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C.A. Storage of Citrus Fruit

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Although controlled-atmosphere (C.A.) storage of apples and pears has been investigated for almost half a century, and is now widely practised commercially, interest in the response of citrus fruits to storage under modified atmospheres has been less marked and the reported results have been variable. While some workers have claimed that C.A. storage of citrus has increased retention of flavour and reduced the incidence of rind pitting, others have reported increased levels of fungal wastage and/or rind damage. It is also apparent from these reports that different species of citrus vary in their responses to C.A. storage and an atmosphere most suitable for one will not be so for another.

C.A. storage implies storage in an atmosphere containing more carbon dioxide and less oxygen than air. Methods of atmosphere control were reviewed by Hall (1968), who emphasized that operation of a C.A. store required cool rooms with a high degree of gas-tightness. Speakers at an Extension School at Orange, N.S.W., in 1969 (Anon. 1969) also discussed C.A. storage techniques.

Some experimental work on C.A. storage of oranges was carried out in Australia some years ago but the results were not encouraging (Huelin 1942). This work was part of comprehensive cooperative investigations on the handling and storage of citrus fruits in New South Wales, Victoria, and South Australia carried out before the 1939–45 war. The C.A. conditions studied did not affect storage wastage to any great extent but did generally produce 'off-flavour' in the fruit. Investigations on C.A. storage of several varieties of citrus fruit have been reported recently by research workers of the United States Department of Agriculture at the Horticultural Field Station, Orlando, Florida. As citrus production in Florida increases, extension of the marketing season of some varieties has become more desirable and there is increasing interest in storage.

Specific Citrus Varieties

Oranges

C.A. storage appears more promising for Valencia oranges than for other citrus fruits in Florida. In the 1966 and 1967 seasons, Valencia oranges were stored at Orlando at 34°F in atmospheres comprising 5, 10, or 15% O_2 in combination with 0, 2·5, or 5% CO_2 (Chace 1969; Chace, Davis, and Smoot 1967). After 12 and 16 weeks' storage, oranges were rated for flavour by a panel of observers. Oranges held in 15% O_2–0% CO_2 for 12 weeks at 34°F had a higher flavour rating than similar fruit held in other controlled atmospheres or in air. In most instances the flavour rating was reduced when the CO_2 concentration was increased.

Pitting (cold injury) tended to be reduced by reducing the O_2 levels in the air (Chace, Davis, and Smoot 1967). Signs of fruit aging, however, were absent on oranges cool-stored in air, but became a serious problem in C.A. storage.

Smoot (1969) reported that no combination of O_2 and CO_2 tested at Orlando prevented fungal decay in fruits stored in various controlled atmospheres. There was some reduction in wastage in Valencia oranges stored at 34°F for 12 and 16 weeks in 15% O_2–0% CO_2 and in 10% O_2–0% CO_2 compared with storage in air. Chace (1969) concluded, however, that maturity of fruit, variability from year to year, and length of storage were factors that influenced the incidence of decay more than the composition of the storage atmosphere. He reported that the determination of the optimum time for harvest was critical if decay losses were to be kept to a minimum. In his storage experiments, fruit harvested at near optimum maturity and stored for 12 weeks developed slightly less wastage than more mature fruit held for only 8 weeks. Smoot (1969) showed that greater amounts of decay (caused by *Penicillium*, *Phomopsis*, and other fungi) developed in Valencias harvested in May and stored for 16 weeks at 34°F than in fruit picked from the same trees in April and similarly stored.

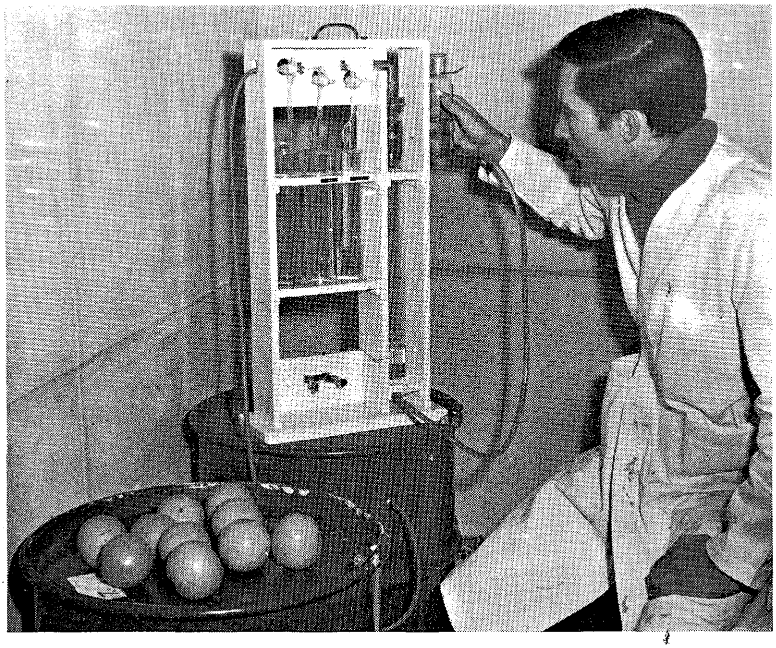
Because of recent revived interest by the Australian Citrus Growers' Federation and other industry groups in the storage of late-picked Valencia oranges, a preliminary co-operative investigation by the N.S.W. Department of Agriculture and the Division has been commenced this season. Valencia oranges supplied by growers from the central coastal districts of New South Wales and from the Murray Irrigation Area have been stored at North Ryde at 41°F, both in air and in controlled atmospheres.

The benefits of long storage for Valencia oranges under Australian conditions, however, are likely to be marginal in most seasons. In districts producing fruit late in the season, Valencia fruit, particularly clonal selections in the Murray River areas, often hangs well on the tree with only slow loss of quality. The Valencia harvest often extends into March or the beginning of the Washington Navel season. Even oranges harvested at optimum maturity could be expected to retain high quality in cool storage for approximately three months only. The higher returns for this good-quality fruit may not offset the additional costs of handling and storage.

The availability of citrus fruit in Australia for almost the whole of the year contrasts with the citrus seasons in Florida where the Valencia harvest is completed by July and further fruit is not available until early-season varieties mature in September–October. Therefore, in the U.S.A. there is an additional incentive to store Valencia oranges for marketing in this period.

Grapefruit

Scholz, Johnson, and Buford (1960) carried out some laboratory-scale experiments on the storage of Texas Red grapefruit in modified atmospheres. C.A. increased decay but surface pitting was considerably reduced at low levels of oxygen. They suggested that 0% CO_2 and 3% O_2 at 45°F was promising for fruit given an effective mould control treatment. From Florida, Chace, Davis, and Smoot (1967) reported that Marsh grapefruit retained high flavour ratings after 8 weeks' storage in 15% O_2–0% CO_2 and 2·5% O_2–5% CO_2 at 50°F, but excessive fungal decay developed in all samples stored longer than 6–8 weeks.



Using an Orsat gas analysis apparatus to measure CO_2 and O_2 in drums used for experimental C.A. storage.

Marsh grapefruit harvested in late June and again in late August in 1969 at Griffith, N.S.W., were stored at 50°F in air and also in a modified atmosphere of approximately 16% O_2–2·5% CO_2 under a polyethylene tent. Fruit from the first harvest was stored 20 weeks, but excessive fungal wastage occurred, even in fruit treated with 500 p.p.m. benomyl and 500 p.p.m. 2,4-dichlorophenoxyacetic acid. The fruit commonly rotted from the stem end, from which *Fusarium* sp. was isolated (T. B. Kiely, personal communication). Grapefruit from the second pick, stored for 12 weeks, developed little decay in all samples, including those not treated with a fungicide. The palatability of the latter fruit from air and C.A. storage was compared by a panel of 80 observers with that of freshly picked grapefruit from the same trees. While 75% of judges rated the stored fruit as acceptable, the fresh fruit which had remained on the trees until late November scored significantly higher flavour ratings and was preferred by a majority of the members of the taste test panel.

Lemons

From the Citrus Experiment Station, Lake Alfred, Florida, Grierson *et al.* (1966) reported that low O_2 levels were promising for extending the storage life of lemons from Florida and California but suggested that CO_2 levels should be kept near zero to avoid increased decay. They suggested an atmosphere of 0% CO_2–6% O_2 at 50°F.

In Australia, lemons grown on the coast have been stored successfully in air for 5–6 months (Long *et al.*, personal communication), provided that the fruit was treated with fungicides before storage to reduce development of wastage. Storage of lemons under Australian conditions is likely to be profitable only in seasons when the summer crop is light.

