CSIRO DIVISION OF FOOD RESEARCH

Food Research Laboratory, North Ryde

Progress report to the Fishing Industry Research Committee - 31 December 1975

Project: Studies on Prawn Processing and Quality

Supervisor: Dr A.R. Johnson, Senior Principal Research Scientist

Prawn Dipping Machine

The prawn dipping machine, designed to treat prawns with a 3,000 ppm sulphite solution to prevent black spot formation was tested under commercial conditions (i) in a processing factory and (ii) on board a prawning vessel in the Gulf of Carpentaria. The results of these trials confirmed that the dipping of large quantities under commercial conditions is feasible. Although the design of the present machine has many limitations, it clearly showed the advantages of controlled dipping in sulphite for the prevention of black spot formation.

In addition, these trials confirmed:

(i) the uptake of sulphite by raw prawns was always below 30 ppm.

(ii) the dip solution needed to be renewed after about 5,000 kg prawns had been dipped.

(iii) the sulphite concentration of the dip solution must not fall below 3,000 ppm.

(iv) bacteria do not grow in the dip solution.

(v) the numbers of bacteria on the raw prawns are slightly reduced after dipping in sulphite.

Tiger prawns dipped in sulphite at sea and subsequently stored in brine for 5 days at 0°C did develop black spot, although not quite as extensively as those which were not dipped. Laboratory trials of dipped and undipped tiger prawns revealed that both could be kept for 10 days in sea water at -1°C before black spot developed. These trials suggest that poor handling of prawns on board the trawler before dipping accelerates the development of black spot.

Effect of Sulphite on Prawn Flavour

Sulphite does not impart an unpleasant taint to prawns, even at levels as high as 250 ppm in the cooked flesh. Rather, it appears to reduce the intensity of the natural flavour and the perceived sweetness of the flesh. The recommendation by CSIRO that the permitted sulphite level in raw prawn flesh be raised to 30 ppm has already been incorporated in the amendments to the Australian standard for export of frozen raw shrimp.

Transportation of Chilled Raw Shrimp

Efforts to develop new methods of transporting chilled raw prawns under dry refrigeration were unsuccessful because of the development of black spot. Blackening could not be prevented even when the prawns were dipped twice in sulphite and held in a chilled inert atmosphere of nitrogen or carbon dioxide gas. It was better to transport chilled, dipped raw prawns in refrigerated sea water than to use the current method of transporting prawns in ice to which salt and sulphite powder are added.

Storage of Raw Prawns in Refrigerated Sea Water (RSW)

Freshly caught raw prawns can be kept in excellent eating condition in chilled RSW for 7 days, if the temperature of the RSW remains between 0°C and -1.5°C. On the eighth day of storage, the prawns develop bitter off-flavours, and their eating quality is unacceptable, although their appearance may be acceptable. This shelf life of 7 days was found for several species. It is most important to maintain a constant RSW temperature; if sudden fluctuations occur, the rate of spoilage and black spot development rapidly increases.

Sufficient information has now been collected to present guidelines for fishermen for the RSW storage of raw prawns.

Field Work

Mrs Ruello made an extensive tour of prawn processing factories and vessels in the Northern Territory and Queensland during April, 1975. Her findings are summarized below:

(i) Most of the staff in processing factories in remote areas are inexperienced in prawn processing; many believe defects such as black spot are caused by bacteria, and consequently heavily treated prawns with chemical solutions and detergents etc. to stop growth of bacteria.

(ii) Fishermen and processors are very conscious of prawn quality as a result of the large numbers of export prawns which were rejected overseas in 1974.

(iii) The industry is enthusiastic about the work being done by CSIRO on quality control of raw prawns and the use of sulphite to control black spot.

(iv) Prawns rejected for export were being sold to processors who process them for the domestic market. Many of these processors are unable to assess the quality of raw prawns and many prawns of inferior eating quality are being sold on the domestic market. In addition these prawns are being processed with inadequate equipment under unhygienic conditions.

(v) Large increase was observed in the practice of 'double freezing' of the catch to (a) avoid brine storage at sea or (b) avoid transportation in ice.

Recommendations

(i) There is a need for an extension service to assist fishermen and processors to maintain the quality of raw prawns.

(ii) Prawns considered unsuitable for export (because of spoilage, infestation by parasites, excessive use of additives etc.) should not be processed for the domestic market.

(iii) Factories processing prawns for the domestic market should be required to conform to the ADA standard for factories which export prawns.

Programme for 1976

(i) This project terminates 30 June 1976, therefore no new experimental work will be commenced. The work of the previous year will be prepared for publication. This includes:

(i) work on the determination of drained weight of individually quick frozen prawns,

(ii) commercial trials of prawn dipping machine.

Following extensive requests for assistance from the prawn processing centres in South Australia and Western Australia, these areas will be visited during the 1976 season to advise industry on prawn quality control and use of sulphite.

Talks

(i) Mrs Ruello presented a paper entitled 'Prawn Handling and Processing' to the 1975 Winter School for Seafood Processors, Hawkesbury Agricultural College, 10 September, 1975.

(ii) Mrs Ruello was invited to lecture at FAO/DANIDA Workshop on Fish Handling, Plant Sanitation, Quality Control and Fish Inspection. The Workshop was held in Bangkok, Thailand, 20 October to 28 November 1975.

Film

A film was made during the sea trials of the prawn dipping machine to demonstrate to fishermen and processors how to dip and store raw prawns. It is hoped that the film will be ready for viewing early in 1976. The film was made by the CSIRO Film Unit.

Publications

RUELLO, Judith H., and McBRIDE, Robert L., (in press).
The Effect of Sodium Metabisulphite on the Flavour of Fried Prawns.
Food Technology in Australia.

SHARP, Alister K., and RUELLO, Judith H., (1974).
A dipping machine for the control of black spot in prawns.
Proceedings of the 1974 Winter School for Seafood Processors
(Hawkesbury Agricultural College).

COMMONWEALTH OF AUSTRALIA
COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION
REPRINTED FROM "FOOD TECHNOLOGY IN AUSTRALIA", VOL. 28, No. 4, APRIL 1976 PAGES 131-133

The effect of sodium metabisulphite on the flavour of fried prawns

JUDITH H. RUELLO and ROBERT L. McBRIDE
CSIRO Division of Food Research, North Ryde, N.S.W., 2113

The effect of sodium metabisulphite on the flavour of fried prawns

JUDITH H. RUELLO and ROBERT L. McBRIDE
CSIRO Division of Food Research, North Ryde, N.S.W., 2113

Sodium metabisulphite is often added to raw prawns exported from Australia in order to control black spot (melanosis). The results given in this article show that free sulphur dioxide has no perceivable effect on flavour at levels below 125 mg/kg in the cooked flesh. At levels of 250 mg/kg in the cooked flesh free sulphur dioxide reduces the intensity of the prawn's natural flavour, but it does not impart a flavour of its own.

Sodium metabisulphite (SMB) is often added to raw prawns exported from Australia in order to control the development of the enzymatic defect known as black spot (melanosis) (Ruello, 1974a). Black spot is the most obvious defect to develop in dead raw prawns and it can be a serious problem in prawns intended for export. It is not, however, a problem on the domestic market, because most of these prawns are boiled soon after catching, while the trawler is still at sea, and prompt cooking inhibits the enzymatic reaction.

