless freely ventilated during this time.
- It can be reduced or even controlled by strong ventilation, by abrasion or washing of the fruit (which would impair the natural protective coating of the skin), by oiled wraps, by some artificial skin coatings, and by at least one chemical treatment, and it is affected by the composition of the surrounding atmosphere. It follows then that any treatment which impedes ventilation, such as gas storage, tends to increase the incidence of scald. There is therefore considerable evidence, though almost entirely indirect, that scald is caused by some substance produced by the fruit itself. This substance (or substances) can be removed by strong ventilation, and its production can be retarded or prevented, and its effects thereby lessened.
- Lastly, at least one of the injurious factors is produced early in the storage period, although the symptoms may not appear until removal to warmer temperatures after long storage.

PRE-STORAGE FACTORS

The development of scald is influenced by many pre-storage factors. Perhaps the most important is the climate during the last six weeks or so before harvest. If the weather during this period is cool with little sunshine, scald is unlikely; in fact scald in ordinary air storage is rarely a problem in Tasmania, England, Northern European countries, and the Eastern States of America. If in the last six weeks the weather is warm and dry with an abundance of sunshine, the apples will be very liable to scald in storage. For this reason scald is a most important problem with the Granny Smith variety in Western Australia and in the Murrumbidgee Irrigation Area.

Recent unpublished work carried out by Mr. G. B. Tindale in Victoria, and similar work carried out by Mr. C. D. Stevenson in Queensland with Granny Smith apples from Stanthorpe, have shown the effects of maturity to be more critical than had been realized. Mr. Tindale has shown that, in Victoria, there is minimum scald when the Granny Smith variety is picked about the third week of April, and that picking a week earlier or later gives increased scald, although by ordinary standards there has been no obvious change in the maturity of the fruit. Tindale has been able to keep Granny Smith apples, picked at the correct maturity and stored without wraps at the low temperature of 29°F, free from scald until November. In the Queensland experiments and in early experiments at C.S.I.R.O., Homebush, the incidence of scald dropped consistently with delayed picking with, perhaps, a sharper drop about the second week of April. So far there has been no sound evidence of scald being directly influenced by such factors as cultural treatments, rootstock, and pruning, although this is, perhaps, largely due to the difficulties invariably associated with obtaining valid data from such field trials.

Published results on the effects of pre-storage delay after picking, which was, until recently, recommended as a control measure, have been conflicting. This is probably

At left: *Superficial scald on Granny Smith apples. Top: Normal form, intensity slight. Centre: Normal form, intensity severe. Bottom: Speckled form.*

because the importance of ventilation during this period, which was clearly demonstrated by American workers over 30 years ago, had been overlooked.

CONTROL IN STORAGE

Until 1955, there had been little real advance in the control of superficial scald since the thorough study of the disorder in America by Brooks, Cooley, and Fisher (1919*a*, 1919*b*, 1923), of the United States Department of Agriculture, immediately after the first World War. Their work, which was carried out because of the mounting seriousness of losses in cool-stored apples, led to the universal use of oiled-paper wraps, and this has remained the most valuable control treatment up to the present time. Their recommendation that wraps should contain at least 15 per cent. mineral oil is still standard practice, and their hypothesis that injury is caused by a volatile substance produced by the apple has not been replaced by a better one.

Since oiled wraps are, in the main, effective if they contain sufficient oil, and since ventilation has been shown to be an important factor, it has been assumed that scald is due to the accumulation around the fruit of one or other of the "apple volatiles", that is, gases given off by the fruits in very small quantities and responsible for the characteristic fruit aroma. So far no one has obtained any good direct evidence of this. Dr. F. E. Huelin, of the Division of Food Preservation and Transport, C.S.I.R.O., who has been working on the relation of volatiles to scald, has identified a number of different volatiles and tested them to see if they cause scald. Most have given negative results, but in 1955 he was able to induce typical scald on Granny Smith apples with vapours of hexyl acetate, although at a higher concentration than would normally be expected in a fruit store.

Following some rather spectacular results obtained by Dr. R. M. Smock (1955) at the Cornell University in America, a pre-storage dip treatment with diphenylamine was tested at C.S.I.R.O., Homebush, in 1955. The results were again spectacular: after long storage, scald was severe on untreated, unwrapped fruit, and absent from unwrapped fruit treated with diphenylamine. Results so far indicate that diphenylamine will, even under severe conditions, completely control scald and it is therefore much better than oiled wraps, which are not always effective with very susceptible fruit or in gas storage. Diphenylamine may be applied as a dip before storage, or impregnated into the fruit wraps or into heavier paper sheets which are placed between the layers of fruit in the box. The problems of residues in the fruit and toxicity to humans are under examination, so that this treatment is not yet ready for commercial use.

Dr. Huelin also found that scald was inhibited by exposure of the fruit during storage to the vapours of commercial hexane. Thus, we now appear to have two inhibitors of scald, and there may be others. This opens up a new and very promising approach to the problem of scald control which is being actively pursued by C.S.I.R.O. and by other fruit storage investigators in Australia. It would be a great practical advantage if the need for wrapping Granny Smiths in oiled wraps for storage could be dispensed with.

The problem of scald is intensified in gas storage, where there is obviously much less ventilation than in ordinary air storage. In gas storage, scald on Granny Smiths is often not prevented by oiled wraps and it may develop on other varieties on which it normally does not occur in air storage. Research at C.S.I.R.O., Homebush, has shown that, in addition to the amount of ventilation, the levels of oxygen and carbon dioxide in the atmosphere affect the incidence of scald. It is increased by raising the percentage of carbon dioxide, but is greatly diminished by reducing the concentration of oxygen to the lowest possible level short of killing the fruit, namely, down to about 2 per cent., even with several per cent. of carbon dioxide in the atmosphere.

The advent of diphenylamine has greatly altered the outlook for gas storage. If it can be applied successfully then one of the biggest difficulties associated with ventilated gas storage, namely, greatly increased scald development, will be overcome. To obtain low oxygen levels in gas storage it is necessary to install a chemical scrubber, which is an additional complication, and the gas sealing of the room must be more efficient than is required for normal ventilated gas storage in which control of the storage atmosphere is brought about simply by regulating ventilation to the air outside. We feel that diphenylamine will control scald in gas storage, and, if its use is approved by health authorities, Granny Smith and other varieties can be treated with it and successfully stored in an atmosphere of 5 per cent. carbon dioxide and 16 per cent. oxygen, with no risk of losses from scald.

Following claims made by Dr. Smock a few years ago (Smock and Southwick 1948), there has been considerable interest recently in the possibilities of improving the storage life of apples by purification of the storage air by various means to remove "fruit volatiles". As a result of investigations by a number of people in different centres (e.g. Maxie and Baker 1954), it now appears that air purification with devices such as activated carbon scrubbers is of little real value and commercial application is not warranted. Regarding scald, Dr. Smock now feels that adequate control of scald is unlikely to be achieved by air purification, although it might have a useful subsidiary effect. These conclusions have been supported by investigations in Australia.