Mandarins and Related Hybrids

C.A. storage has not shown real promise for extended storage of mandarins and related citrus fruits (Temple oranges, Orlando tangelos) in Florida. There has been little interest in storage of mandarins in Australia.

Limes

Salama, Grierson, and Oberbacher (1966) found that any modification of the storage atmosphere increased decay in Florida limes so that C.A. storage was always damaging to this citrus fruit.

Conclusions

Research in Florida has indicated that C.A. storage shows more promise for extending the marketing season of Valencia oranges than other varieties of citrus. At present in Australia, the evidence of possible benefits would not justify commercial trials.

Further studies have been begun on the response of Australian citrus fruit to controlled atmospheres, particularly effects of volatiles on development of off-flavours. However, storage of oranges for longer than 4–6 weeks is likely to be profitable only in seasons when fresh fruit is either not available or of poor quality. For such short periods normal cool storage in air is quite satisfactory for fruit that has been correctly selected and prepared.

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The Australian Prawn Industry

II. Quality aspects for export prawns

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Although 16·4 M lb of frozen headed prawns, valued at $7·64 M, were exported in 1969, there exist deficiencies in both technology of handling and knowledge of eating quality. This paper presents taste-panel and chemical tests for quality in the export pack and also the results of a survey of the salt content of export prawns and prawns on sale in Sydney.

Present handling practices in the Gulf of Carpentaria may result in an increase in the salt content of prawns from 0·4% to 7%; at this level texture is irreversibly toughened. Thus, a maximum of 2·5% salt has been specified for the export pack. Our results show that taste testing would provide a useful tool for quality control in the processing plant.

An earlier paper (Montgomery, Sidhu, and Vale 1970) described the resources of prawns available for local consumption and export, their characteristics, and the methods used for quality evaluation of prawns sold in the national markets. Australia's production for export is predominantly of the larger-sized prawns, grading 10–15, 16–20, and not exceeding 30 per lb. Since a large proportion of this production comes from the Gulf of Carpentaria and from New Guinea and Gulf of Papua waters of latitudes between 8 and 17°S., a tropical region with a year-round temperature averaging 26°C, a severe restriction is imposed on the time that should elapse between catching, placing in cool storage, and processing at the shore plant before freezing. This restriction, together with the advantages associated with self-contained refrigeration aboard the fishing vessel, has resulted in the large-scale replacement of ice for cooling. The trend is for vessels to be converted to mechanical refrigeration, with increased emphasis on freezing the catch at sea (Montgomery and Sidhu 1968).

Only the larger prawn-fishing vessels 50 ft or more in length are able to accommodate the installations required for pre-freezing storage, freezing, and subsequent frozen storage. Pre-freezing storage is carried out in refrigerated sea-water (R.S.W.) tanks, usually constructed of stainless steel with capacities from 3500 lb of prawns upwards. Freezing is most often carried out in brine-freezing units employing a saturated salt solution (limiting temperatures −21°C) or sometimes the more expensive sugar–salt–glucose medium in which a slightly lower temperature (−23°C) is attained.

Limitations on space and time required for freezing generally preclude blast freezing in Australian prawning vessels but plate freezers have been installed in some vessels. Capacities of brine-freezing units vary from 80 lb per hr up and holds for frozen storage from 40,000 lb. The temperature of the freezer hold should preferably be −20°C. In practice, there is a tendency to overload the refrigeration capacity of both the freezer and storage hold, especially when the catches are heavy. Consequently, temperatures in the storage hold may fluctuate from −20°C to just below 0°C. These conditions cause rapid deterioration in quality and development of black spot.

Preservation by Superchilling

Superchilling has now emerged as a practicable procedure for preserving fatty fish such as salmon in an acceptable condition for longer periods than are possible with normal icing methods (Roach *et al.* 1967). The fish are kept at −3 to −4°C in a quasi-frozen condition by raising the salt concentration in R.S.W. to 5–7%. For fatty fish containing 5–20% fat, excessive salt uptake has not resulted in serious quality deterioration; however, the application of superchill to prawns with a fat content of 0·4% poses problems of salt penetration and associated textural and biochemical changes.

Smaller vessels, 30 ft or so in length, are unable to accommodate the freezing and frozen-storage facilities, so R.S.W. holding tanks have been installed to which additional salt may be added according to the projected time at sea. This produces effective superchill conditions in the R.S.W. holding tanks. Although addition of 3–4% salt to sea-water is all that is required for superchilling, a concentration of 17% salt has been found in some R.S.W. tanks on board fishing vessels operating in the Gulf of Carpentaria. A salt content of 7–8% can be expected in prawns stored in such conditions.

Salt uptake from R.S.W. is faster in prawns that have had the head and intestinal tract removed than it is in intact prawns. Heading at sea is not common at present in Australian waters but may be used to make more storage space available when catches are heavy.

Exposure of whole or headed prawns to high salt concentrations may also occur at the shore processing plant where chilled prawns are held in R.S.W. or superchilled sea-water before processing. This exposure time is short, however, compared with 3–3½ days required for equilibration of the salt in brine solutions containing prawns; salt uptake would not be appreciable unless an excessive concentration was used in the superchilling tank.

Substantial physical and chemical changes occur in prawns held in R.S.W.; salt and water are taken up and soluble protein and minerals are lost to the sea-water. After storage for 11 days, shrimp lose 25% of their original weight of solids and gain about 6% in overall weight from salt and water uptake (Seagran, Collins, and Iverson 1960). The salt uptake by prawns is more rapid and the total absorbed is higher as the salt concentration of the brine increases and the prawn to sea-water ratio increases.

In practice, a ratio of whole prawns to R.S.W. of 1:1 would probably result in a concentration of 1·5% salt in prawns after 3–3½ days' storage, whereas there would be 3% salt in prawns held in superchilled (6% salt) sea-water for the same time. Uptake of substantial amounts of salt then ceases. Since the proposed maximum salt concentration is 2·5%, the prawn to superchilled sea-water ratio should be more than 1:1; we suggest a ratio of 2:1 or 3:1 if more than two days' storage in superchilled sea-water is planned.

Thus in the smaller vessel where prawns are held for transport in R.S.W. tanks, the salt content of the prawns arriving at the processing plant will depend on the concentration of salt in the R.S.W. tank, the prawn to R.S.W. ratio, the time and temperature of holding, and whether the prawns have been headed before immersion.

Glazing and Salt Uptake

Prawns for export are packed by hand in 5-lb blocks, 10½ in. × 7 in. × 2 in., in aluminium moulds, flooded with cold fresh water, and frozen. On removal from the freezer the blocks are freed from the mould, dipped in fresh water at 0°C to complete the glaze, packed, and placed in frozen storage at −18°C. Sometimes it has been assumed that salty prawns could have obtained their salt from sea-water used as a glaze, but this is not so. A maximum concentration of 1% salt could be expected in the pack when the ratio of glazing sea-water to prawns was 1:5 and the prawns did not take up salt from any other source. In general, prawn processing specifications prescribe potable water for glazing purposes; this definition precludes the use of sea-water and in most cases bore water. Australian prawn processing plants, as a prerequisite for registration, must have access to supplies of fresh potable water and have facilities for chlorinating it before use.

Brine Freezing and Salt Uptake

Salt uptake can be kept below 1% by using the brine-freezing procedures described by Dassow (1954) and Aldrin (1967) in which a fresh-water rinse is used before and after brine freezing.

Prawns in perforated baskets of 50 lb capacity are given a preliminary dip in chilled fresh water and frozen in a brine spray or circulating saturated salt solution (23·3% salt, 88·6° Sal) between −21°C and −17°C. When fully frozen they are glazed by rinsing again in fresh water at 0°C. The second rinse removes salt deposited by the brine and coats the prawns with an adherent fresh-water glaze. The frozen prawns are then stored at −20°C.

The total salt content of prawns is not likely to exceed 1–1·5% when freezing periods are less than one hour. Twenty-four hours' immersion was required to produce a salt content of 2·5% in shrimp frozen at sea immediately after catching (Dassow 1954). A salt content of 5·72% was observed during the present investigation for brine-frozen prawns landed at Townsville (Table 7). These prawns had, however, an initial concentration of 5·12% before brine freezing. The high concentration of salt was induced by prolonged storage in superchilled sea-water containing an excessive amount of salt.