At present SMB is added indiscriminately; hence it is not unusual to find export prawns containing free sulphur dioxide (FSD) levels exceeding the permitted limit of 10 mg/kg (Ruello, 1974a; Commonwealth of Australia, Department of Primary Industry, 1970). It is difficult to control black spot effectively and maintain FSD contents in raw flesh consistently to 10 mg/kg or less (Ruello, 1973). Even the method recommended by the Australian Department of Agriculture * for black spot control (Commonwealth of Australia, DPI, 1970) gives FSD levels ranging from 3 to 18.5 mg/kg in raw prawn flesh (Ruello, 1973).

As SMB is widely used in industry, it is important to know what effect it has on the eating qualities of prawns. A sensory experiment was therefore carried out to determine the minimum FSD level that causes a flavour change in fried prawns that could be detected by a trained panel, and the nature of any flavour changes due to the presence of FSD.

* formerly known as Department of Primary Industry

COLLECTION AND PREPARATION OF PRAWNS

For all tasting sessions freshly caught eastern king prawns *Penaeus plebejus* (45–55 to the kg) were collected at the Sydney Fish Centre, Pyrmont, N.S.W., and transported in ice to the Food Research Laboratory, Ryde. There they were washed in fresh tap water, headed, shelled, deveined and dried on paper. SMB was applied by soaking 1.3 kg batches of raw prawn tails in 2 l of chilled (0°C) SMB solution of predetermined concentration for 24 hr. Trial taste testing sessions were held using prawn tails containing six levels of FSD between 20 and 250 mg/kg prepared as shown in Table 1. As a high variability was found in FSD levels between replicates of individual prawn tails, the samples were presented at subsequent sessions as prawn patties; these were prepared as shown in Table 2. Each batch of control samples was prepared from 1.3 kg of raw prawn tails held in 2 l of chilled (0°C) distilled water for 24 hr. Each batch of 1.3 kg of prawn tails gave enough material for two tasting sessions.

All of the samples were fried in oil to simulate the normal cooking method used in the countries to which these prawns are exported.

Prawn Tails

Prawn tails were removed from the soaking solutions, rinsed once in tap water and then dried on paper. They were shallow fried at 180°C in a commercial grade vegetable oil, two min for each side, and served hot to the panellists.

Prawn Patties

Rinsed prawn tails were dried on paper, and then finely minced in a kitchen mincer. The minced flesh was thoroughly mixed for 15 sec in an electric mixer at low speed and then was moulded by hand into patties of approximately 17 g. The patties had sufficient cohesion to retain their shape during cooking

TABLE 1
Free sulphur dioxide (FSD) content of soaking solutions and of fried prawn tails used in the trial tasting sessions.

FSD content of soaking solutions (mg/kg)	FSD content of fried tails average of 4 x 50 g samples (mg/kg)	FSD content of fried individual tails, averaging of 6 tails (mg/kg)
300	19.4 SD* = 8.6	NA†
400	27.9 SD = 12.4	NA
700	78.8 SD = 7.6	NA
800	108.9 SD = 19.9	NA
1,300	162.3 SD = 26.9	NA
1,400	237.8 SD = 51.5	243.3 SD = 47.8

* SD = Standard deviation
† NA = data not available

without addition of a binder. The patties were shallow fried at 180°C, 2 min for each side, and were served hot.

Measurement of Sulphite

The FSD content of solutions was measured iodometically by the method of Vogel (1951). Sulphite solutions of known concentrations were made from analytical grade sodium SMB.

A modification of the method described by Shipton (1954) was used to measure the FSD content of the prawn sample. Using the apparatus shown in Fig 1, 20 ml

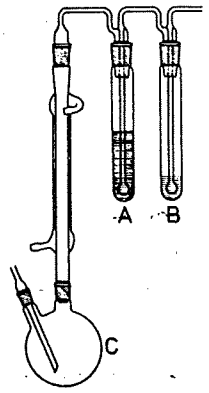


Fig. 1. Distillation apparatus for determination of sulphite as sulphur dioxide.

of 0.02M iodine were added to trap A instead of 15 ml of 3% hydrogen peroxide, and 10 ml of 0.01M sodium thiosulphate were added to trap B (so as to collect any released iodine) instead of 5 ml of 3% hydrogen peroxide. After the sample had refluxed in the acid solution of trap C for 30 min the contents of trap A and B were combined and titrated against 0.01M sodium thiosulphate; two drops of 1% starch solution were used as indicator. Results are expressed as free sulphur dioxide (FSD) (mg/kg).

At the trial taste sessions, four replicate samples, each containing about five or six fried tails (about 50 g), and six replicates comprising a single fried tail were analysed. Six replicates of a 50-g sample containing about five fried patties and six replicates of one raw pattie were analysed in association with sessions 1–12.

SENSORY EVALUATION

Some 31 people, naive with respect to the purpose of the experiment but all familiar with taste testing procedures, were selected for screening. As it was expected that prawns treated with SMB would probably have a 'sulphite' flavour the panellists were subjected to a series of threshold tests in which they were asked to taste six solutions in ascending order of FSD concentration ranging from tap water (nil FSD) to a FSD solution of 300 mg/kg. Tasters were asked to note the first solution in which they noticed a flavour different from water, and to identify the flavour if possible. Then followed a series of triangle difference tests which involved tap water and tap water containing FSD at 100 mg/kg. On the basis of performance in all tests, 18 people were selected for consistency and sensitivity to FSD solutions as panellists for the prawn tasting trials.

Prawn Tails

Triangle difference tests were used to obtain an indication of the FSD level at which a flavour change is detected in fried prawn tails. At each session the taster was presented with three prawn tails and asked to taste them in a specific order balanced within the session, to choose the one with a flavour differing from the other two, and if possible, to describe the flavour difference. Each session was balanced, in that half the trials tasted consisted of two tails containing FSD and one control: the other half consisted of two controls and one tail containing FSD. All sessions was identical except for differences in the level of FSD in the fried tails (Table 1).

Standard taste testing conditions described by Christie (1964) prevailed in the Sensory Evaluation Laboratory.

The trial tests indicated that most tasters could detect a flavour difference when the average FSD level of the fried tails was about 250 mg/kg. However, tasters showed an apparent lack of consistency in their responses to individual samples from one SMB treatment. Subsequent chemical analyses showed that much of the variability in taster response was associated with variation in the FSD levels of replicate samples. The variability in FSD content within each replicate was reduced when the flesh had been finely minced and mixed thoroughly. The minced flesh could then be served as patties of homogeneous composition and proved to be suitable samples for sensory evaluation.

Before further sensory tests were carried out, the panel was asked to assess the acceptability of control patties using a nine point Hedonic scale: these patties were found to be highly acceptable. During these tasting sessions the panellists also reported that the oil used for frying imparted a strong flavour to the patties and tended to mask their flavour. Accordingly the panel assessed five brands of vegetable oil for flavour and odour; the blandest one was selected for all subsequent tests.