At present there is much interest in the use of sealed case-liners of plastic film for apples and pears (e.g. Ryall and Uota 1955). These have characteristic resistances to the diffusion of oxygen and carbon dioxide, and suitable films such as polythene will produce a very satisfactory "in-case gas storage". In some instances considerable reduction of scald has been obtained by using case liners; the effects are probably due to low-oxygen gas storage, and are in line with gas storage results at C.S.I.R.O., Homebush. Work is continuing on plastic case liners, which are expected to have a place in commercial storage. They are being used extensively in the United States, especially for pears, not only for home storage and marketing, but also for export.

From time to time overseas workers (e.g. Christopher 1947) have suggested the pre-treatment of apples with comparatively high concentrations of carbon dioxide to control scald, and some success has been reported. This method was tested on several lines of Granny Smiths at C.S.I.R.O., Homebush, but was found to be of no practical value.

RECOMMENDATIONS

There is some evidence, from the work of C.S.I.R.O. and others, that lower storage temperatures delay the appearance of scald. Such temperatures also maintain better green colour, firmness, and flavour. It is therefore recommended that the Granny Smith variety be picked well matured, placed in storage as soon as possible, and stored at a temperature of 30°F. The fruit should be wrapped in good-quality oiled paper containing at least 15 per cent. of the correct grade of refined mineral oil, and undersized wraps should not be used. If necessary, wrapping in oiled wraps, at least under New South Wales conditions, can be delayed for up to six weeks without risk of seriously affecting the control of scald.

At the present time the Standards Association of Australia is preparing a standard specification for oiled wraps, which will greatly help the grower and packer to obtain oiled wraps of satisfactory quality. However, the oil content can decrease significantly during storage from one season to the next. The loss can be minimized by storing the wraps in large packages, well wrapped in waxed paper, polythene sheet, or such like, and holding in a cool store if possible.

REFERENCES

Brooks, C., Cooley, J. S., and Fisher, D. F. (1919*a*).—Apple scald. *J. Agric. Res.* **16**: 195–217.

Brooks, C., Cooley, J. S., and Fisher, D. F. (1919*b*).—Nature and control of apple scald. *J. Agric. Res.* **18**: 211-40.

Brooks, C., Cooley, J. S., and Fisher, D. F. (1923).—Oiled wrappers, oils and waxes in the control of apple scald. *J. Agric. Res.* **26**: 513-36.

Christopher, E. P. (1947).—The use of CO_2 to prevent scald of stored apples. *Refrig. Engng.* **53**: 311–14, 342–6.

Maxie, E. C., and Baker, C. E. (1954).—Air filtration studies in a commercial type apple storage. *Proc. Amer. Soc. Hort. Sci.* **64**: 235–47.

Ryall, A. L., and Uota, M. (1955).—Effects of sealed polyethylene box liners on the storage life of Watsonville Yellow Newtown apples. *Proc. Amer. Soc. Hort Sci.* **65**: 203–10.

Smock, R. M. (1955).—A new method of scald control. *Amer. Fruit Gr.* **75** (11): 20.

Smock, R. M., and Southwick, F. W. (1948).—Air purification in the apple storage. Bull. Cornell Agric. Exp. Sta. No. 843.

This paper is based on an address given to the 16th Annual Conference of the Commonwealth Cold Storage Association held in Sydney in June 1956.

Shrinkage during Chilling, Freezing, and Storage of Meat

By E. W. Hicks
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THE weight loss from meat is generally expressed in percentage loss per month. This is convenient for trade purposes but it is not the most logical method when considering how and why shrinkage occurs and how much is likely to occur under particular conditions. This is because evaporation takes place from the surface of the meat, and the amount of loss depends, among other things, on the extent and nature of the exposed surface.

EFFECT OF NATURE AND QUALITY OF MEAT

The area of exposed surface per ton of beef depends on the size and shape of the pieces. With carcass or quarter meat, the area per ton is generally less for large animals than for small ones. Thus beef has a smaller area per ton than mutton or veal. It is well known that shrinkage in good-quality beef tends to be less than in poor-quality. This is partly because the area per ton is less in good quality beef but the effect is mainly due to a different cause. Exposed cut muscle tissue can be described as almost completely wet, in the sense that it will evaporate at much the same rate as a surface wetted with water or covered with ice, and its evaporation properties generally remain almost unchanged during storage. There is very little exposed muscle in carcass meat, and the other parts of the surface have quite different properties. Most of these surfaces are covered by a thin layer of connective tissue with much the same evaporation properties as muscle, but it is thin and easily dried out. Underlying that are other types of tissue, much of it fatty. The fatty tissues will evaporate little water and will not transmit much water from lower down. Consequently these areas become practically dry, non-evaporating areas once the overlying connective tissue has lost its water. Thus, when a carcass first comes from the slaughter floor it behaves as a surface which is wet all over and it loses water at a high rate. During chilling, freezing, and storage more and more of the surface becomes virtually dry, so that the potential evaporation rate decreases. Most of this decrease in wetness occurs early in the process but the rate of weight loss continues to decrease slowly in storage.

This is a somewhat oversimplified picture of the evaporation properties of meat; there are possibilities of behaviour lying between that of the ideal muscle and the ideal fatty tissue postulated in our picture. However, I believe our simplified picture is complete and accurate enough to enable us to understand most of the things which go on during handling and storage.

We have not yet enough detailed information on the evaporation properties of beef in storage, but it is probable that good-quality beef in storage has an average wetness of one third or less. Beef which has a poor covering of fat may evaporate as much as twice as fast because of the difference in the nature of the surfaces.

When beef is cut into smaller pieces, the potential shrinkage rate is increased because the area of exposed surface is increased and, what is more important, most of the additional surface is tissue, which will continue to lose water at a high rate during storage.

Thus variations in the quality of meat can alter the potential shrinkage rate by a factor of about two, and subdivision of quarters can increase it by a much larger factor.

LOSSES DURING CHILLING

A substantial loss of water from beef during chilling is inevitable because the beef surfaces must be significantly warmer than the air of the chiller during the cooling process. Actual weight losses during chilling which have been reported range from a little under 1 per cent. to about 3 per cent. The well-authenticated claims for 1 per cent. or less seem to be for incomplete chilling of beef with a very good fat covering, e.g. cooling for a nominal 24-hour period, which can in fact be as short as 18 hours. Consequently this figure should not be regarded as one which can be easily realized in practice. On the other hand losses as high as 3 per cent. represent an extravagance which can easily be avoided.