Brine-frozen prawns are thawed in fresh running water at the processing plant so that they can be handled while being headed. During thawing and washing the salt content is reduced to such low levels that saltiness has not been a problem. If, however, the prawns contained 7–8% salt at any time after being caught they would have a very tough texture, irrespective of whether they were subsequently washed or not, and would not be acceptable for export or local consumption. Salt concentrations of 7–8% are not normally reached during brine freezing of freshly caught prawns but could result after prolonged storage in strong refrigerated brines when followed by brine freezing.

Prawns grading 21–25 per lb require from 10 to 20 min immersion in brine at −17°C to be fully frozen. The freezing rate is thus much faster than it is in still air, but the quantity frozen is limited by the brine tank reserve (volume of brine) and the refrigeration capacity of the compressor, both of which are limited on small vessels. As a result continuous throughput is not possible. Calculations show that the usual 5½-ton refrigeration unit installed on small vessels can freeze about 400 lb of prawns per hr when employed for freezing only. Usually the refrigeration unit, in addition, must supply refrigeration for the frozen storage hold, and consequently throughput would be reduced. Under these circumstances a production of 80–160 lb of frozen prawns per hour is practicable.

Quality Control for Export

The processor of frozen prawns for export should apply quality control tests to ensure that his product is not excessively salty and that it does not suffer from iodoform taint, foreign or objectionable flavours, or textural defects of toughness or mushiness (softness). The use of organoleptic tests in quality control is illustrated in Table 1 and the detection of saltiness and tough texture in Tables 2 and 3. Quality assurance is

Table 1
Tasters Score Form

Booth No. **Date** **Time** **Name**

Product Prawns fried in batter, curried, and in sauce

We would like to know what you think of these products made from banana prawns. Please check appropriate remark to show how much you like or dislike the texture and flavour and give reasons

Texture	Sample A	Sample B	Sample C	Flavour	Sample A	Sample B	Sample C	
Like extremely				Like extremely				9
Like very much				Like very much				8
Like moderately				Like moderately				7
Like very slightly				Like very slightly				6
Neither like nor dislike				Neither like nor dislike				5
Dislike very slightly				Dislike very slightly				4
Dislike moderately				Dislike moderately				3
Dislike strongly				Dislike strongly				2
Dislike extremely				Dislike extremely				1

Table 2
Taste Test Rating for Export Prawns
Mean score (9 judges) and standard error

	Texture			Flavour		
Test 1	(*a*) In batter	(*b*) Fried only		(*a*) In batter	(*b*) Fried only	
Mean score	8·4	7·9		8·5	7·9	
S.E.	±0·24	±0·38		±0·17	±0·38	
D.F. = 8						
Test 2	(*a*) In batter	(*c*) Curried	(*d*) In sauce	(*a*) In batter	(*c*) Curried	(*d*) In sauce
Mean score	8·7	8·2	8·4	8·9	8·6	8·8
S.E. (D.F.)	±0·21(9)	0·25(7)	0·4(4)	0·10(9)	0·13(7)	0·20(4)

afforded by the inspection system of the Commonwealth Government operating under the Fish Exports Regulations of the Department of Primary Industry. The Commonwealth regulations limit the salt content of export prawns but the regulations of the principal importing countries do not. Foreign and local regulations are concerned mainly, but not exclusively, with such attributes as colour, appearance of the pack, labelling, count per pound, net weight, and inclusion of foreign material; all of these are characteristics that could be used by the unscrupulous to deceive or mislead customers. Flavour and texture are more difficult to measure but are equally important; a numerical expression on a hedonic scale is demonstrated in the taste test form in Table 1.

Quality Test Results

Assessments of organoleptic quality were made in the Division's Taste Test Laboratory under standard conditions. Quantitative measurements of salt contents were made by Method 18.009 of the Association of Official Agricultural Chemists (1965).

Table 3
Salt Content, Texture, and Flavour in Random Sampled Export Prawns

Salt content (%)	2·86	2·47	7·17
Taste Test		Texture	
Mean score	6·9	7·6	2·3
S.E. (mean) (18 D.F.)	±0·27		
S.E. (diff. means)	±0·38		
		Flavour	
Mean score	7·0	7·9	3·2
S.E. (mean) (18 D.F.)	±0·40		
S.E. (diff. means)	±0·57		

Organoleptic Quality.—A panel of nine tasters was asked to rate on a hedonic scale the flavour and texture of samples from a normal production run of banana prawns from the Gulf of Carpentaria. The samples, 5-lb blocks of glazed banana prawns (*Penaeus merguiensis*) grading 11–15 per lb, were shipped frozen and stored at $-20°C$ on arrival at the laboratory. The prawns were thawed in plastic bags in flowing water at 15·5°C. The shell and intestinal tract were removed, leaving the tail intact. Test 1 (Table 2) was performed on prawns fried after being dipped in batter and rolled in bread crumbs, also on prawns without batter fried in vegetable oil. The batter consisted of flour, skim-milk powder, egg powder, salt, and monosodium glutamate. Test 2, in addition, included prawns prepared in a curry, and others in a savoury sauce recommended for this type of product.

The mean score and standard error of the mean for the tasting tests are recorded in Table 2 which shows that the tasters found no defects in the samples presented, the rating of more than 8 for both texture and flavour indicating a very high degree of acceptability. There were no adverse comments.

Objective Tests

Objective tests for quality on the pack presented in Table 2 included total bacterial count; 5000 organisms per g by standard plate count method, incubated for 24 and 48 hr at 37°, was set as the limit; *E. coli* count, (MPN) nil per 100 g; trimethylamine nil and total volatile bases less than 7 mg N per 100 g. These tests indicate that negligible bacterial spoilage had occurred during processing and the product was of high quality.

Salt in Local and Export Prawns

Although initial testing showed no obvious defects, further tests were conducted on the basis of complaints received about the general quality of the export prawns. The complaints concerned excess saltiness, extreme toughness, and a tendency for the prawns to disintegrate when cooked in boiling 3% salt solution (a procedure similar to normal cooking used for quality assessment tests).

Three of 12 cartons of prawns taken at random from stocks at a processing plant near the Gulf of Carpentaria contained prawns that were extremely salty (7·17, 7·32, and 7·36% salt) and were caught by one fishing vessel. The extreme saltiness was accompanied in each case by a tough and rubbery texture. All the tasters were in agreement and all declared the product unacceptable. Considerable amounts of muscle protein exuded from the body of the prawns as they were boiled in the salt solution. When prawns were thawed in contact with fresh water for 2 hr their salt level decreased but the toughness remained. All the samples tested had been in frozen storage at −18°C for 14 days. The results of organoleptic tests on three of the samples containing 2·86, 2·47, and 7·17% salt are presented in Table 3, using nine tasters, the prawns being prepared in batter in the same way as in the previous tasting test (Table 2).

The results in Table 3 show that untrained tasters are readily able to differentiate between prawns of high and low salt content and tough and normal texture. A comparison of Tables 2 and 3 shows a reproducibility in flavour and texture characteristics for good-quality prawns from the Gulf of Carpentaria. The tasters' scores for differences between salt contents of 2·87 and 2·47 are not significant ($P = 0 \cdot 05$); the difference between the scores for these and for a salt content of 7·17 is significant ($P < 0 \cdot 001$). We conclude that taste tests would be a useful adjunct to quality control at the prawn processing plant.

Salt Content and Consumer Acceptance

The relation of salt content to consumer acceptance of prawns is illustrated by the results (Table 4) of taste tests done on two samples of frozen tiger prawns processed near the Gulf of Carpentaria. Sample A contained 2·61% salt and sample B 3·38% salt; after washing for 1 hr in fresh running water the salt content was reduced to 1·82% and 2·15% respectively. The prawns thawed with and without washing were submitted to a panel of 10 tasters for an assessment of saltiness, after being cooked for 5 min in boiling 3% salt solution. The scoring scale was: insufficient salt (score 1); right amount of salt (score 2); moderately salty (score 3); highly salty (score 4). The results are summarized in Table 4.

Table 4
Tasting Test Scores for Saltiness in Tiger Prawns

Treatment	Sample A Salt Content (% peeled wt.)	Sample A Mean Score	Sample B Salt Content (% peeled wt.)	Sample B Mean Score
Thawed in air	2·61		3·38	
After cooking	2·20	2·60	2·32	2·90*
Thawed in water	1·82		2·15	
After cooking	1·59	2·65	1·85	1·90*
S.E. of mean ±0·26, 27 D.F.				

* These differences were significant ($P = 0 \cdot 05$).

The results of the organoleptic tests for saltiness showed that 80% of the tasters judged prawns containing 1·59, 2·20, and 2·32% salt to be acceptable. The mean scores for these three salt levels were 2·65, 2·60, and 2·90 respectively. Half the tasters judged prawns of salt content 1·85% to be insufficiently salty, but were probably influenced in their judgment of this sample by its somewhat insipid flavour. No instances of toughness were reported.