Prawn Patties

As the trial tests suggested that a flavour change may be detected in cooked prawns having a FSD content of about 250 mg/kg, two separate series of triangle difference tests were carried out in which all conditions were identical to those described above except that patties were used instead of whole tails and the average FSD content of the fried treated samples were 125 (sessions 1–6) and 250 mg/kg (sessions 7–12) respectively.

RESULTS

Free Sulphur Dioxide Contents

FSD contents of samples from the trial sessions and for each pair of sessions 1 to 12 are given in Tables 1 and 2. The average FSD content during session 1–6 was 150 mg/kg in raw patties and 125 mg/kg in fried patties: during sessions 7–12 it was 300 mg/kg in raw patties and 250 mg/kg in fried patties.

By comparing the results in Tables 1 and 2 it can be seen that mixing the flesh to form patties reduced the standard deviation between samples within each pair of sessions, but the standard deviation still remained high in these homogeneous samples, ranging from 8.6 to 14.6 mg/kg (Table 2). This variability appears to arise mainly from an unavoidable variation in uptake or loss of FSD during frying; the analytical procedure has a high reproducibility (Shipton, 1954). Reduction in FSD content

TABLE 2
Free sulphur dioxide (FSD) content of soaking solutions and of raw and fried prawn patties used in tasting sessions 1–12.

Tasting Sessions	FSD content of soaking solution (mg/kg)	Average FSD content RAW Average of 6 single patties (mg/kg)	Average FSD content FRIED Average of 6 x 50 g samples (mg/kg)	Average loss on frying (%)
controls 1-12	0 distilled water	3.0 SD* = 0.8	NA †	NA
1-2	750	165.3 SD = 8.6	104.9 SD = 12.4	36.5
3-4	750	172.1 SD = 9.4	147.9 SD = 14.6	14.2
5-6	750	139.3 SD = 13.1	101.1 SD = 12.4	27.4
7-8	1400	NA	243.2 SD = 11.6	NA
9-10	1400	296.8 SD = 14.6	258.9 SD = 11.1	12.8
11-12	1400	304.1 SD = 9.6	251.4 SD = 9.1	17.3

* SD = Standard deviation
† NA = data not available

during frying varied from 12.8% to 36.5% (Table 2).

Sensory Tests

Sessions 1–6 and 7–12 were analysed separately using the same technique. The variate analysed was arc sin ($\sqrt{p}$), where p was the proportion of the panel who correctly identified the odd sample at each session. A t-test then showed that in sessions 1–6 the panel found no significant difference between the patties treated with SMB and the control patties and the proportion of 'correct' identification could be attributed to random guessing (Table 3). In sessions 7–12 the panel detected a difference between control patties and patties treated with SMB and this difference was statistically significant at $p < 0.01$ (Table 3). These results show that FSD in fried prawn flesh has its first perceptible effect on flavour at a level somewhat greater than 125 mg/kg.

TABLE 3
Results of sensory tests on fried prawn patties.

	Sessions 1-6	Sessions 7-12
Correct responses (no.)	35	59
Total responses (no.)	104	100
Correct responses (%)	33.6	59**

** Statistically significant at $p < 0.01$. The level of correct identifications in sessions 1-6 could be attributed to chance alone.

Although most tasters correctly identified SMB treated samples in sessions 7–12, they did not notice the presence of a 'sulphite' or 'sulphurous' taint in them, but instead they consistently commented that the treated prawns 'lacked sweetness' and 'lacked prawn flavour'. In comparison, prawns without FSD were described as being 'sweeter' or having a 'stronger flavour' or a 'more true prawn flavour'. These observations show that the effect of FSD is to depress both the intensity of the characteristic prawn flavour and also the perceived sweetness of the flesh.

CONCLUSIONS AND RECOMMENDATIONS

Levels of FSD up to 125 mg/kg seem to have no deleterious effect on the flavour of fried prawns and this level corresponds to a FSD content of about 150 mg/kg in the raw flesh under the conditions of this experiment. Even at levels as high as 250 mg/kg in the fried flesh (corresponding to about 300 mg/kg in the raw flesh), FSD does not impart an unpleasant taint to prawns, although it seems to reduce the intensity of the natural flavour.

The permitted Australian limit of 10 mg/kg in raw prawns is unrealistically low in relation to the variability in FSD uptake and the 'blank' value of prawns. Even under controlled laboratory conditions the standard deviation of the FSD content of replicate, homogeneous samples of raw flesh ranged from 8.6 to 14.6 mg/kg. Control prawn samples gave a 'blank' FSD reading of 3 (± 0.8) mg/kg. We suggest that the present limit should be reconsidered and suggest that a level of 30 mg/kg in raw prawn flesh would be more realistic. This level would allow for effective black spot control, and the variability in FSD uptake, but is still well below the level of 300 mg/kg in the raw flesh at which a flavour difference was distinct.

ACKNOWLEDGEMENT

This work was partly financed by a grant from the Fishing Industries Research Trust Account.

Received 18 Aug. 1975
Accepted 5 Dec. 1975

REFERENCES

CHRISTIE, E. M. (1964) *Lab. Pract.* **13**, 630.

COMMONWEALTH OF AUSTRALIA. DEPARTMENT OF PRIMARY INDUSTRY (1970) *Standard for Export Frozen Uncooked (Green) Shrimp.* Govt Printer, Canberra.

RUELLO, J. H. *National Prawn Seminar, Maroochydore, Qld, 22–27 1973.* Govt Printer, Canberra (in press).

RUELLO, J. H. (1974a) *Fd Technol. Aust.* 26. 186.

RUELLO, J. H. (1974b) *Aust. Fish* **33** (2), 6.

SHIPTON, J. (1954) *CSIRO Fd Preserv. Q.*, **14**. 54.

VOGEL, A. I. (1951) *A Text-Book of Quantitative Inorganic Analysis: Theory and Practice,* 2nd Edn. Longmans, Green, London.

Prawns—fresh and frozen

By Judith H. Ruello

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

This article describes the Australian prawn industry and advises how to handle and store prawns and what to look for to ensure that they are of good quality

Commercial prawning began in Australia during the 1790s, soon after the first European settlement was established at Sydney Cove. The industry remained small and insignificant during the 19th century because ice was scarce or unavailable. It grew spectacularly in the 1950s following the development of oceanic prawning in New South Wales and Queensland. Twelve years later new grounds were found in the Gulf of Carpentaria, Western Australia and South Australia, and these became the basis of a lucrative export industry (Fig. 1).

Although the catch has dramatically increased, there is often an undersupply to the domestic market. This is because most prawns are exported and because the domestic demand has increased at an even faster rate than the supply.

About eight species of economic importance are fished from estuaries and the continental shelf. Along the eastern coast the main species are the Eastern King, the School and the Greentail, while in northern tropical Australia the Western King, Tiger, Banana and Endeavour prawns are the most common.* The Western King is the species which is fished commercially in South Australia. In general, prawns caught in rivers, lakes or harbours tend to be small, whatever the species, but if they move to oceanic waters, as do Eastern and Western Kings, Banana, Tiger and School prawns, they will grow to a considerable size.

* Readers are referred to the article 'The Australian prawn industry', by W. A. Montgomery, G. S. Sidhu and Gwenda L. Vale, in *CSIRO Fd Preserv. Q.* **30**, 21–7 (1970), which presents colour plates of four of the species of prawn found in Australian waters.