The most important controllable factor affecting the weight loss during chilling is the rate at which the air temperature is brought down to 32°F. or a little lower. Thus a large refrigerating capacity is necessary to restrict water loss during chilling. In the early stages of chilling the rate of water loss is determined mainly by the difference in temperature between the meat and the air, and the effect of humidity is not great. However, in the later stages the relative humidity is all important and this should always be taken into account in designing chillers in which beef will remain for more than 24 hours. For domestic trade, shrinkage during chilling should be restricted as far as possible; however, a relatively high rate of evaporation is desirable in the later stages of chilling beef for export, so that it is sometimes desirable to take steps to *reduce* the humidity in chillers for export beef.

LOSSES DURING FREEZING

The factors affecting weight loss during freezing are similar to those affecting the loss during chilling. We have seen that fast chilling with a low average air temperature leads to relatively low losses. The same is true of freezing. There is a definite lower limit to the air temperature during chilling, namely, the freezing point of the beef, but there is no such limit for freezing, so the possible variations in loss are relatively large for freezing.

In general, blast freezers operating at a low temperature give less loss in weight than natural-circulation freezers operating at higher temperatures. Much greater savings are possible by eliminating the separate chilling phase and loading hot meat straight into blast freezers. A saving of 2 per cent. or a little more in the loss between dressing and the completion of freezing is often obtainable by changing from conventional chillers and slow freezers to fast freezing of unchilled meat in blast freezers. It should be noted, however, that a large part of this saving is not usually permanent but is offset by greater losses during storage.

The table at right shows a set of experimental data of weight losses during freezing and storage. It will be seen from this that the total loss of weight up to the end of freezing was about 2·2 per cent. In this particular experiment there was still a difference of 1·9 per cent. after 20 weeks' storage, although the rate of loss from the blast-frozen beef in storage was twice that from the beef handled in the usual way. While these figures are, no doubt, correct they do not seem to be representative of average conditions in our stores and in ships carrying beef to Britain. A loss of 0·3 per cent. per month from normally handled beef (i.e. 4·7 times that found in this experiment) seems to be fairly typical, although it is known that much higher and much lower rates of loss occur in particular stores. It is evident that the total losses would have been much closer if the samples had been stored under less favourable conditions.

LOSSES DURING FROZEN STORAGE

It has already been mentioned that there are enormous variations in the losses in existing stores, ranging from almost zero to over 1 per cent. per month.

The main factor affecting water loss in storage is, of course, the relative humidity in the store. Unfortunately it is very difficult to measure this in a frozen store and there seems to be no immediate prospect of a cheap, reliable instrument becoming available to do this. However, in most instances the operator of a store can do little about the control of the humidity in his stores; we should endeavour to design stores so that the humidity will normally be high. The basic principles governing the effect of variations in design on the weight losses from goods in a store are well known, but they have not been studied in enough detail to be able to predict at all accurately the quantitative effect of a given change. It is clear, however, that good insulation is necessary to restrict shrinkage, and the cooling system should be designed to operate at a temperature as little as possible below the storage temperature. Large, natural-circulation rooms are generally favoured. While it is, no doubt, possible to build stores with forced-air circulation, in which weight losses will be small, weight losses tend to be rather high in most existing forced-circulation rooms. Losses are very high in some of them.

Percentage Weight Losses from Beef during Freezing and Storage

Data of Howard and Lawrie (1956)*

Weight Loss during:	Blast-frozen without Prior Chilling	Normal Handling
Chilling	Nil	(1·5)†
Freezing	0·60	1·33
20 weeks' storage at −10°C	0·74	0·36
Total (as % initial hot weight)	1·34	3·22

* Howard, A., and Lawrie, R. A. (1956).—Studies on beef quality. I. Effect of blast-freezing hot beef quarters. C.S.I.R.O. Aust. Div. Food Pres. Transp. Tech. Pap. No. 2.

† This was not measured in the experiments. The figure taken is a representative value from earlier measurements in the same chillers.

Brine-washed coolers are sometimes used in forced-circulation stores. These have some great advantages which are well known, but a great deal of care in controlling the density of the brine is necessary to prevent avoidable increases in shrinkage of meat in store. Weight losses may be doubled as the result of using brine densities which are not always considered excessive by the operators. The heat input by fans has a significant effect on weight losses from cargoes. Consequently efforts should be made to keep the fan power as low as possible by careful design of ducts, avoidance of unnecessarily high rates of air flow and, particularly, by choosing efficient fans.

An advantage of forced-circulation rooms is that they can be used for fairly fast freezing of meat as well as for storage. Dual-purpose rooms of this sort are sometimes very useful but it seems very difficult to design them so as to avoid relatively high shrinkage when meat is stored in them.

Rates of shrinkage varying by a factor of 8–10 can occur in different parts of a large natural-circulation frozen store. The highest rates occur on surfaces which "see" a warm wall (i.e. surfaces which receive direct radiant heat from a warm wall, such as the outer tier of carcasses). The increase in the average loss per ton of meat in the store caused by local warming near outside walls is not yet known accurately and it may be quite small. It is of considerable economic importance with frozen salmon, which are very susceptible to freezer-burn, and double baffle walls inside the true outer walls have been installed in a number of Canadian salmon stores to overcome the warm wall effect. We cannot yet say definitely whether it is likely to be profitable to do the same thing in meat stores.

The deposition of ice on the cooling coils is an unwanted process which inevitably accompanies the transfer of heat to the coils. If no heat had to be removed from the storage space we would not need to remove any water. This is the principle behind the jacketted stores which are in use for salmon storage in Canada. In these the storage space is a closed chamber inside the insulated walls and separated from them. The heat penetrating the insulation is absorbed by air circulating through the jacket between the walls and the storage chamber. These stores are rather troublesome and expensive to design and build but they do give very low shrinkage rates and they seem to have proved good investments for the storage of frozen salmon.

The storage temperature is another very important factor affecting shrinkage of meat. If the relative humidity remained unaltered, a reduction in storage temperature from 14 to 0°F. would result in reducing the shrinkage rate to a little less than half. Of course, changing the temperature of a store will affect its humidity, but theoretical calculations and experimental data from a number of sources indicate that actual savings in shrinkage by reducing the temperature are only a little less than the theoretical values derived by assuming constant humidity.

EFFECTS OF PACKAGING AND STOWAGE

When apples are packed in cases the rate of water loss becomes much less than that from apples freely exposed in the store. Apples near the centre of the box lose only about one-fifth of the amount lost by freely exposed apples. This is, of course, due to resistance to the movement of water vapour away from the fruit—what we call diffusion resistance. No doubt the same sort of thing occurs in large stacks of meat, particularly in natural-circulation stores. We have not yet been able to carry out experiments to find out how large this effect is. We would not be surprised if it is a good deal less than with apples in boxes, but presumably it is of some importance.