Effect of Cooking on Salt Content

The concentration of salt in prawns is altered by the method of cooking; cooking in oil increases the salt by evaporating water, and cooking in boiling 3% brine causes an increase or decrease depending on the initial salt concentration in the prawns. Table 5 illustrates this effect on prawns of a high and low initial salt content.

It is apparent from Table 5 that for prawns containing 2·5% salt, cooking in oil raises the salt concentration to an unacceptably high level. Repeated tasting of prawns the concentration to that of sea-water. Heading the prawns on board has been prohibited under State Fisheries legislation for some time in Western Australia, so that there has been less risk of a high salt content in the prawns processed in that State.

Conclusion

The primary purposes of the present study were to characterize the eating quality of prawns from the Gulf of Carpentaria by reference to the use of a taste panel and to resolve the effects of salt content on quality.

Normal prawns taken fresh from the sea have a salt content of approximately 0·45% and a water content of 78%; the figures for frozen tails are very similar, with a salt content of 0·41% and of water 77·5%. The fat content (without ova), as determined by ether extraction, is comparatively low at 0·4–0·7%. Aldrin (1967) found that shrimp caught near the Ivory Coast contained 0·43% salt, 76·29% water, and 0·81% fat. As a consequence of the low fat content and the absence of a subcutaneous layer of fatty tissue there is little to retard salt exchange with external solutions, and rapid loss or uptake of salt takes place when prawns are immersed in water or brine solutions. The practical significance of the high permeability of prawns to salt penetration is that prawns stored for 3–3½ days in superchilled (6% salt) sea-water in 1:1 ratio will exceed the proposed limit of 2·5% salt. If stored in stronger brines a higher content of salt could be expected. To reduce the salt content the alternatives are to use a higher prawn to brine ratio, to reduce the salt concentration, or to wash the prawns in fresh water on arrival at the shore plant.

A considerable proportion of the prawn catch is now brine-frozen on board the fishing vessel and stored in freezer holds until delivery at the shore plant. Brine freezing contributes little to the salt content of the catch, provided fresh-water washes are used before and after brine freezing. Aldrin (1967) found that the salt contents of prawns increased from 0·43% to 0·99% for whole prawns and to 1·00% for headed prawns during brine freezing at −16°C using fresh-water immersions.

Brine-frozen prawns are thawed in fresh water at the shore processing plant before heading, packaging, and freezing. Rapid leaching of the contained salt occurs and such prawns are unlikely to exceed acceptable salt levels. Our investigations did not include the assessment of quality changes in prawns that had been brine-frozen, thawed in fresh water, and re-frozen, but Dassow (1954) noticed no deleterious effect. If, however, pre-storage in strong brines caused a salt content of 7% in the prawns or a combination of pre-storage conditions and brine freezing raised the salt to this level, a permanently tough texture would result. The toughness is not removed by washing. It is probable that the texture change occurs at a 5% salt level.

A salt content of 2–2·5% in prawns appears to be acceptable according to taste-panel assessments, and salt contents of this order are found in prawns retailed in the Sydney area. However, prawns originally containing 2·5% salt, if cooked in edible oil or broiled, would probably contain over 3·5% salt and would not be acceptable.

Freezing prawns in still air or in plate or air-blast freezers would avoid the problem of high salt uptakes and deterioration of texture; however, freezing would be slower and care would be needed to preserve the product from desiccation.

Acknowledgment

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Fruit Cool Stores — The Insulated Structure

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If part of a crop is to be available out of season and if orderly marketing is to be maintained, it is essential to have means of storing produce so as to retain as much as possible of its original quality. Storage of fruit at low temperatures is a major factor in delaying aging; for this purpose an insulated storage building is essential.

A fruit cool store represents a major capital investment, the cost of insulation being one of the significant elements. This article explains the factors affecting the amount of insulation to be used and provides a basis for selection under Australian conditions.

Nomenclature

- t_A, Ambient temperature — *highest* likely average outside temperature over a period of 72 hr (°F)
- t_S, Space temperature — mean temperature of stored produce (°F)
- Δt, Temperature difference, $t_A - t_S$
- Btu, British thermal unit of heat
- Q, Heat leakage rate (Btu/ft^2/hr)
- T, Thickness of insulation (in.)
- k, Heat transfer coefficient (Btu/ft^2/hr/degF/in. thickness)
- U, Overall conductivity (Btu/ft^2/hr/degF)
- R, Resistivity, $1/U$
- f_o, f_i, Outside and inside surface film conductivities (Btu/ft^2/hr/degF)

Introduction

Each year a proportion of the Australian fruit crop goes into long-term storage, the final quality depending on the strict maintenance of optimum conditions throughout storage. Research over many years has shown that the maintenance of certain conditions of storage will result in maximum retention of quality and maximum return to the orchardist.

Many research workers consider that Australian fruit cool stores rarely provide optimum storage conditions and so represent an inefficient investment for the orchardist. Some time ago, a fruit storage research conference (Anon. 1964) concluded that the main problems in the storage of fruit arose from:

- Poor temperature control,
- Serious deficiencies in the design and performance of cool stores.

Orchardists are unlikely to be able to specify their requirements in engineering terms; they have depended on the advice of suppliers and contractors who can only be expected to make proposals in terms designed to meet potential competition. A well-known refrigeration contractor has said, 'a discerning customer is one who can ask the right questions and assess the answers with some knowledge behind him'. Performance guarantees are of little help because the performance of a fruit cool store can be difficult to measure, and measurements may extend over 12 months.

Tindale (1964) reported that cool stores as we know them today first appeared in this country about 80 years ago. Today the capacity of Australian fruit cool stores amounts to 20 million bushels and is steadily increasing.

Apart from a survey by Rostos (1960), little is known of the precise conditions existing in cool stores in practice and of the tolerances that are accepted as normal. Although research has determined optimum conditions of storage for fruit it may be economically impracticable to provide ideal conditions under all circumstances.

One of the difficulties facing the designer of a fruit cool store is that of evaluating the situation so as to be able to provide those inherent conditions that will most nearly meet requirements at minimum cost. There would be no virtue in reducing the allowable variations in temperature to very small proportions, if doing so increased the capital and running costs without any significant improvement in the quality of the fruit or increased return to the orchardist.

System Elements

A fruit cool store comprises the following elements:

- An insulated enclosure.
- Cooling coils to cool the air.
- Fans for moving the cooled air through the fruit.
- Refrigeration plant to cool the produce and to remove the heat produced by respiration of the produce, leakage through the insulation, the fans and lights, people, doors being opened, etc.
- Instruments to monitor conditions.
- Controls to maintain conditions.
- Generators and scrubbers, if controlled-atmosphere (C.A.) storage is used.

When designing a fruit cool storage system it is necessary to consider the effect of the system elements on

- Accuracy of temperature control.
- Uniformity of temperature distribution.
- Maintenance of correct humidity.
- Adequacy of cooling capacity.
- Maintenance of insulation effectiveness.
- Maintenance of a gas seal, if C.A. is used.

There may be interactions between the system elements, e.g. if the cool store is insufficiently insulated additional refrigeration will be required to remove the extra heat entering through the insulation. A larger cooling coil will then be required, and if temperature variations are to be kept within acceptable limits an additional volume of air will have to be circulated. This will result in the use of additional fan horsepower and additional refrigeration to remove the extra fan heat. The effect on the fruit could be an increase of desiccation.

It would be possible on purely economic grounds to balance the cost of additional insulation against the cost of refrigeration, but other factors intervene. The capital cost of the refrigeration plant is determined by its cooling capacity, and this is usually dictated by the need to cool the incoming warm fruit quickly. Hall (unpublished data, 1965) recommended that 'the store should be capable of reducing the temperature of 25 per cent of its total capacity of warm fruit to 40°F at an average rate of three quarters of a degree fahrenheit per hour'. Heat leakage through the insulation is approximately one-quarter to one-third of the heat given off in cooling the fruit, hence a large increase or decrease in the amount of insulation provided will not materially affect the refrigeration *capacity* required.

Refrigeration requirements for long-term storage differ markedly from those for the initial cooling of the fruit. When the fruit is at storage temperature, the main heat gain comes from that entering through the insulation. Refrigeration capacity is not limiting because it is already adequate for cooling the warm fruit. Since a high relative humidity is needed to restrict weight loss in stored fruit, the surface area of the cooling coils must be relatively large because the coils should operate at a temperature close to the storage temperature. This is when the amount of insulation becomes important, as it is desirable to minimize heat leakage through the insulation so that the cooling coils have only to handle little more than the heat of respiration of the fruit itself. This should be accomplished with a minimum of air circulation and fan horsepower and the least variation of temperature within the storage.