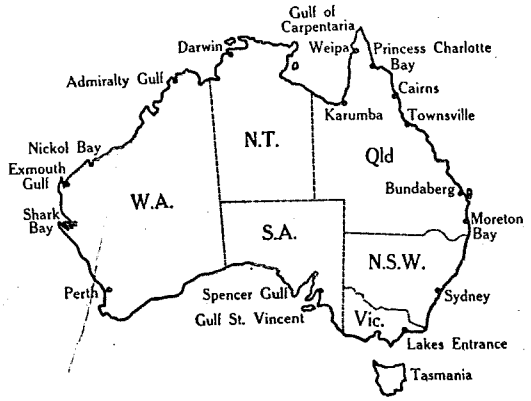


Fig. 1. Map of the principal fishing areas in Australia.

Seasons

During the summer months of November, December, January and February plentiful supplies of fresh boiled prawns are available from southern Queensland and northern New South Wales. Brisbane is well supplied with local 'bay' prawns from Moreton Bay during summer and Sydney has a small local summer fishery. Although limited, the Sydney fishery is unusual because the prawns are brought to market raw, and it is possible to purchase live prawns at the Sydney fish markets. During late autumn and winter many estuarine areas of New South Wales and Queensland are not fished commercially, but this is when fishing starts in northern tropical areas and enormous catches can be taken. Although most of the catch is exported, some frozen raw prawns are sold on the domestic market.

Australians are still reluctant to buy frozen raw prawns, partly because they

prefer to eat fresh boiled prawns, and also because they are unfamiliar with ways of preparing raw prawns. During winter, when freshly caught raw prawns are unavailable, merchants thaw frozen raw prawns and sell them as 'fresh' raw prawns, or boil them and market them as 'fresh' boiled prawns. As it is difficult to tell how long the prawns have been thawed or at what temperature they have been thawed and stored, consumers will find it better and cheaper to buy whole blocks of frozen raw prawns to thaw and cook at home. During glut years, raw prawns which are unsuitable for export (for reasons to be discussed later) are often 'dumped' on the domestic market. Consumers, particularly those in southern States, should be on guard during the winter months to ensure that they are buying a quality product.

Quality assessment of fresh prawns

Most Australian fishermen know how to supply first-quality fresh, boiled and raw prawns to all available markets, but loss of quality may occur if fishermen handle the catch poorly and when merchants do not transport and store the prawns correctly. It is unlikely that spoiled prawns will be offered for sale, but it is not uncommon for inferior prawns to reach the retail markets or to be served in restaurants. The consumer must know what to look for in order to get the best value for money, but this will be difficult for consumers who buy prawns infrequently and who are unfamiliar with the appearance, flavour and texture of freshly caught prawns. With practice, the consumer can determine the quality of prawns by careful examination.

Appearance

Appearance is one of the few factors considered by consumers before they buy prawns. Carefully handled prawns, whether boiled or raw, should be whole and undamaged. The heads should not be loose, broken or squashed; bodies should not be squashed or have the tail fan broken off. No part of the flesh should be exposed.

Raw prawns should be washed free of all mud and fish slime, and the flesh should be translucent and firm, not white or opaque. Once dead, raw prawns must be well iced or they will blacken as a result of a condition known as 'black spot' which is caused by enzymic reactions in the prawn. Although it is not harmful to eat prawns with black spot, it spoils their appearance and it is an indication to consumers that the prawns have been poorly handled after being caught.

Boiled prawns should not blacken and may be held somewhat longer than raw prawns, with or without ice. If undercooked, boiled prawns will blacken; these 'black head' prawns are considered unsafe to eat because contaminating bacteria may not have been killed by the mild heat treatment and may have multiplied to dangerous levels during storage. 'Black head' prawns are condemned by inspectors and it is unlikely that any would reach the retail trade. Sometimes a boiled prawn may have a 'brown head'; this is a result of the so-called 'liver' bursting when the prawn is cooked, giving the entire head region a brownish colour. It does not indicate poor handling or spoilage. Fresh boiled prawns should not feel slimy and should not be covered with 'dew'. This 'dew' is sometimes described as 'sweat'; most 'sweaty' prawns are frozen prawns which have been thawed.

Colour

The natural pigmentation of raw prawns differs for each species and within each species. For example, Eastern King prawns taken from rivers and estuaries of New South Wales are normally olive-green but the same species caught off southern Queensland is deep red. All prawns turn pink on boiling but not all will be the same colour. For instance, Eastern King prawns turn a rich red which is highly favoured by consumers, whereas other species such as the Western King and the School turn a paler dull pink. When these prawns are sold alongside bright red species some consumers tend to think, wrongly, that their colour has faded and that they are stale. The colour of boiled prawns does not noticeably change on storage and is therefore no guide to freshness. There is strong buyer resistance to pale pink boiled prawns, and it is not uncommon for some species, especially Western King prawns, to be dyed. Although this is not permitted, and some are condemned by inspectors, quantities of dyed prawns do find their way onto retail markets.

Fig. 2. School prawns being sorted by fishermen on the Clarence River, N.S.W. Photo: N. V. Ruello

Freezer burn

Freezer burn is the term used to describe the white patches which may appear on the shell of frozen prawns that have become dehydrated during storage. It cannot be disguised so if 'fresh' prawns have these white patches on the shell it indicates that they have been frozen, stored and then thawed before marketing. As prawns with freezer burn are partly dehydrated, their texture is drier and tougher than when freshly caught.

Soft shell

Normally, a prawn's shell is hard and shiny, but sometimes the shell has a dull appearance and feels soft and paper thin. The prawns may even look as if they have been slightly squashed. These are 'soft-shelled' prawns which have just moulted and have been caught before the new shell has hardened. Soft-shelled prawns are difficult to peel, but their eating quality is not diminished.

Flavour

The flavour of a cooked prawn is a good guide to freshness because prawn flavour disappears during storage. This is particularly true of prawns kept on melting ice; the flavour components are washed out by the melting ice and after 2 or 3 days the prawns will be flavourless. Consumers would have to be familiar with the flavour of particular species to be able to make meaningful judgments about the degrees of freshness. Freshly boiled prawns have a mild, pleasant and distinctive flavour which is slightly different for each species.

Live prawns have a low salt content of about 0·4%, and when freshly boiled without salt they do not have a salty taste. Most consumers prefer some salt to be added, and it is common practice to boil prawns in sea water or salted water. The added salt enhances the natural flavour and the consumer should barely be aware of a salty taste. Salt is sometimes added to the ice or brine in which the prawns are

stored or transported in order to increase their shelf life. These prawns become extremely salty, and as it is difficult to remove the saltiness they may be inedible. Sometimes, merchants add salt to stale prawns completely lacking natural flavour in order to add 'flavour', and all the consumer tastes is a mild saltiness in the prawns. Inexperienced consumers assume wrongly that this salty taste is the natural flavour of prawns.