Protective packaging, namely, enclosing materials in films which are effective barriers against the passage of water vapour, is much discussed these days. In the frozen meat trade it is used extensively for small units such as edible offals and retail-sized cuts. It is virtually a necessity with these because they have very high potential shrinkage rates because of their size and the nature of their surfaces. Good packaging is particularly important with materials subject to freezer-burn. Protective wraps or bags could also be used to reduce shrinkage from carcass or quarter meat, and it has often been done experimentally. There are, however, some practical difficulties, such as films tearing during handling, but the main objection seems to be that the savings are too small to justify the cost.

Fish are commonly glazed, that is, covered by a thin layer of ice by dipping in water or spraying with water after freezing. This prevents loss of water from the fish itself during storage so long as the glaze remains complete. This procedure has not often been used for meat but it seems to work quite satisfactorily and to have no undesirable secondary effects. It is being used by some American operators for low-grade cuts of meat which are stored for subsequent processing. This, of course, is material with a high potential shrinkage rate.

LETTER TO THE EDITOR

VACUUM PROCESSING OF APPLES

Dear Sir,

At the conclusion of a letter from F. E. Atkinson on "Vacuum Processing of Apples" in your December issue (*C.S.I.R.O. Food Pres. Quart.* **16**: 78) you stated that this method has not been tried in Australia.

May I correct this statement and inform you that this Company carried out experiments on the vacuum pack of apples in April and July 1947. In 1948 production exceeded 12,000 16-oz cans of apple slices, and 2000 30-oz cans of solid pack. In 1949 production (of apple slices only) exceeded 78,000 16-oz cans and 5000 30-oz cans. Total production has now exceeded 500,000 cans. In our opinion the vacuum pack for both apple slices and solid-pack apple gives a superior pack to the non-vacuum method.

Plaistowe & Co. Ltd.,

Perth, Western Australia.

Equilibrium Relative Humidity

By J. F. Kefford
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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; and Vol. 16 (1956), pp. 7–10. Critical comments on the procedures described, and suggestions for modified or alternative methods found to be useful in practice, will be welcomed.

THE immediately preceding parts of this series discussed the determination of solids content in canned foods. One object of the control of solids content in some canned foods is to ensure adequate keeping qualities. Solids contents above certain limits, or conversely moisture contents below certain limits, are commonly considered to inhibit microbial spoilage. It is true that microorganisms, like the higher organisms, require water for growth. However, the fundamental index of the ability of a foodstuff to support the growth of microorganisms is not the water content but the *water activity* (Scott 1956), which may be regarded broadly as a measure of the availability of water to the microorganisms.

WATER ACTIVITY

The water activity (a_w) of a food is defined by the expression:

$$a_w = p/p_0,$$

where p_0 is the vapour pressure of pure water and p is the aqueous vapour pressure of the foodstuff at the same temperature. Water activity varies with temperature but the variation is not important over the normal range of storage temperatures for foods.

Now the quantity $p/p_0 \times 100$ is the equilibrium relative humidity (ERH) of the foodstuff, and therefore water activity is numerically equal to equilibrium relative humidity expressed as a fraction, i.e. $a_w = \text{ERH}/100$. Water activity may be said to be a property of the food itself, while ERH is a property of the atmosphere immediately surrounding the food.

The lowest water activities at which various microorganisms are able to grow depend to some extent on the composition of the medium, but it is possible to state rough minimum limits. Thus most bacteria are inhibited at $a_w < 0{\cdot}95$, and most yeasts at $a_w < 0{\cdot}90$, although some osmophilic yeasts will grow at $a_w = 0{\cdot}61$. Moulds grow readily at $a_w = 0{\cdot}75$–$0{\cdot}80$. The significance of these limits is apparent when they are considered in relation to the water activities of some common foods, e.g. in fresh beef $a_w = 0{\cdot}993$, in jams $a_w = 0{\cdot}70$–$0{\cdot}83$, in fruit cakes $a_w = 0{\cdot}73$–$0{\cdot}85$, and in dried milk $a_w = 0{\cdot}2$ (approx.).

Most heat-processed canned foods do not depend upon control of water activity to inhibit microbial growth in the unopened can. Some foods, however, such as jams, spreads, puddings, cakes, and yeast extracts, are likely to have water activities which permit the growth of moulds. These products are not always packed under conditions such that the can and its contents are free from viable mould spores, and often they are required to keep for considerable periods after the can is opened and the contents exposed to atmospheric contamination. To avoid the possibility of spoilage it is necessary to maintain close control over the factors affecting water activity, the main ones being the soluble solids content and the composition of the soluble solids. For instance the water activity is lowered by increasing the ratio of sugars to starch, or of monosaccharides to total sugars.

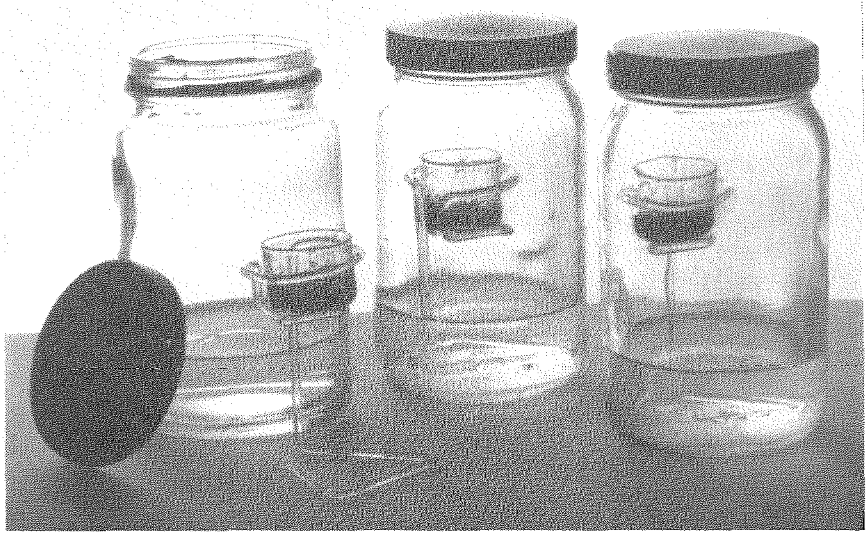
Knowing the chemical composition of a food, it is possible to calculate its water activity (Grover 1947; Money and Born 1951), but a direct determination by measuring the ERH of the product is generally preferred.

EQUILIBRIUM RELATIVE HUMIDITY

From the practical viewpoint, the ERH of a food may be regarded as the humidity developed in a sealed vessel containing the food when the amount of free space is small, or alternatively, as the humidity of an atmosphere in which the food will neither take up nor lose water. These two concepts provide the bases for a variety of methods for the estimation of ERH, many of which are reviewed by Landrock and Proctor (1951*a*).

The humidity of the atmosphere in equilibrium with a food may be determined by observing the dew-point (Hughes 1942), by absorbing the water vapour and measuring the change in volume (Jones 1951), by the use of hygroscopic indicator salts (Pouncy and Summers 1939), or by means of an electric hygrometer (Karel, Aikawa, and Proctor 1955) or a lithium chloride hygrometer (Mossel and van Kuijk 1955).