Hicks (1959) stated, 'If a store is not well insulated, running costs are excessive and it is very difficult or perhaps impossible to maintain reasonably uniform temperatures in all parts of the stack. This is likely to lead to high evaporative water loss from the fruit.'

Insulation Requirements

The thickness of insulation T to be used is dependent on the following factors:

- The temperature difference Δt between the ambient temperature t_A and the storage temperature t_S.
- The conductivity of the insulating material. (k the heat transfer coefficient is a measure of this.) A material with a low k factor is a good insulant.
- The rate Q at which heat is to be allowed to enter the structure under working conditions.

From Fourier's law, the thickness of insulation in inches required for a heat transfer rate of Q Btu/ft^2/hr when the difference between ambient and space temperatures is

Table 1

Highest Average Temperature* (°F) Likely to Persist for 3 Days Each Month in Orange, N.S.W.

J	F	M	A	M	J	J	A	S	O	N	D
77	76	75	70	60	51	51	57	64	69	73	75

*Average temperature = ½(max. + min.) for each day.

Δt degF and the heat transfer coefficient is k Btu/ft²/hr/degF/in. is given by

$$T = \frac{\Delta t \times k}{Q}.$$

Each factor in this equation will be considered in turn.

Design Temperatures

The procedure outlined in British Standard Code of Practice CP406 (1952) is a satisfactory guide for determining the ambient temperature t_A, namely, 'the highest predictable average over a period of 72 continuous hours'; this varies with the district and time of year. For example, Commonwealth Bureau of Meteorology estimates of the highest average temperatures (°F) that are likely to persist for three days in each month for the country town of Orange, N.S.W., (elevation 3000 ft) are shown in Table 1.

At Orange, fruit is not likely to be stored from December to March, so the figures for January and February may be ignored and t_A becomes 75°F.

If the structure is exposed to sunlight it is necessary to take account of the 'sun effect'; A.S.H.R.A.E. Handbook of Fundamentals (1967) indicates that at least 4°F should be added to the ambient temperature to compensate for this effect. Table 2 gives figures for t_A for the principal fruit-growing areas in New South Wales.

Table 2 also includes temperature differences (Δt) based on a space temperature of 32°F, which is typical for apple storage.

If produce is stored at temperatures significantly different from 32°F then adjusted values of Δt should be used.

Thermal Conductivity

Expanded polystyrene is a popular insulating material; for practical purposes it has a k factor of 0·26 Btu/ft²/hr/degF/in. (see tables appearing in Atkins and Hall (1967)). If a timber-framed structure is used in which timber studs penetrate the insulated space, an adjustment must be made to compensate for the poorer insulating quality of timber; k for hardwood is 1·1 Btu/ft²/hr/degF/in. The effects of timber studs, external and internal cladding, and surface film coefficients are shown in the Appendix.

If other forms of construction are used and/or other insulants are involved, it will be necessary to calculate other working values of k for the composite structure. Some results are given in Table 3.

Rate of Heat Transfer

To arrive at an acceptable figure for the rate of heat transfer Q Btu/ft²/hr, recourse will be made to the accumulated experience of others. A perusal of long-accepted standard reference books showed that a figure of 4 Btu/ft²/hr was commonplace in the past, whereas recent British practice suggests that a figure of 3 Btu/ft²/hr is gaining favour. There is also an old 'rule of thumb' which allows 1 in. of cork ($k = 0{\cdot}3$) for each 10 degF(Δt); this is equal to a rate $Q = 3$.

To avoid setting too high a standard, a compromise figure for Q of 3·5 Btu/ft²/hr is used in the following calculations; this probably represents average commercial practice.

Thickness of Insulation

In the example chosen, i.e. a timber frame structure located in Orange having polystyrene insulation and exposed to the sun:

From Table 2, $\Delta t = 47$ degF

From Table 3, $k = 0{\cdot}29$ Btu/ft²/hr/degF/in.

$Q = 3{\cdot}5$ Btu/ft²/hr.

Table 2

Ambient Temperatures (°F) and Temperature Differences for Various Localities in N.S.W.

Locality	Elevation (ft)	Unshaded t_A	Unshaded Δt	Shaded t_A	Shaded Δt
Orange	3000	79	47	75	43
Batlow	2500	79	47	75	43
Kentucky	1000	89	57	85	53
Tenterfield	2700	86	54	82	50

Table 3

Working Values of k for Assessing Insulation Thickness

Insulant	Type of Construction: Timber Frame	Panel	9 in. Brick
Expanded polystyrene	0·29	0·25	0·22
Expanded polyurethane	0·19	0·16	0·15
Slag/glass wool batts	0·30	—	—

Table 4
Recommended Thickness of Polystyrene Insulation (in.)

District	Walls and Ceiling Timber Frame	Panel	Masonry	Floor
Orange/Batlow, N.S.W.	4	3½	3	1½
Kentucky/Tenterfield, N.S.W.	4½	4	3½	1½
Stanthorpe, Qld.	4½	4	3½	1½
Mornington/Geelong/ Goulburn Valley, Vic.	4½	4	3½	1½
Huon Valley/ Launceston, Tas.	3½	3	2½	1
Lenswood, S.A.	4½	4	3½	1½
Fremantle, W.A.	5	4½	4	1½

Notes.—(1) These figures should be regarded as minima, to be exceeded if improved performance is required.

(2) A cool store erected inside another building, i.e. shaded from the sun, may have its insulation thickness reduced by ½ in.

(3) Thicknesses given to nearest half inch.

The thickness of insulation required (T) can be found using the formula

$$T = \frac{\Delta t \times k}{Q} = \frac{47 \times 0 \cdot 29}{3 \cdot 5} = 3 \cdot 9 \text{ in.}$$

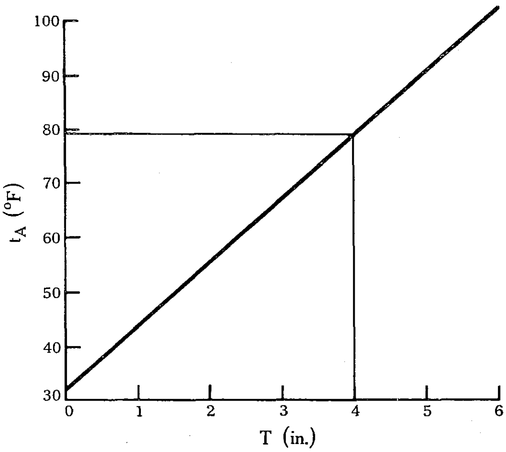
The nearest standard thickness should be chosen, in this case 4 in.

When considering the requirement for floor insulation the same principles apply, except that it is considered reasonable in the absence of factual information to assume that Δt for the floor will be only one-half that for the walls. Table 4 summarizes the information for several districts.

Construction Systems

There will probably be as many different proposals for construction methods as there are readers of this article. It is not intended to go into details, except to offer the opinion that if a 'do-it-yourself' programme is adopted the most likely result will be a timber-framed or brick structure, whereas for contract-built structures prefabricated panel construction will probably receive serious consideration.

Whatever method is adopted, it is import-



This figure may prove a useful guide to assist those who plan to erect a fruit cool store in areas where the climatic conditions differ from the examples given.

ant to place emphasis on the provision of an effective vapour barrier (V.B.) on the outside of the insulation. It is well known that the object of the V.B. is to prevent moisture from accumulating in the insulation; moist insulation is a very poor barrier to heat and most insulating materials are susceptible to the ingress of moisture over a long period. Prefabricated construction, in which the outer skin is a sheet of metal, offers an excellent safeguard, but even with 'home-built' stores the use of a material such as Vapastop[R] will provide an effective V.B., depending only on the time and care expended on fixing and on sealing all penetrations. Overlapping joints should be used, with two runs of sealer.

Theoretically, it is unnecessary to line the inside of an insulated structure but usually it is desirable for several reasons:

- To protect the insulation from damage.
- To provide a surface that is easily cleaned.
- To reduce the risk of fire spreading rapidly.

The lining material used should be more permeable to the passage of water vapour than the insulation itself to ensure that any moisture in the insulation can pass through to the cooling coils, i.e. there should not be a vapour dam.