Texture

Fresh prawns have a firm texture and should not be mushy, chewy or tough. It is not true that large prawns are tougher than small prawns; when freshly caught they have the same eating qualities as small prawns. Toughness develops in prawns that have been frozen and thawed, in frozen prawns that have become dehydrated under frozen storage, in prawns containing more than 4% salt and in prawns stored in acidic solutions. Most of the prawns from the northern fisheries are frozen at least twice, and the processed prawns have a noticeably tougher texture than freshly caught prawns. Many consumers have now become accustomed to the tougher texture and prefer the processed prawns to freshly caught prawns which they consider to be 'too soft'. Some consumers think that prolonged cooking toughens prawns. This can be true for prawns that have been frozen or cooked already, but is not true for freshly caught raw prawns.

Bacterial contamination

Raw prawns must be boiled long enough to kill contaminating bacteria and inactivate enzyme systems. The boiled prawns must then be cooled quickly in clean water, iced and placed in clean containers to restrict the growth of bacteria. Nearly all the prawns which are caught for the domestic market are boiled and iced aboard the trawler soon after catching. In most instances the prawns are unloaded the same day that they are caught. Many people think, incorrectly, that it is unnecessary to be scrupulously clean when handling boiled prawns because the shell protects the flesh from bacterial contamination. However, it is easy to contaminate the flesh when peeling a prawn because most of the bacteria are found on

Fig. 3. Fisherman boiling prawns on a gas cooker. Photo: N. V. Ruello

the shell and head. As boiled prawns are intended to be eaten without further cooking, they must remain chilled while on retail display. Most modern shops now display prawns inside refrigerated cabinets which protect them from airborne bacteria and handling by the public, but it is still considered quite acceptable, if not traditional, to buy from a large heap of prawns which is often not iced and completely exposed to dust, flies and handling by the public.

Many prawns are taken from lakes at night by commercial fishermen using set pocket nets or by amateur fishermen using drag nets or hand-held scoop nets. It is common to cook and cool these prawns in the lake water. This water is often dirty, and sometimes the prawns can become heavily contaminated with bacteria. Outbreaks of food poisoning resulting from eating contaminated prawns have occurred, particularly in New South Wales during the late 1940s. Handling techniques have improved, but during glut periods large

quantities of prawns are still condemned because of 'black head'.

Quality of frozen prawns

Following the development of an export market, limited supplies of frozen raw prawns are now available on the domestic market. These are usually very large Banana prawns from northern Australia. The 'quality' of export prawns does not refer to their freshness, flavour and texture, but to the size and appearance of the prawns; small prawns are not exported regardless of their degree of freshness. 'Top quality' large prawns are those that only require heading before freezing and therefore the tail must appear perfect. This means that it must be free of discolorations and any signs of breakage. These defects often disappear when the shell is removed; thus so-called 'inferior quality' prawns are headed and partly shelled to form a cutlet. If the tail is broken or black, they are completely shelled to form meat.

The freshness and eating quality of tropical prawns mainly depends on how they are handled on the trawlers. Many problems were encountered in handling large catches of raw prawns caught in remote areas, but these have been overcome by freezing the prawns at sea. At the factory the prawns are thawed, headed and refrozen in export packs. Usually the prawns retain their freshness and eating quality despite double freezing. The exporters themselves apply strict quality standards for export prawns and sell their reject material to merchants who supply the domestic market. Sometimes, particularly in remote areas, reject prawns are processed with inadequate equipment under unhygienic conditions. Stale or spoiled prawns can be treated with chemicals which bleach black spot and remove 'off odours', and the treated prawns then pass as 'fresh' prawns. These chemicals cause changes in the appearance of the flesh and pigments but most consumers would not notice them and they are best detected by chemical analysis.

The availability and cost of 'top quality' prawns often only reflect export demand, so not all frozen prawns sold locally are of inferior quality. Freezing itself should not noticeably affect eating quality; it causes marginal loss of flavour and only slightly firms the texture if the prawns are well wrapped and kept at −20°C or below. Nevertheless, it is not uncommon for reject prawns to be tough, completely lacking natural flavour or to be excessively salty; but, regardless of their poor eating quality, they are very popular because most consumers are unfamiliar with freshly caught prawns. While the domestic demand for prawns remains strong it is unlikely that the quality of tropical prawns sold locally will improve as a result of buyer resistance to tough, tasteless or salty prawns.

Other frozen products

Some companies are producing breaded prawns, i.e. raw prawns that have been coated with bread crumbs and then frozen. The prawns are nearly always those that are too small for export but are often of excellent eating quality. Limited quantities of small prawns are boiled and marketed frozen. Packs of *i*ndividually *q*uick *f*rozen (IQF) boiled prawns of excellent eating quality are usually available in the large cities. IQF prawns should not be confused with the blocks of frozen imported cooked prawn meat from Asia. The latter are popular because the prawns are completely prepared and cheap, but unfortunately they are often of very inferior eating quality, being tough and tasteless, and in some instances carrying high numbers of bacteria.

Extract from CSIRO Food Research Quarterly
March 1977.

Physical data on uncooked prawns

This note summarizes the physical data required by Australian fishermen and processors to calculate, for instance, freezing rates or to determine the quantity of prawns which will fill tanks of chilled sea water.

The data were obtained from measurements on four commercial species of prawns, but the results probably apply to other species as well. The species tested were: tiger prawns, *Penaeus esculentus*; eastern king prawns, *P. plebejus*; school prawns, *Metapenaeus macleayi* and greentail prawns, *M. bennettae*. (Colour illustrations of three of these species—king, tiger and greentail, the latter being formerly known as *M. mastersii*, appeared in *Food Preservation Quarterly*, Vol. 30(2), June 1970, p.23.)

Freshly caught uncooked school, king and greentail prawns were collected from Tuggerah Lakes (N.S.W.) and from the Sydney Fish Centre, Pyrmont. The prawns were packed in ice and transported to the Food Research Laboratory at Ryde. Uncooked tiger prawns and large eastern king prawns were collected in Brisbane, packed in ice and air freighted to Sydney.

Size grades

The prawns were divided into three size grades according to their count per kilogram. Large prawns were those that numbered less than 40 to the kilogram, medium prawns were those that numbered between 40 and 90 to the kilogram and small prawns were those that numbered more than 90 to the kilogram.

Measurements

Samples of at least 50 prawns of each size grade and species were used to determine: the percentage recovery on heading and shelling to 'tail', 'cutlet' and 'meat'; percentage of adhering water; the true density and the load density. Before each determination the prawns were rinsed in water and drained for 20 min on an inclined (30°) No. 16 sieve. There were no samples of the large grade from the school or greentail species.

Percentage recovery after heading and shelling

Prawn 'tails' were prepared by removing the 'head' (cephalothorax) from the 'tail' (abdomen) with scissors. Prawn 'cutlets' were made by removing the shell of the first five abdominal segments by hand from the prawn 'tail' and prawn 'meat' was prepared by removing all the shell from the prawn 'cutlet'. The prawns were weighed before and after being headed and shelled and the recovery was calculated as a percentage of the initial weight.

Percentage of adhering water

Adhering water is defined as the water which fails to drain from freshly immersed prawns after 2 min on an inclined (30°) No. 16 sieve.