The alternative approach involves measurement of the weight changes that occur in samples of a foodstuff held in atmospheres of known humidity. A simple procedure based on this principle was described by Hicks (1944) and has been used in this Laboratory since that time. An essentially similar method described by Landrock and Proctor (1951*a*, 1951*b*) and a weight equilibration method devised by Wink (1946) have been proposed as standard methods by the Packaging Institute Food Committee (1953).



Apparatus for determining the equilibrium humidity of foods

Relations between Concentration and Density of Sulphuric Acid Solutions and Equilibrium Humidity

Relative Humidity (%)	Concentration of H_2SO_4 (g/100 g soln.)				Specific Gravity			
	0°C	10°C	20°C	30°C	0°C	10°C	20°C	30°C
95	10·8	10·9	11·0	11·1	1·081	1·077	1·073	1·069
90	17·5	17·6	17·8	18·0	1·131	1·127	1·123	1·119
85	22·2	22·4	22·7	23·0	1·169	1·164	1·160	1·156
80	26·1	26·4	26·6	26·9	1·200	1·196	1·191	1·187
75	29·3	29·7	30·0	30·3	1·227	1·223	1·219	1·214
70	32·2	32·5	32·9	33·2	1·241	1·246	1·242	1·238
65	34·7	35·1	35·6	36·0	1·272	1·268	1·265	1·261
60	37·1	37·6	38·1	38·6	1·293	1·289	1·286	1·283
55	39·5	40·0	40·5	41·0	1·313	1·310	1·307	1·304
50	41·7	42·3	42·8	43·4	1·333	1·331	1·328	1·325
45	43·9	44·5	45·1	45·7	1·353	1·351	1·349	1·346
40	46·1	46·8	47·4	48·0	1·373	1·372	1·370	1·368
35	48·5	49·1	49·7	50·3	1·396	1·394	1·392	1·390
30	50·8	51·5	52·1	52·8	1·419	1·418	1·416	1·415
25	53·2	54·0	54·7	55·3	1·443	1·443	1·442	1·440

DETAILS OF METHOD

In the method of Hicks (1944), three screw-top jars are used as constant-humidity chambers, each containing, to a depth of approximately 1 in., a sulphuric acid solution of known equilibrium humidity (see the table above and Jones (1951)). For instance, in a determination on a product thought to have ERH of the order of 75 per cent., the jars might contain sulphuric acid solutions giving relative humidities of 80, 75, and 70 per cent. respectively.

Approximately equal amounts (2–5 g) of the test product are weighed accurately into three standard-sized dishes, one of which is placed on a glass support above the acid in each jar (see illustration on p. 12). The jars are tightly sealed and held at a well-controlled constant temperature, e.g. 30°C, and the dishes are reweighed at intervals.

It is not necessary to wait for the samples to reach equilibrium at the three humidities. A good estimate of the equilibrium value is obtained by plotting the total weight change of each sample after two days against the relative humidity of the storage atmosphere. Both positive and negative weight changes are observed. A curve is then drawn through the three points and the humidity corresponding to zero weight change on the curve is taken as the ERH. If higher precision is required, the test is repeated using a narrower range of humidities, e.g. if the first test gave a result of 76 per cent., appropriate humidities for the second test would be 78, 76, and 74 per cent. Care must be taken that the amounts of water transferred are not great enough to affect the acid concentration appreciably. Preferably, the procedure including the weighing is carried out in a constant-temperature room; but it is possible to work with a smaller chamber, such as an incubator, provided the temperature is controlled within satisfactory limits. Fluctuations great enough to cause condensation on the walls of the jars must be avoided.

REFERENCES

GROVER, D. W. (1947).—The keeping properties of confectionery as influenced by its water vapour pressure. *J. Soc. Chem. Ind. Lond.* **66**: 201.

HICKS, E. W. (1944).—Equilibrium relative humidity of foodstuffs. *C.S.I.R.O. Food Pres. Quart.* **4** (4): 3.

HUGHES, E. B. (1942).—Modern concepts of analysis. with special reference to food. *Chem. & Ind.* **1942** : 103.

JONES, F. R. (1951).—An accurate method for the determination of aqueous vapour pressure: the equilibrium humidities of solutions of sulphuric acid. *J. Appl. Chem.* **1**: S144.

KAREL, M., AIKAWA, Y., and PROCTOR, B. E. (1955).—New approach to humidity equilibria data. *Mod. Packag.* **29** (2): 153.

LANDROCK, A. H., and PROCTOR, B. E. (1951*a*).—Measuring humidity equilibria. *Mod. Packag.* **24** (6): 123.

LANDROCK, A. H., and PROCTOR, B. E. (1951*b*).—A new graphical interpolation method for obtaining humidity equilibria data, with special reference to its role in food packaging studies. *Food Tech., Champaign* **5**: 332.

MONEY, R. W. and BORN, R. (1951).—Equilibrium humidity of sugar solutions. *J. Sci. Fd. Agric.* **2**: 180.

MOSSEL, D. A. A., and VAN KUIJK, H. J. L. (1955).—A new and simple technique for the direct determination of the equilibrium relative humidity of foods. *Food. Res.* **20**: 415.

PACKAGING INSTITUTE FOOD COMMITTEE (1953).—Moisture equilibria of food products. *Mod. Packag.* **26** (5): 133.

POUNCY, A. E., and SUMMERS, B. C. L. (1939).—The micro-measurement of relative humidity for the control of osmophilic yeasts in confectionery products. *J. Soc. Chem. Ind. Lond.* **58**: 162.

SCOTT, W. J. (1956).—Water relations of food spoilage micro-organisms. *Advanc. Food Res.* **7** (in press).

WINK, W. A. (1946).—Determining the moisture equilibrium curves of hygroscopic materials. *Industr. Engng. Chem.* (*Anal.*) **18**: 251.

BOOK REVIEW

FOOD PRESERVATION IN INDIA

"FRUIT AND VEGETABLE PRESERVATION INDUSTRY IN INDIA." (Central Food Technological Research Institute: Mysore, 1956). Price: 15*s*. sterling.

BY organising a symposium on the problems of the fruit and vegetable preservation industry in India, and now publishing this record of the proceedings, the Central Food Technological Research Institute of the Indian C.S.I.R. has made a valuable contribution to progress in the assessment and solution of those problems. Eighty-five of the participants in the symposium came from outside the Institute and many of these contributed papers to the symposium, but a large proportion of the papers came from members of the staff of the Institute.

The preservation of fruit and vegetables by canning, cool storage, and other methods is on a very much smaller scale in India than in Australia, North America, or Europe. The reasons for this are mainly economic, as is made clear in several of the contributions in this book, and, almost inevitably in such a situation, technological standards in the industry are not always as high as they might be. Many of the contributions to the symposium are clearly designed to inform processers of ways in which their techniques might be improved. There are also a number of papers outlining possibilities for the manuture of new processed foods from Indian raw materials. Many of the papers are reports of laboratory work. These are mainly exploratory in character and concerned with local raw materials.