In the case of C.A. stores (except the 'blanket' type) the V.B. has to be made into a gas barrier. This requires the exercise of considerably more care than usual in the sealing of all joints and penetrations and the use of the best sealing materials; unless this is done the room will not be gas-tight and remedial action may be very difficult, if not impossible, unless the inside surface is sealed, with the consequent formation of a vapour dam.

Conclusion

There are many and varied opinions concerning the correct amount of insulation to use when building a fruit cool store. This article sets out a method by which a satisfactory conclusion can be reached based on certain known facts, i.e. climatic conditions, storage temperature, the properties of insulating materials, and the allowable rate of heat flow through the structure. Using the information in the manner suggested will permit a solution for any form of construction and for various operating conditions.

Appendix

The following calculations show how the insulating properties of a typical timber frame structure can be estimated.

The structure consists of 4-in.-thick slabs of expanded polystyrene 30 in. wide fixed between 2-in.-thick hardwood studs. A vapour barrier is fixed to the outside of the studs and covered with $\frac{3}{16}$-in. asbestos cement sheeting. The inside surface is lined with $\frac{3}{16}$-in. tempered hardboard. The layers of air in contact with the outer and inner surfaces contribute to the insulating properties of the structure.

In a wall having 2-in. studs and 30-in.-wide slabs of polystyrene, $\frac{1}{16}$ of the wall area is timber. Consider a wall of unit area: k for polystyrene $= 0 \cdot 26$, k for hardwood $= 1 \cdot 1$.

The average rate of heat transfer per inch thickness is

$$\left(\tfrac{15}{16} \times 0 \cdot 26\right) + \left(\tfrac{1}{16} \times 1 \cdot 1\right) = 0 \cdot 312 \text{ Btu/ft}^2\text{/hr/degF.}$$

If the whole area were occupied by polystyrene the rate of heat transfer would be $1 \times 0 \cdot 26 = 0 \cdot 26$ Btu/ft^2/hr/degF.

The timber studs therefore increase the heat transfer rate by about 20%.

Now, consider the effect of the cladding and the surface air films, which can be estimated by adding the resistances to heat transfer of each component of the wall structure.

Component	*Resistivity*
Outside air film, $f_o = 6 \cdot 0$	$\frac{1}{6 \cdot 0} = 0 \cdot 17$
$\frac{3}{16}$ in. Asbestos cement $k = 2 \cdot 0$	$\frac{1}{2 \cdot 0} \times \frac{3}{16} = 0 \cdot 09$
Vapour barrier (negligible)	—
4 in. Polystyrene/timber wall $k = 0 \cdot 26 + 20\% = 0 \cdot 312$	$\frac{4}{0 \cdot 312} = 12 \cdot 80$
$\frac{3}{16}$ in. Tempered hardboard $k = 1 \cdot 5$	$\frac{1}{1 \cdot 5} \times \frac{3}{16} = 0 \cdot 125$
Inside air film, $f_i = 1 \cdot 65$	$\frac{1}{1 \cdot 65} = 0 \cdot 61$
Total resistivity	$= 13 \cdot 795$
Resistivity of 4 in. polystyrene alone $= 4/0 \cdot 26$	$= 15 \cdot 4$

The air surface films and cladding materials therefore decrease the rate of heat transfer by about 10%.

The net effect of the timber studs, air surface films, and cladding materials is to increase the rate of heat transfer by 20% less 10% = 10%.

Thus a 'working' value of k for the timber frame structure being considered is $0 \cdot 26 + 10\% = 0 \cdot 29$.

Note.—In this example, $f_o = 6 \cdot 0$ assumes a 15 m.p.h. wind and $f_i = 1 \cdot 65$ assumes still air.

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Temperatures in Canned Foods during Processing

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The temperature history at the slowest heating or critical point in a can of food during heat processing must be known in order to determine process schedules. It may be determined by using thermocouples, and in many instances may be obtained by mathematical calculation. This note describes modifications of Jakobsen's method of calculating temperature histories.

Jakobsen (1954) found that curves based on the hyperbolic secant had a shape closely approximating the time:temperature curves for heating and cooling of canned foods. Jakobsen gave the following equations:

$$u = 1{\cdot}02\,\mathrm{sech}(skt) = \frac{2{\cdot}04}{e^{skt} + e^{-skt}} \qquad (1)$$

where

$$u = \frac{T_r - T}{T_r - T_o},$$

$$s = \frac{4R_1^2}{D^2} + \frac{\pi^2}{H^2}\ (\mathrm{cm}^{-2}) \qquad (2)$$

(for round cans).

R_1 = 1st positive root of 0th-order Bessel function of the first kind
D = inside diameter of round cans (cm)
H = inside height of cans (cm)
T_r = retort temperature for sterilization
T_o = initial temperature of canned food
T = temperature at critical point of canned food at time t
k = thermal diffusivity (cm^2/min)
t = processing time (min)

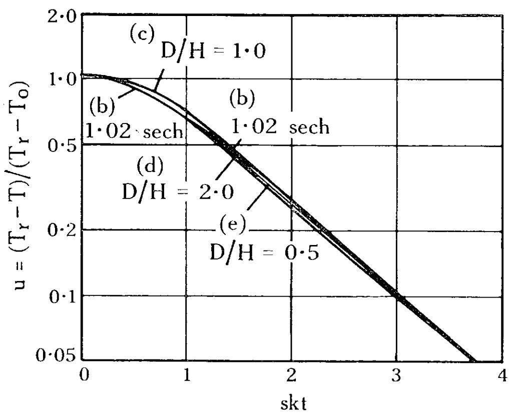

Fig. 1.—Curve (*b*) is the generalized can centre temperature *u* plotted as a function of *skt* according to Jakobsen's formula. Curves (*c*), (*d*), and (*e*) are theoretical heating curves for cans with proportions *D*/*H* of 1·0, 2·0, and 0·5 respectively (after Jakobsen).

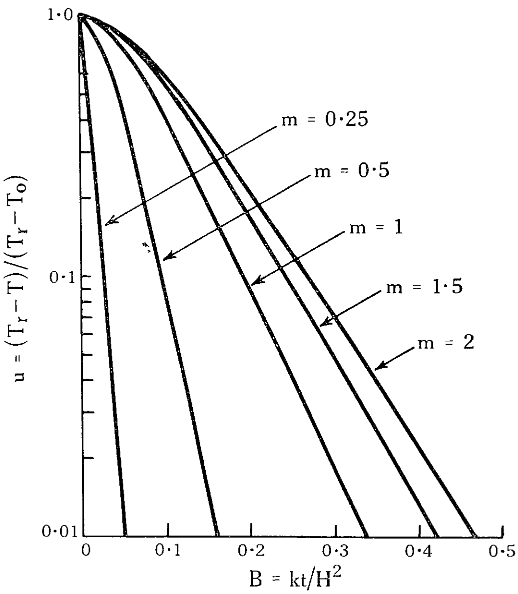

Fig. 2.—Dimensionless heating curves for several shape factors (*m*) of a round can of thermally conductive food.

Throughout this discussion it is assumed that the can of food is exposed instantly to retort temperature, the resistance of the metal can to heat flow is negligible, the thermal diffusivity of the product is constant during the process, and the product is initially at a uniform temperature.

Jakobsen obtained the curves shown in Figure 1 for the centre temperature of cans with proportions D/H 0·5, 1·0, and 2·0 by plotting u on a logarithmic scale against skt according to (1).

Equation (2) may be changed as follows:

$$s = (R_1^2/m^2 + \pi^2)/H^2 = A/H^2, \qquad (3)$$

where $m = r/H$, $r =$ inside radius (cm) of cans. Then

$$skt = A.kt/H^2 = A.B, \qquad (4)$$

where $B =$ Fourier modulus kt/H^2 and $A = (P_K/m)^2 + (2n-1)^2\pi^2$ and P_K is the Kth positive-root of the 0th-order Bessel function of the first kind and n is a dummy integer (following Hayakawa and Ball 1968).