The prawns were drained for 20 min and then weighed (W_1). The drained prawns were then immersed in water and tipped onto a previously weighed No. 16 sieve (W_2); the prawns were drained for 2 min. The prawns and sieve were then weighed (W_3) and the percentage of adhering water was calculated as:

$$[(W_3 - W_2 - W_1)/W_1] \times 100$$

True density

The density of each whole, uncooked prawn was calculated by dividing its weight by its volume. The weight was measured after the prawns had drained for 20 min on an inclined (30°) No. 16 sieve. The volume was measured as the difference between the weight of a cylinder of water and the weight of the same cylinder of water containing a fully immersed, freely suspended prawn. If the weight of the drained prawn is W_1, the weight of the cylinder of water is W_2, and the weight of the cylinder of water and prawn is W_3,

the density of prawn $= W_1/(W_3 - W_2)$ g/ml.

Load density

The load density is defined as the weight

2.

Physical data of uncooked prawns

Property	Prawns Large (< 40/kg)	Medium (40–90/kg)	Small (> 90/kg)
Average percentage recovery on heading and shelling to:			
'tail'	57 (2·4)[A]	60 (2·4)	64 (2·7)
'cutlet'	50 (2·5)	52 (2·3)	54 (2·5)
'meat'	46 (2·5)	48 (2·5)	50 (2·6)
Average percentage of adhering water	5·5 (0·02)	7·5 (0·04)	10 (0·14)
Average density (g/ml)		1·08 (0·011)	
Load density in water (kg/m^3)		600	
Water content[B] (%)		70	
Average freezing point[B] (°C)		−2·2	
Specific heat above freezing[B] (J/kg °K)		$3·6 \times 10^3$	
Specific heat below freezing[B] (J/kg °K)		$1·9 \times 10^3$	
Latent heat[B] (J/kg)		$2·8 \times 10^5$	

[A] Values in parentheses are the standard deviations.
[B] 'ASHRAE Handbook of Fundamentals' (1972), page 573. (American Society of Heating, Refrigerating and Air-Conditioning Engineers: New York.)

of prawns which may be randomly packed into a water-filled container so that the water may move freely among the prawns. The load density was measured by means of a perforated plastic box with dimensions 0·6 m × 0·4 m × 0·3 m (0·072 m^3). The box was immersed in water, and then removed and allowed to drain for 20 min and weighed (W_1). It was then filled with drained prawns and immersed in water to ensure that the prawns were packed so that water could just move freely past them. The box and prawns were removed and drained for 20 min and weighed (W_2). The load density = $(W_2 - W_1)/0·072$ kg/m^3.

Results

The results of these measurements and other appropriate data on the physical properties of uncooked prawns are given in the accompanying table. No differences were noted between the species for any of the properties measured, but differences were found for the different grades of prawn for percentage recovery on heading and shelling and percentage of adhering water.

Acknowledgment

This research was financed by a grant from the Fishing Industry Research Trust Account.

JUDITH H. RUELLO

F 101

Reprinted from "FOOD TECHNOLOGY IN AUSTRALIA", Vol. 26, No. 5, MAY 1974, Pages 186-190
COMMONWEALTH OF AUSTRALIA
COMMONWEALTH SCIENTIFIC & INDUSTRIAL RESEARCH ORGANIZATION

HANDLING AND PROCESSING BANANA PRAWNS OF THE GULF OF CARPENTARIA

J. H. RUELLO
CSIRO Division of Food Research, North Ryde, N.S.W., 2113

SUMMARY

The banana prawn fishery of northern Australia aims at producing a high quality product mainly for export. This article discusses various problems encountered in the handling and processing of the prawn catch at Karumba, which make it difficult to maintain consistent high quality. Recommendations are made for overcoming these.

INTRODUCTION

During the past five years the Gulf of Carpentaria has become Australia's most important prawn fishery, and in 1970-71 it yielded more than half of the country's total prawn exports of 6.7 million kg, valued at $A17 million. Large prawn stocks in the Gulf were discovered by a joint Commonwealth and Queensland Government survey undertaken between 1963 and 1965, and a fishery rapidly developed in this region. About twenty vessels were fishing in the Gulf in 1967 when processing facilities were first established at Karumba (Fig. 1), but the numbers grew quickly and in 1970, at the height of the prawning season, there were about 250 vessels operating.

Several species are caught: the western king prawn, *Penaeus latisulcatus;* the endeavour prawn, *Metapenaeus endeavouri;* the banana prawn, *P. merguiensis;* and the brown tiger prawn, *P. esculentus.* The last two, and in particular the banana prawn, are by far the most important and in 1970 nearly 70 per cent of all prawns taken from the Gulf were banana prawns (Anon. 1973a).

Although, as the market stands at present, fishermen are able to sell all the prawns they can catch, the highest prices are paid for those that meet the standards required for export to Japan and the U.S.A., and it is in the interests of all concerned to turn out a product of the highest possible quality. This is not easy. Karumba, the main port and the major processing centre in the Gulf, is isolated and lacks modern facilities. Many of the prawning vessels were designed for southern fisheries and are not adequately equipped for the banana prawn fishery, a tropical fishery which presents the fishermen with special problems that are invariably greater than any they may have experienced with other species in more temperate regions.

An unusual feature of the fishery is that very large quantities of prawns can be taken within a short span of time. The prawns are caught during the day when they form dense schools and create "mud boils" that can be easily spotted from an aircraft. Catches of several thousand kg per trawl are not uncommon and sometimes it is possible to load a vessel to capacity in one day. Despite the obvious attractiveness of this type of prawning, the sheer quantity of the catch and the speed with which it is taken, often strain the capacity of existing equipment and crews.

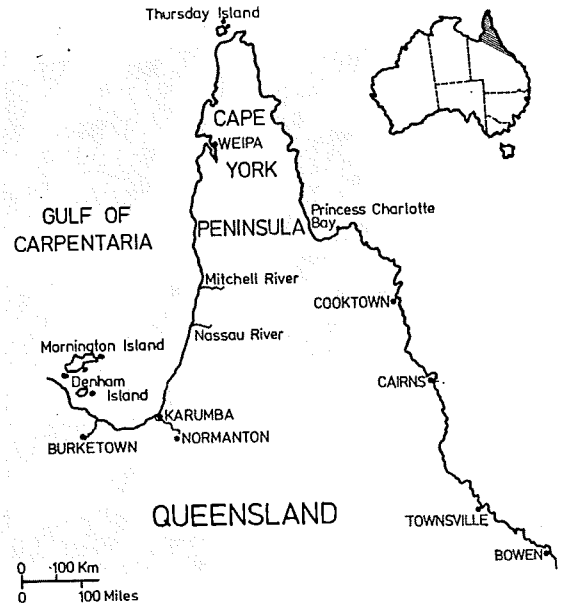


Fig. 1
Australia's most productive prawning grounds are found in the waters off the east coast of Queensland north of Bowen, and in the Gulf of Carpentaria. This map shows the main fishing ports and the centres for prawn processing.
(Photo: D.P.I. Fisheries Branch.)