The main interest of the book to Australian food technologists will probably be in the picture it gives of the problems in the preservation of fruit and vegetables, as seen by Indians, and the way in which their colleagues at the Central Food Technological Research Institute and other Indian research institutions are dealing with these problems.

ANSWERS TO INQUIRIES

MEAL FROM CRAYFISH AND PRAWN WASTE

A reader seeks information on the preparation from crayfish and prawn waste of meal for feeding to animals and poultry.

The problem of the disposal of waste material from crayfish has already arisen in Australia in connection with the preparation of frozen crayfish tails and headless prawns for export to the United States. About two-thirds of the weight of the raw material is waste in the case of crayfish and about a half in the case of prawns. The catching and processing of prawns and crayfish have increased considerably in the last 10 years, and the operations are seasonal.

In some overseas countries waste material of this nature is processed to produce meal for feeding animals. In South Africa the greater part of the waste from crayfish tailing and canning plants is utilized in this way, and in the United States some waste from shrimp processing operations is converted into meal for poultry. It remains to be proved whether the methods used in these countries can be made profitable in Australia. In South Africa crayfish processing is carried out on such a scale that large quantities of raw material are available for crayfish-meal production for the greater part of the season. In addition fish-meal is often being produced in nearby factories during the crayfish season, and some of the fish-meal processing equipment can be used for handling crayfish waste. In the United States the shrimp industry is very large, and the quantities of waste material which regularly become available during the season warrant the installation of equipment to process it. In Australia the production of meal, though not profitable in itself, may in some cases prove to be the best method of solving the problem of waste disposal.

The methods used in South Africa for the production of animal-feeding meal from crayfish offal have been investigated by the Fishing Industry Research Institute of Cape Town. The work carried out by this Institute has been described in its Progress Report No. 2, October 1947, and Progress Report No. 4, February 1949. The offal, after a preliminary treatment for about 20 minutes with steam at about 220°F, is pressed to remove some of the liquid, subsequently dried in trolley tunnel driers (or rotary driers), and milled to produce fine meal. It is necessary to reduce the moisture content of the offal to 55 per cent. or lower, before drying, to overcome the tendency for the material to "ball up" and stick to the drying surfaces, particularly in rotary driers. In South Africa small quantities of crayfish offal are completely sun-dried before milling. In other cases it is partially sundried; but most of the material milled comes direct from the crayfish processing plants.

Progress Report No. 4 deals particularly with investigations into methods for effecting an initial reduction in the moisture content of crayfish offal. One of the most effective methods is to use a curb press on pre-cooked material. A continuous screw press is equally effective, provided that the pre-cooking of the raw material has coagulated the proteins. Experiments have shown that a fish screw press can handle properly pre-cooked hot crayfish offal to produce a non-cohesive press cake. This cake when milled can be dried at a similar rate to ordinary milled fish press cake in a rotary steam-heated drum drier. The investigators considered that crayfish offal was likely to cause more rapid wear on the screw press screens than the offal from fish such as pilchards, and that some changes in design would be necessary to avoid undue wear to these parts.

Dried meal produced from crayfish waste was found to have an average protein content of slightly less than two-thirds that of ordinary fish-meal. The relatively lower market value of the crayfish-meal must be taken into account in assessing the prospects for economic utilization of the offal.

The methods used for converting crayfish offal into dried meal can be applied to waste from prawn processing operations. At present the quantity of waste from Australian factories beheading prawns is very small and may even be insufficient to make economically feasible the preparation of meal by sun-drying.

NEWS from the Division of Food Preservation and Transport

NEW DIVISIONAL HEADQUARTERS

The Standing Committee on Public Works of the Commonwealth Parliament has recommended the erection of new central laboratories for the Division of Food Preservation and Transport, at North Ryde, a suburb of Sydney a little over six miles in a direct line north-west of the city. The estimated cost is £650,000. The site, an elevated one nearly 200 feet above sea level, is within an area zoned as a green belt by Sydney's town planners, and is part of 20 acres resumed by C.S.I.R.O., and already occupied in part by the Organization's Coal Research Section.

The Standing Committee commented on the cramped, unsatisfactory conditions in the existing laboratories at the State Abattoirs and Meat Works at Homebush, and approved plans for new buildings which will provide greatly improved facilities for research. The new headquarters will have a total floor area of 67,000 square feet, compared with 27,000 at Homebush. The building will be constructed of steel and concrete, with curtain walls of glass and sheet metal. Internal partitions will be demountable wherever possible to enable alterations to be made to the interior to meet the changing needs of the research teams. There will be four main blocks of buildings:

- The main laboratory block and cold rooms.
- The processing block and associated laboratories.
- The administrative block, which includes a library and meeting room, is connected to a building containing the staff dining-room and a unit where tasting tests on foods will be conducted.
- Workshops, stores, and garages.

The blocks have been so arranged that extensions may be made without difficulty. The buildings will include an engine room and boiler house, an oil store, and several minor structures. A reservoir, to ensure an uninterrupted water supply, and a water tower are also to be provided. The cold rooms and most of the laboratory buildings will have two floors, the other buildings one only.

In addition to physical, chemical, and microbiological laboratories, the plans provide special rooms for radio-tracer investigations, chromatography, infra-red spectrophotometry, photography, glass-blowing, and for studying the use of ionizing radiations for sterilizing foods. A large pilot plant building will include equipment for investigations on the canning, dehydrating, and freezing of foods. The buildings will be serviced with gas and electricity, hot and cold water, distilled water, compressed air, and steam, in accordance with needs. The library, one microbiology laboratory, the rooms for infra-red spectrophotometry and photography, and the tasting-test booths will be air-conditioned.

KILLING FRUIT FLY IN ORANGES

In 1955 serious outbreaks of the Queensland fruit fly occurred in the Murrumbidgee Irrigation Area and in parts of the Murray Valley, and the New Zealand Government refused to accept oranges from in or near the affected areas for fear of introducing the fly into New Zealand. Since Australia usually exports to New Zealand from the above areas about a quarter of a million cases of oranges each year, the ban was a serious threat to the Australian citrus industry. Recognizing this, the Australian Agricultural Council took immediate steps to intensify investigations into practicable methods of killing fruit fly in oranges after harvesting. Funds were provided by the citrus industry, the Commonwealth Government, and the Governments of New South Wales, Victoria, and South Australia.

Investigations have been planned by a technical committee, responsible to the Standing Committee on Agriculture and representing C.S.I.R.O., the Commonwealth

Department of Primary Industry, and the Departments of Agriculture in New South Wales, Victoria, and South Australia. The aim of the investigators is to devise a method of treatment which will effectively kill the fly, but not injure the fruit, and be practicable under orchard, shed, or packing-house conditions. Tests are being made of two methods: (1) storing the oranges at 31°F for periods varying from 14 to 21 days, and (2) fumigating the fruit with ethylene dibromide.