Substituting $A.B$ for skt, (1) becomes

$$u = 1\cdot 02 \text{ sech } (A.B) = \frac{2\cdot 04}{e^{A.B} + e^{-A.B}}. \qquad (5)$$

In the theoretical dimensionless temperature scale u is unity at the start of heating and approaches or eventually becomes 0 (Gurney and Lurie 1923). Hence on the basis of Gurney and Lurie's theory, the factor 1·02 that Jakobsen included in his equation to make the zero-time-ordinate of the asymptote equal to the theoretical value (2·04) of the log factor j, may be erased, and (5) becomes

$$u = \text{sech } (A.B) = \frac{2\cdot 0}{e^{A.B} + e^{-A.B}}. \qquad (6)$$

In Table 1, u values computed for several

Table 1

Calculated u Values for Several Values of Fourier Modulus (B) and Shape Factor (m)

				$m = 2$					
B	0	0·025	0·05	0·10	0·15	0·20	0·25	0·30	0·40
$A \times B$	0	0·283	0·566	1·132	1·697	2·263	2·829	3·395	4·526
e^{AB}	1	1·327	1·761	3·102	5·459	9·612	16·929	29·815	92·389
e^{-AB}	1	0·754	0·568	0·322	0·183	0·104	0·059	0·034	0·011
$e^{AB} + e^{-AB}$	2	2·081	2·329	3·424	5·642	9·716	16·988	29·849	92·400
$u = 2/(e^{AB} + e^{-AB})$	1	0·961	0·859	0·584	0·354	0·206	0·118	0·067	0·0216
				$m = 1\cdot 5$					
B	0	0·025	0·05	0·10	0·15	0·20	0·25	0·30	0·40
$A \times B$	0	0·311	0·622	1·244	1·866	2·488	3·110	3·732	4·976
e^{AB}	1	1·365	1·862	3·469	6·462	12·037	22·421	41·762	144·897
e^{-AB}	1	0·733	0·537	0·288	0·155	0·083	0·045	0·024	0·007
$e^{AB} + e^{-AB}$	2	2·098	2·399	3·757	6·617	12·120	22·466	41·786	144·904
$u = 2/(e^{AB} + e^{-AB})$	1	0·953	0·834	0·532	0·302	0·165	0·089	0·048	0·0138
				$m = 1\cdot 0$					
B	0	0·025	0·05	0·10	0·15	0·20	0·25	0·30	—
$A \times B$	0	0·391	0·783	1·565	2·348	3·131	3·913	4·696	
e^{AB}	1	1·478	2·188	4·783	10·464	22·897	50·049	109·505	
e^{-AB}	1	0·676	0·457	0·209	0·096	0·044	0·020	0·009	
$e^{AB} + e^{-AB}$	2	2·154	2·645	4·992	10·560	22·941	50·069	109·514	
$u = 2/(e^{AB} + e^{-AB})$	1	0·929	0·756	0·400	0·189	0·087	0·040	0·018	
			$m = 0\cdot 5$				$m = 0\cdot 25$		
B	0	0·025	0·05	0·10	0·15	$B = 0$	0·05	—	—
$A \times B$	0	0·825	1·650	3·300	4·950	0	5·245		
e^{AB}	1	2·282	5·207	27·113	141·175	1	189·615		
e^{-AB}	1	0·438	0·192	0·037	0·007	1	0·005		
$e^{AB} + e^{-AB}$	2	2·720	5·399	27·150	141·182	2	189·62		
$u = 2/(e^{AB} + e^{-AB})$	1	0·735	0·370	0·074	0·0142	1	0·0105		

m values according to (6) are tabulated with values of B and other numerical terms used in the calculation. Figure 2 was obtained by plotting the u value on the logarithmic ordinate against the values of B on the arithmetic abscissa.

Figure 2 shows clearly the effect of can shape factor on the temperature history at the centre of the can. A similar chart has been presented by Hayakawa and Ball (1968) and by Hayakawa (1969). At small values of u (e.g. $u \leqslant 0 \cdot 1$), both Hayakawa's and the author's dimensionless heating curves appear to coincide. At larger values of u and where $m > 1$, values of B in Hayakawa's chart are slightly smaller than the values of B in the author's chart. The differences increase with increases in u and m.

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News from the Division

New Appointments

Mr. J. L. Smith joined the Division as an Experimental Officer on July 16 to work at the Tasmanian Regional Laboratory in Hobart, on problems concerned with the processing and preservation of fish, arthropods, and molluscs, or products derived from them. Mr. Smith holds the degree of B.Sc. from the University of Sydney.

Mr. R. J. Steele has been appointed Experimental Officer in the Division's Food Technology Section at Ryde, where he has been engaged since July 27 in research on the applications of physical chemistry and electrochemistry to problems in the preservation and processing of foods. Mr. Steele graduated B.Sc. in Industrial Chemistry from the University of New South Wales in 1966, and is currently completing the requirements for the degree of Ph.D. from the same university.

Dr. Kirsten Andersen, of the Genetics Department, University of Copenhagen, commenced a one-year post-doctoral fellowship in the Division's Plant Physiology Unit at the beginning of August.

Visiting Workers

Mr. Hasan Ariol, F.A.O. Fellow from Turkey, is spending 6–9 months in the Food Technology Section, studying quality control of processed foods, especially vegetables.

Mr. Muhamad Waseem, Colombo Plan Fellow from Pakistan, commenced a 13-week visit to the Food Technology Section, where he is working with Mr. D. J. Casimir, chiefly on the processing of fruit juices.

Mr. Derek D. Oudit, an Australian Commonwealth Scholar on leave from the Ministry of Agriculture, Trinidad and Tobago, West Indies, is spending approximately three years with the Fruit Storage Section. As a major requirement for a higher degree from the Department of Food Technology at the University of New South Wales, Mr. Oudit is studying the effects of the composition of the atmosphere on fruits, especially tomatoes, bananas, and cucumbers, when exposed to chilling temperatures after harvest.

Mr. Frank Bergius, a final year undergraduate from the Food Technology Department of the University of Strathclyde in Glasgow, took up a three months' appointment at the Meat Research Laboratory, Cannon Hill. His travel to Australia was sponsored by the English Speaking Union.

Mr. Colin Kennedy, of Mountain Maid Foods, and Mr. Denis King, of J. Hutton Pty. Ltd., were guests of the Division's Food Technology Section, where they received practical instruction in food processing techniques and quality control from Mr. P. W. Board.

Among other visitors to the Division during the last quarter was Professor Gerhard Bünemann, Director, Institute of Fruit Growing, Berlin, who is spending sabbatical leave with the Division of Plant Industry at the Tasmanian Regional Laboratory in Hobart.

Transfer

Mr. B. B. Beattie, Fruit Officer (Research), returned to the N.S.W. Department of Agriculture early in June, after working for approximately three years in the Division's Fruit Storage Section on the improvement of grape packaging, the use of fungicides in the prevention of post-harvest rotting, and the effect of temperature on the storage life of pears. Mr. Beattie is currently studying the economics of orchard cool stores.

Overseas Travel

Mr. E. G. Davis attended the Twelfth Meat Industry Research Conference in Hamilton, N.Z., where he presented a paper on packaging materials, in July.

Mr. J. F. Kefford took part in the Third International Congress of Food Science and Technology, SOS70, in Washington, D.C., in August.

Mr. J. B. Davenport received a travel grant from the Commonwealth Foundation to enable him to attend a meeting of the British Association and the Harden Conference of the Biochemical Society.

Mr. M. B. Smith left Australia at the end of August, also to participate in the Harden Conference and the Eighth International Congress of Biochemistry, in Switzerland.

Special Courses for Food Technologists

The Division is planning a number of specialist schools for the Australian food industry. It is hoped to hold the first of these in July 1971, on the topic 'Instrumental Techniques'. Details will be available shortly and will be sent to all Australian recipients of this journal.

Myles Sykes Memorial Lecture

The Food Technology Association of Tasmania has instituted a Myles Sykes Memorial Lecture to honour the memory of S. M. Sykes, who died on November 17, 1969.

Myles Sykes was leader of the Food Research Unit at the CSIRO Tasmanian Regional Laboratory, and in this capacity he devotedly supported the Tasmanian food industry with technical advice.

The first Myles Sykes Memorial Lecture was delivered in Hobart on Thursday, October 1, by Mr. J. F. Kefford, Assistant Chief of the Division, who spoke on the subject 'Food Science Serves the Food Industry'.

International Union of Food Science and Technology

At the conclusion of the Third International Congress of Food Science and Technology, held in Washington, D.C., August 9–14, 1970, formal ceremonies were held marking the founding of an International Union of Food Science and Technology with an initial membership of 20 nations. Mr. J. F. Kefford, Assistant Chief of the Division, and Vice-President, Australian Institute of Food Science and Technology, was Australian delegate to the first General Assembly of A.I.F.S.T. on August 14. Mr. Kefford was elected to the Executive Committee of the Union for a four-year term, and was appointed Chairman of the Education and Training Committee.

Financial Contributions, 1969/70

In the year ending June 30, 1970, the Division had a total budget of $2,062,884. Of this amount, the Australian Meat Research Committee contributed $405,000 in support of the Meat Research Laboratories at Cannon Hill, Qld., $15,500 was contributed by the Organization's Executive for developmental projects, and $135,694 was contributed by other statutory bodies and State Government departments. In addition, the Food Industries Equipment Fund received $19,700 from 88 firms connected with the food industry as support for its activities.