HANDLING AND PROCESSING PROCEDURES

At sea

Once the catch is aboard the vessel the prawns are sorted from the trash, washed, and then stored in refrigerated sea-water (RSW) tanks. The vessels that are able to do this adequately are those that were especially designed and built for the banana prawn fishery. Most vessels, however, are equipped only with small sorting trays capable of holding up to 500 kg. When catches exceed this they cannot be sorted and washed efficiently, particularly as fishermen hurry to clear the deck in readiness for the next catch, which may be taken in less than 30 minutes. Facilities are so poor on some vessels that the crew does not even attempt to sort or wash the catch. This is especially true of vessels where the sorting tray forms the lid of the RSW tank (Fig. 2), or, alternatively, where the RSW tank is located a considerable distance from the sorting tray. On these vessels it is more usual for the catch to be emptied directly into the RSW tanks. Such a procedure has the advantage of quickly clearing the deck and rapidly cooling the warm prawns, but unfortunately the catch remains unsorted and unwashed.

Banana prawns are usually stored in RSW for at least a couple of days before they are unloaded. Most vessels have some equipment for the mechanical chilling of sea-water, but the most efficient sys-

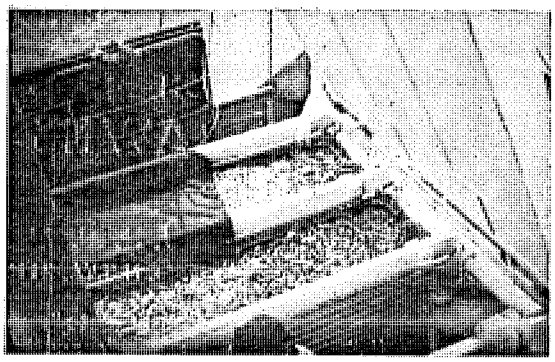


Fig. 2

The "Sortrite" suction unloader is being used to unload this catch at Karumba. All the brine has been pumped out of the brine tanks, as the prawns are sucked up the pipe at the far left of the picture.

tems are those in which the RSW is recirculated through an external heat exchanger, and thus some degree of temperature control is possible. In the majority of vessels the refrigeration coils are sealed within the walls of the tanks or else line its internal surfaces (Fig. 2). To prevent a build-up of ice on these coils fishermen add salt to the RSW, forming a "super-cooled" brine.

Although the widespread use of RSW has virtually eliminated the problem of spoilage, other defects may develop which can make prawns unsuitable for export. For instance, the prawns can develop black spot, an enzymatic discolouration which can be controlled by adding sodium metabisulphite to the RSW. High salt uptake may develop if prawns are stored in strong brine solutions for several days. Extensive physical damage may also occur as a result of excessive surging action of the RSW especially during rough sea conditions. Fishermen try to reduce the amount of damage by dividing the tanks into smaller units with wooden baffles, by pumping nearly all of the RSW out, or by letting it freeze, but none of these methods are entirely satisfactory.

Unloading

Not all vessels fishing in the Gulf unload at shore-based processing factories, many discharge their catches to factory ships rather than return to Karumba. At the peak of the season vessels have to queue for unloading facilities, and may be tied up beside the wharf for one or two days. Some of the difficulties associated with unloading can be attributed directly to poorly designed RSW tanks. Access to tanks built below deck is often severely restricted because of the limits imposed by the vessel's design, and unloading, whether by hand or machine, is slow. Tanks that use non-recirculating RSW become iced-up and must be thawed before unloading can commence. In tanks where refrigeration coils line the interior of the walls, prawns get wedged between the exposed coils and the walls, and are damaged when they are dislodged during unloading.

At Karumba, two methods of unloading are used. A "Sortrite"* suction unloader is used by at least one factory. It consists of a telescoping pipe connected to a cyclone chamber. Suction is created by a blower, and the prawns are separated from the air in the cyclone chamber and then delivered to the aqua-flow conveyor system. During unloading the pipe is lowered into the RSW tank (Fig. 2) and since the suction pipe is not flexible enough to be pushed into the corners of the tank, the prawns must be shovelled directly under the unloader. This mechanical method of unloading is fast but it results in a fair percentage of damaged prawns which do not meet standards because of broken tail fans or partial crushing.

Prawns are also unloaded by hand. They are removed by hand operated scoop from the RSW tanks and emptied into a large net basket on the vessel. The net basket is then raised and swung onto the wharf where the prawns are emptied into fibreglass bins. This unloading method gives rise to little physical damage, but it is very slow. A method similar to this is used to unload prawns from the catcher vessels to the factory ships.

Processing

Nearly all banana prawns sold for export are processed as blocks of frozen prawn "tails" or prawn cutlets (peeled "tails"); prawns of poorer quality are shelled and packed as prawn meat. Factories attempt to process a catch as soon as it is unloaded, and where this can be done a high quality product usually results; but if the catch is too big or for some other reason the factory is unable to handle it expeditiously, the unprocessed prawns are frozen in saturated brine. Both at shore-based factories and on factory ships, very large quantities of whole banana prawns are individually quick frozen (IQF) by immersion in saturated brine (at -18°C) (Fig. 3). Although this is an efficient way of preserving large catches, it is only a temporary measure as most of the banana prawns are not exported in the whole IQF form, but are simply stored in this form until it is convenient to process them fully. IQF prawns from factory ships are unloaded at ports in north Queensland and then sent to N.S.W. in refrigerated trucks for final processing. The effect of this double-freezing on the eating quality is unknown. In addition excessive salt uptake can occur during brine freezing. This can be avoided if the prawns are dipped into fresh water before and after freezing (Dassow, 1954), but at Karumba or on the factory ships no special precautions are taken to reduce salt uptake. Moreover, the prawns are brittle when deep frozen and extensive physical damage may occur

Fig. 3

I.Q.F. (individual quick freezing) of prawns in a brine immersion freezing unit.
(Photo: "Australian Fisheries").

* Registered trade name.

while they are being packaged and thawed.

During the peak of the season it is often not possible either to fully process or individually quick freeze the catch as it is unloaded, and the remainder is mixed with ice. If the prawns are to remain in prime condition in ice for several days, then they should be re-iced daily (Collins, Seagran & Iverson, 1960). It is tedious and difficult to mix large quantities of prawns with ice particularly if physical damage is to be avoided.

Only about half the prawns unloaded are processed at Karumba. The balance is packed in an ice-salt mixture in fibreglass bins, and sodium metabisulphite or sodium erythrobate is added to help prevent black spot formation. Some are transported by road to the east coast of Queensland before processing. The rest, intended for final processing in N.S.W., are "headed" at Normanton (80 km inland, Fig. 1) and the tails are packed in an ice-salt mixture in fibreglass bins and sent in canvas-covered trucks to northern N.S.W., a journey of three to five days.

Prawns that travel a long way before processing are liable to deteriorate on the journey. High salt uptake can occur because some of the catch is in contact with an ice slurry containing 12% salt. Sodium metabisulphite or sodium erythrobate create acidic conditions (pH 4.5) which may alter the texture of the prawns (Ahmed, Mendenhall & Koburger, 1973). The fibreglass bins do not provide sufficient insulation during these long journeys, particularly as they may be exposed to high winter ambient temperatures.

Other towns in the Gulf for instance Weipa, are used as unloading sites during the height of the season. As there are no processing facilities in these towns the prawns unloaded there are sent to the east coast of north Queensland for processing. At the peak of the banana prawn season many vessels may unload at these centres and facilities become so overtaxed that large quantities spoil soon after unloading and are dumped (Anon., 1973b).