The research is being carried out in Victoria and South Australia; in the laboratories of the C.S.I.R.O. Division of Food Preservation and Transport at Homebush, N.S.W.; and in the joint C.S.I.R.O.–N.S.W. Department of Agriculture Citrus Research Laboratory at Gosford, N.S.W., where buildings have been erected for breeding the Queensland fruit fly, inoculating the fruit, and carrying out some chemical work. The Division of Food Preservation and Transport is devoting itself to research on the effect of the sterilization treatments on the oranges, while the efficacy of the several treatments for killing the fruit fly is being investigated by officers of the Entomological Branch of the New South Wales Department of Agriculture. In Victoria and South Australia officers of the State Departments of Agriculture are doing some work on cold storage treatment, and they are giving special attention to the sterilization of oranges by fumigation with ethylene dibromide under plastic tents.

It has already been shown to the satisfaction of the New Zealand Government that the fruit fly may be killed in oranges by holding the fruit for 14 days at 31°F, and the New Zealand plant quarantine regulations have been amended to include holding fruit at a flesh temperature of 31 ± 1°F for 14 days as a specific measure against the Queensland fruit fly in oranges. The method is suitable for Valencia oranges, whether grown in coastal or inland areas, and for inland Navel oranges picked not later than mid July. It is, therefore, an acceptable quarantine treatment for most oranges likely to be exported. There may be considerable differences in the liability to cold injury of fruit from different orchards in the one district, and even from different blocks on the one orchard. This must be taken into account in the practical application of the treatment.

PUBLICATIONS BY STAFF

EFFECTS OF OZONE ON CHILLED MEAT. I. THE DECOMPOSITION OF OZONE IN THE PRESENCE OF MEAT. *G. Kaess. Aust. J. Appl. Sci. 7: 242–62 (1956).*

The investigation has as its aim the study of the effect of constant continuous concentrations of ozone on the storage life of chilled meat. The experiments described in Part I were designed to provide fundamental data for the establishment of the experimental conditions in the storage experiments, especially in relation to the control of the generation of ozone and the maintenance of desired ozone levels in the reaction system.

Experiments on the decomposition of ozone were carried out in glass desiccators in which the temperature and relative humidity of the air were kept constant. In the absence of meat, the slow rate of breakdown of ozone agreed with monomolecular law. The velocity constant of the reaction depended upon the maximum ozone concentration to which the grease (silicone "DC4 Compound") used in the desiccators had been exposed.

When slices of lean beef about 1 mm thick were introduced into the desiccators, the rate of breakdown of ozone was greatly increased. The rate of decomposition of ozone by the meat was in fairly close agreement with the monomolecular law. With a constant ozone concentration maintained continuously the logarithm of the rate of reaction with the meat decreased linearly with time.

THE ALKALI-CATALYSED ISOMERIZATION OF UNSATURATED COMPOUNDS. *J. B. Davenport, A. J. Birch*, and A. J. Ryan*. Chem. & Ind.* ***1956****: 136–7 (1956).*

STUDIES IN THE NATURAL COATING OF APPLES. III. SATURATED ACIDS OF THE CUTICLE OIL. *J. B. Davenport. Aust. J. Chem. 9: 416–9 (1956).*

Parts I and II of this series (for abstracts see *C.S.I.R.O. Food Pres. Quart.* **12**: 19–20)

* Department of Organic Chemistry, University of Sydney.

described four fractions: oil, wax, ursolic acid, and "cutin" occurring in the natural coating of Granny Smith apples and discussed the changes in these fractions during storage. The oil fraction increases to 3–4 times its original concentration on the fresh fruit during storage and this change is accompanied by increased resistance of the skin to gaseous diffusion. Because of the importance of this effect in storage, a detailed chemical investigation of the oil has been undertaken. The saturated acids, making up 10·3 per cent. of the cuticle oil, were found to consist principally of stearic and arachidic acids, with smaller amounts of palmitic acid, behenic acid, and acids of higher molecular weight than behenic acid.

STUDIES ON BEEF QUALITY. Parts I–III. *A. Howard and R. A. Lawrie. C.S.I.R.O. Aust. Div. Food Pres. Transp. Tech. Pap. No. 2 (1956).*

I. THE EFFECT OF BLAST-FREEZING HOT BEEF QUARTERS

Although it is normal slaughterhouse practice in Australia to cool beef at —0·5 to 1·5°C for 1–3 days before placing it in the freezing chambers, there has been a tendency in commercial practice recently to accelerate the freezing of carcass meat. These experiments investigate the influence on quality of blast-freezing hot beef quarters while the post-mortem break down processes were still taking place.

Paired beef quarters from 18 carcasses were used to compare the relative effects on palatability and on "drip" during thawing, of blast-freezing without prior chilling, and of chilling and freezing in the normal commercial manner.

It proved impossible in a blast tunnel at —35°C and an air speed of 250 ft/min to cool the beef quarters at a sufficiently high rate to freeze them before the onset of rigor mortis, and thus there was no excessive "drip" on thawing. On the contrary there was some suggestion that the drip from the blast-frozen beef was lower, especially when, during ancillary experiments, the onset of rigor mortis was delayed by certain pre-slaughter injections.

The overall percentage weight loss from before freezing until after 20 weeks' storage at —10°C was considerably less in the blast-frozen beef quarters.

The blast-frozen beef was significantly less palatable. It was generally less acceptable and, in particular, less tender than that chilled and frozen by normal commercial practice.

II. PHYSIOLOGICAL AND BIOCHEMICAL EFFECTS OF VARIOUS PRE-SLAUGHTER TREATMENTS

An examination has been made of the effects of induced pre-slaughter conditions on the development of rigor mortis and on its associated biochemical changes in the muscles of beef steers.

The general biochemical characteristics of beef muscle were found to be similar to those of other species such as the rabbit. On the other hand, contrary to their effect on the muscles of the animals hitherto studied in such experiments, neither fasting nor enforced exercise alone depleted muscle glycogen reserves sufficiently to raise the ultimate pH of the musculature above normal values, although a combination of fasting and exercise appeared to do so. This finding may be partly attributed to the considerable magnitude of these reserves in beef muscle, but the present investigation has suggested that other biochemical factors peculiar to ruminant muscles may be implicated.

Of the applied treatments, the most striking were relaxation associated with severe hypermagnesaemia, and hypercalcaemia, which respectively slowed down and accelerated the onset of rigor mortis with its associated biochemical changes and insulin-induced convulsions which virtually depleted muscle glycogen reserves.