The Division of Food Preservation wishes to express its appreciation to all these organizations for their generous assistance.

Government Departments and Statutory Bodies

Australian Apple and Pear Board
Apple and pear storage investigations

Australian Dried Fruits Association
Investigations on dried tree fruits

Australian Meat Research Committee
Research on the quality, processing, storage, and

transport of meat; also on the mechanical skinning of sheep

Department of Primary Industry

Fruit fly sterilization investigations (funds contributed by the Commonwealth, six States, and the Australian Banana Growers' Council)

Metropolitan Meat Industry Board, Sydney

Muscle biochemistry investigations

N.S.W. Department of Agriculture

Fruit storage investigations

National Packaging Association of Australia

Investigations on food packaging

Queensland Fish Board

Grant for research on the occurrence and prevention of taints in mullet

Wheat Industries Research Council

Studies on plant physiology

Australian Honey Board

Research on honey quality

Contributors to Food Industries Equipment Account, 1969/70

Abattoir Construction & Engineering Co. Pty. Ltd.
W. Angliss & Co. (Aust.) Pty. Ltd.
Ardmona Fruit Products Cooperative Ltd.
Arnotts Biscuits Pty. Ltd.
Australian Bakels (Pty.) Ltd.
Australian Cellophane (Pty.) Ltd.
Australian Consolidated Industries Ltd.
Australian Fibreboard Container Manufacturers' Association
Australian Food Research Laboratories
Australian Paper Manufacturers Ltd.
James Barnes Pty. Ltd.
Berri Co-operative Packing Union Ltd.
Berri Fruit Juices Co-operative Ltd.
Blue Moon Fruit Co-operative Limited
British Tobacco Company (Australia) Limited
A. J. Bush & Son Pty. Ltd.
Campbell's Soups (Aust.) Pty. Ltd.
Cascade Cordials Pty. Ltd.
Cerebos (Australia) Ltd.
Citrus Products Co.
Coca-Cola Export Corporation
Conkey & Sons Ltd.
Containers Ltd.
Sidney Cooke Chemicals Pty. Ltd.
Cottees General Foods Ltd.
Cygnet Canning Co. Ltd.
Dark's Ice & Cold Storage Ltd.
Darling Downs Cooperative Bacon Association Ltd.
Davis Gelatine (Aust.) Pty. Ltd.
Gordon Edgell Pty. Ltd.
Elmer Products Pty. Ltd.
F.M.C. (Aust.) Limited
Fremantle Cold Storage Co. Pty. Ltd.
Frig-Mobile of Australia Pty. Ltd.
J. Gadsden Pty. Ltd.
W. G. Goetz & Sons Ltd.
Golden Circle Cannery
Gordon Brothers Pty. Ltd.
Griffith Co-operative Cannery Ltd.
Keith Harris & Co. Ltd.
H. J. Heinz Company Aust. Ltd.
Hall-Thermotank (Aust.) Pty. Ltd.
Hunter Valley Co-operative Dairy Co. Ltd.
H. Jones & Company (Sydney) Pty. Ltd.
Jusfrute Limited
Kyabram Preserving Company Ltd.
Lawley & Housego Pty. Ltd.
Marrickville Holdings Ltd.
Mayfair Hams & Bacon Co.
Craig Mostyn & Co. Pty. Ltd.
Mountain Maid Foods Co-operative Ltd.
Muir & Neil Pty. Ltd.
National Packaging Association of Australia
The Nestlé Company (Australia) Ltd.
Northern Pear Growers Association Ltd.
Nugan (Griffith) Pty. Ltd.
Orange Fruitgrowers Co-operative Cool Stores Ltd.
Overseas Containers (Australia) Pty. Ltd.
Harry Peck & Co. (Aust.) Pty. Ltd.
W. C. Penfold & Co. Pty. Ltd.
Pict Limited
Tom Piper Limited
Producers Cold Storage Ltd.
Producers Co-operative Distributing Society Ltd.
Reckitt & Coleman Pty. Ltd.
Schweppes (Aust.) Ltd.
Sidac-Rayophane (Aust.) Pty. Ltd.
South Australian Fishermen's Co-operative Ltd.
Taubmans Industries Ltd.
Tooheys Ltd.
Trans-Ocean Containers Pty. Ltd.
Unilever Australia Pty. Ltd.
Union Carbide Aust. Ltd.
Uncle Ben's of Australia Pty. Ltd.
United Fruit Company Pty. Ltd.
United Packages Limited
F. J. Walker Ltd.
Watts Winter Pty. Ltd.
Western Australian Ice & Cold Storage Association
George Weston Foods Ltd.
White Wings Ltd.
Winn Food Products
Woolworths Ltd.
XLNT Foods Pty. Ltd.
Arthur Yates & Co. Pty. Ltd.
G. S. Yuill & Co. Pty. Ltd.

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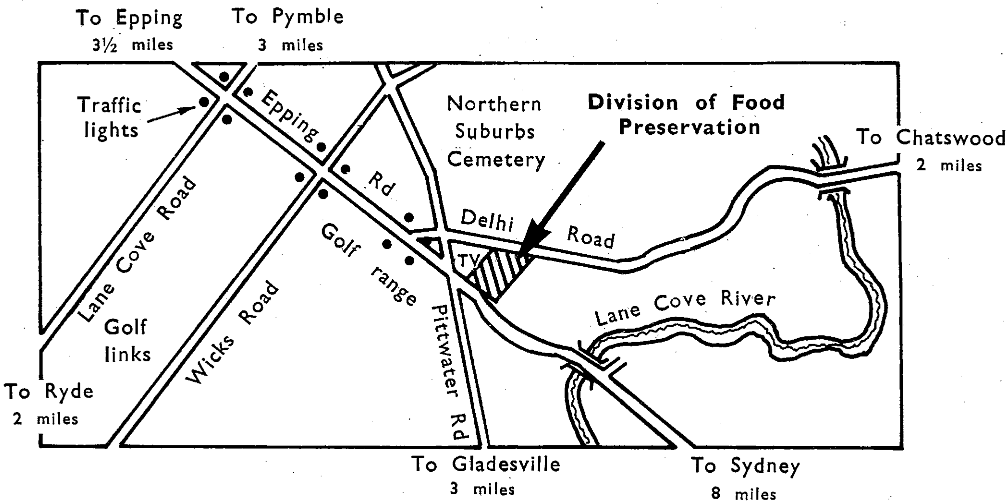
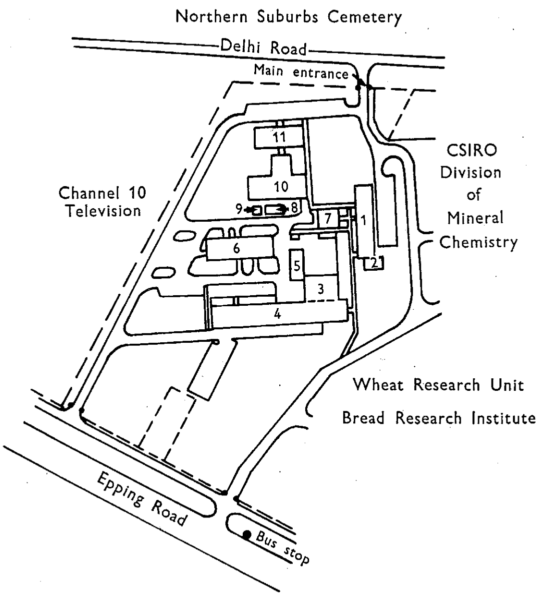


The main entrance to the Division is in Delhi Road, but the grounds may also be entered from Epping Road.

Buses on Routes 285–290 running between Wynyard and Epping railway stations pass the Epping Road entrance. Alight near Channel 10 television studios.

Buses on Barnes Coach Bus Route 54 from Chatswood railway station either terminate at the Northern Suburbs Cemetery near the Delhi Road entrance to the Division or continue on to Macquarie University.

Buses on Hunter's Hill Bus Co. Route 43 from Chatswood railway station running to Top Ryde pass the Epping Road entrance. Alight near Channel 10 television studios.



1 Administration and library
2 E. W. Hicks meeting room
3 Controlled-temperature rooms
4 Food science building
5 Boiler house and engine room
6 Workshops and store
7 Canteen and taste test room
8 Sulphuring room, liquid air plant
9 Refrigeration plant for blast freezer
10 Food processing building
11 Food technology building