Evidence of a considerable depletion of glycogen reserves from the muscles of certain control steers in the absence of fasting or fatigue has been provisionally attributed to an inherent "excitability" in the animals concerned. Attempts to identify the cause and to control the incidence of this excitability by the pre-slaughter administration of thyroxin, thyroid extract, methylthiouracil, and adrenalin proved ineffective.

III. INFLUENCE OF VARIOUS PRE-SLAUGHTER TREATMENTS ON WEIGHT LOSSES AND EATING QUALITY OF BEEF CARCASSES

Data on the weight losses from carcasses during freezing and holding in frozen storage, thawing as quarters, and holding as butchers' cuts, and on the criteria of eating quality before and after storage, have been examined to determine the influence of a number of treatments given to the animals before slaughter.

Though a number of these treatments had had pronounced biochemical effects, the only treatment which had outstanding effects on weight losses and eating quality was the production of tetany by injection of a massive dose of insulin. This produced a carcass with pH approximating that *in vivo*, and the meat gave low values for laboratory drip. The eating quality was seriously affected, the meat being dark, poor in flavour, and with an unattractive texture. There was some evidence suggesting that where, either naturally or by treatment, the pH of the musculature in rigor mortis is raised above the normal value for well-fed, rested animals, this is reflected in decreased laboratory drip and general eating quality. The implications of this suggestion are discussed.

Sufficient evidence was obtained to indicate that treatments which delayed removal of adenosinetriphosphate (ATP) in the development of rigor mortis also affected moisture losses and eating quality; this aspect warrants further study.

Incidentally to the study of the effects of the applied treatments it was demonstrated that meat which had been chilled for a short period at low temperature was superior to stored frozen meat in juiciness and intensity of flavour and possibly of odour. This effect on frozen meat is interpreted as an effect of storage rather than of freezing.

Copies of the 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.)

FOOD SCIENCE ABSTRACTS

Abstracts in this section have been taken from Food Science Abstracts *with the kind permission of the Controller of Her Majesty's Stationery Office, London.*

PROPOSED NEW METHOD OF WHOLESALING FRESH MEAT, BASED ON PASTEURIZATION BY GAMMA IRRADIATION. *L. E. Brownell, J. V. Nehemias, and J. J. Bulmer. U.S. Atomic Energy Comm., Tech. Inform. Serv., Industr. Inform. Br., TID–8001,* 7 pp. *(1955).*

The procedure proposed for consideration by packing-houses and retailers depends on the use of radiation pasteurization to extend the refrigerated shelf-life of fresh meat. Standard cuts of fresh meat, fresh minced meat, cut-up chicken, etc. would be prepared and packaged in retail-size portions in the packing-house, and pasteurized by means of a relatively small dose of γ-radiation before dispatching to the retailer. The advantages of this method to the packing-house, retailer, and consumer are listed. The benefits of the procedure from the public health standpoint are indicated, and microbiological and taste panel studies are summarized.

FACILITY DESIGN UTILIZING GAMMA RADIATION FOR MEAT PASTEURIZATION. *L. E. Brownell, J. J. Bulmer, and J. V. Nehemias. U.S. Atomic Energy Comm., Tech. Inform. Serv., Industr. Inform. Br., TID–8002, 13 pp. (1956).*

In the publication referred to in the preceeding abstract it is shown that the refrigerated storage life of pre-packaged cuts of fresh meat might be increased by γ-irradiation. A proposed installation is described, using ^{137}Cs or ^{60}Co as source, capable of treating 14 tons of meat per hour, and of pasteurizing meat at a cost of 0·5 to 1 cent per lb. Taste tests and feeding trials with rats have not disclosed any undesirable flavours or toxic properties in meat so treated. The parasites in meat that are responsible for trichinosis and other diseases would be destroyed by irradiation.

RADIOISOTOPE UPTAKE IN MARINE ORGANISMS, WITH SPECIAL REFERENCE TO THE PASSAGE OF SUCH ISOTOPES AS ARE LIBERATED FROM ATOMIC WEAPONS THROUGH FOOD CHAINS LEADING TO ORGANISMS UTILIZED AS FOOD BY MAN. *R. W. Hiatt, H. Boroughs, S. J. Townsley, and G. Kau. U.S. Atomic Energy Comm., Tech. Inform. Serv., Oak Ridge, Tennessee, AECO–3079, Rep. 1954–1955, Hawaii Marine Lab., Univ. Hawaii, Honolulu, 46* pp. (*1955*).

About 98 per cent. of an oral dose of ^{89}Sr was eliminated by tunny fish in 24 hours, and about 95 per cent. by Tilapia in 4 days; after these periods, the rate of elimination became very slow. Of the ^{89}Sr remaining after the period of rapid elimination, 95 per cent. was present in structural tissues (skin, muscle, opercular bones, and skeleton). Cartilage may have a greater affinity for strontium than ossified tissue; ^{89}Sr accumulated in the hyaline cartilage of the eyes of the fish. Accumulation of strontium in the scales increased with time. The half-life of ^{89}Sr in structural tissues was probably more than 1 year; the biological half-life in internal organs of tunny was less than 24 hours, the period of retention diminishing with increase of vascularity of the organ. The amount of ^{89}Sr in a tunny could be predicted from external determinations of radioactivity in the caudal fin.

PRE-COOKED FROZEN FOODS. A SYMPOSIUM SPONSORED BY THE QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES, QUARTERMASTER RESEARCH AND DEVELOPMENT COMMAND, U.S. ARMY QUARTERMASTER CORPS, CHICAGO, *1954. Adv. Bd. Quartermaster Res. Dev. Cttee. Foods, Nat. Acad. Sci-Nat. Res. Counc., Washington, 76 pp.* (*1955*).

The papers contributed to the symposium were as follows: I. Introduction: scope and purpose of the symposium, by D. K. Tressler. II. Pre-cooked Frozen Foods in Use: pre-cooked frozen food research in the Air Force in-flight feeding programme, by E. L. Robertson; pre-cooked frozen food research by the Navy, by A. C. Avery; use of pre-cooked frozen products in hotels, restaurants, and railroad dining cars, by P. P. Logan. III. Preparation and Processing: pre-cooked frozen meat products, by G. E. Vail; texture stability in frozen sauces, gravies, and other foods, by H. Hanson; frozen cooked rice, by E. B. Kester and M. M. Boggs; the nutritive value of pre-cooked frozen foods, by F. Fenton; monosodium glutamate and food flavours, by D. R. Peryam. IV. Quality Control and Stability: use of anti-oxidants in pre-cooked frozen foods, by H. R. Kraybill; use of quality control programmes, by C. F. Evers: keeping quality during storage of pre-cooked frozen foods, by J. G. Woodroof and E. Shelor. V. Microbiological Aspects: need for sanitation standards in production and processing, by M. F. Gunderson; current microbiological standards of quality for pre-cooked frozen foods and their basis, by M. M. Rayman, D. A. Huber, and H. Zaborowski; what can be expected of temperature indicators, by Z. I. Kertesz.