QUALITY ASSESSMENT

These inefficient handling and processing procedures give rise to most of the defects that make prawns of too low a standard for export as prawn 'tails' and prawn 'cutlets'. The principal defect is physical damage. For instance many of the prawns' tail fans may be broken or the tails squashed; this may occur at any stage, yet could be greatly reduced by modifying the existing procedures. Damaged prawns are fully shelled and exported as prawn meat, a less lucrative export product. Black spot can be a problem in raw prawns. Although prawns with black spot are not necessarily unfit to eat, they are rejected because the presence of black spot suggests that the prawns have not been stored under the best conditions. Now that this defect occurs infrequently because of the widespread use of sodium metabisulphite or sodium erythrobate (used both to prevent and to bleach any black discoloration) it is possible for prawns to appear excellent and yet be of inferior quality. The bleached prawns may be unsuitable for export because of defects due to bacterial spoilage or excessive uptake of sulphite. In most instances these defects do not effect the prawns' appearance, they are usually only detected analytically.

Experimental. In order to assess the quality of the prawns from the Gulf of Carpentaria, samples were taken at different stages in the handling and processing system and laboratory studies were carried out to test for certain defects.

Salt Content. High salt content can affect eating quality in two ways. If it exceeds 2.5 per cent the prawns are unacceptably salty to most consumers, and if it exceeds 5 per cent the flesh becomes tough and rubbery (Montgomery, Sidhu & Christie, 1970). Method 18.009 of the Association of Official Agricultural Chemists (1965) was used to estimate the salt content.

Analysis of what is called RSW indicated that most fishermen add salt to increase the salinity of the sea-water from 3.5 per cent to between 5.6 and 6.8 per cent. However, the salt levels of most of the prawns unloaded at Karumba did not exceed 2 per cent; this was probably because they were stored on the vessels for no more than four days. One vessel was noted, however, to have stored its catch in a 6 per cent brine for 7 to 8 days and the prawns when unloaded, had a salt content of 3.2 per cent.

Thorough washing with fresh water during processing can reduce saltiness. However, this technique is of little significance at Karumba, because water is in short supply and the prawns receive only brief spray rinses. The water supply not being restricted at the processing centre in N.S.W., the prawns may be immersed in water for as long as 40 minutes and lose a good deal of their saltiness. Such a reduction in salt content is essential, because all banana prawns processed in N.S.W. have been brine frozen on a factory ship, or have travelled in an ice-salt mixture for three to five days. Salt levels of between 2.3 and 2.4 per cent were found in prawns that had been treated in either of these ways before processing.

Even though excessive salt levels were not often found, the present handling and processing practices do tend to bring about undesirable increases in salt levels in any prawns that are not fully processed immediately after unloading.

Sulphite Content: The sulphite content was estimated according to the method of Shipton (1954). Sulphite was found in the RSW of 60 per cent of the vessels examined, in most instances at concentrations below 100 mg/l; the prawns stored in these brines had not incorported any sulphite. The brine from one vessel had a sulphite level of 531 mg/l and the prawns 60 mg/kg, which considerably exceeds the export limit of 10 mg/kg.

As it is difficult for fishermen to control the level of sulphite uptake, it would be better if the prawns were dipped in a solution of sodium metabisulphite rather than being stored in RSW to which sodium metabisulphite has been added. This would provide sufficient protection against black spot and would also limit sulphite uptake.

Bacterial Counts. Total plate counts per gram (TPC) were estimated as follows: samples were homogenized according to the National Health and Medical Research Council (Aust. 1967) method, and plated on brain heart agar and incubated for five days at 20°C. Some samples were tested for the pre-

sence of the following pathogens: (1) *Vibrio parahaemolyticus*, (2) total coliform, (3) faecal coliform, (4) *Salmonella*, (5) Coagulase +ve *Staphylococci:* The techniques used were described by Thatcher and Clark (1968) [I, p. 108; II, Method 1. p. 72; III, Method 1. p. 77; IV, Method 2, p. 93, and V, Method 1. p. 115].

The total viable counts of bacteria on prawns after several days' storage in RSW were generally between 10^3 and 10^5/g. Similar TPC were obtained for both prawns and RSW indicating that the counts reflect the number of bacteria on the outer surface of the prawns. The relatively high counts on some prawns may be attributed to the presence of mud and fish slime, and much of the variation found is probably a result of variations in the sorting and washing procedures on board the vessels. In most vessels prawns are stored at temperatures below 0°C and this low temperature would be an important factor in limiting bacterial growth; on vessels where the catch is sorted and washed before being placed in RSW, bacterial spoilage rarely occurs.

No *Vibrio parahaemolyticus* or *Salmonella* were found, other pathogens were found in prawns from two vessels but in low concentrations. As coliform bacteria are not indigenous to prawns (Williams & Rees, 1952), they were probably of human origin, introduced while the catch was being handled. The presence of pathogens indicates the need to clean nets thoroughly, sorting trays, and RSW tanks, so as to prevent cross contamination. This is a difficult procedure as supplies of potable water are limited and water from the Norman River at Karumba contains factory effluent.

CONCLUSIONS AND RECOMMENDATIONS

Handling and storage methods in use on board most vessels damage a significant portion of the large banana prawn catches and unnecessarily introduce excessive amounts of salt and sulphite which affect the eating quality of the prawn. Even when prawns are unloaded in prime condition at processing centres, they cannot always be processed immediately and the stop-gap measures used by processors may lead to quality loss. There is no doubt that procedures could be introduced into the banana prawn fishery which would eliminate most of the problems discussed in this article; the cost, however, would be considerable. This fishery is characterized by markedly fluctuating catches, and because of economic uncertainties fishermen and processors are reluctant to expand their facilities.

If improvements are to be made a new approach is called for. The following recommendations, which should reduce many of the difficulties discussed, can easily be adopted on most prawn fishing vessels. Among the most important are containerization of the prawn catch on board the vessels, provision of an automatic dip tank for treating prawns for black spot, and the use of recirculating RSW in the storage tanks.

Handling the Catch. The catch should be emptied onto a sorting tray large enough to contain the entire catch from each trawl (the prawns should not be dumped onto the deck) and a canopy should be raised to shade the catch during sorting and washing. The prawns should be passed down a chute to a dip tank and mechanically passed through a sea-water solution of sodium metabisulphite. They should then be transferred to perforated lidded containers which are held in a main insulated tank through which RSW is recirculated.

Unloading the Catch. The individual prawn boxes should be quickly removed from the vessels and placed directly into waiting road transport or holding rooms of factory ships or processing factories.

Processing the Catch. To raise the quality of prawns exported from Karumba the prawns should be thoroughly washed in fresh water during processing. This is impossible with the present inadequate fresh water supply but the problem should be kept in mind if a better supply becomes available.

Transportation. Salt and sodium metabisulphite or sodium erythrobate should not be added to the mixture of prawns and ice in the fibreglass tank and the melting ice should be allowed to drain from the prawns.

Adoption of these recommendations would not involve a large financial outlay. It would considerably increase the efficiency of both fishermen and processors in handling the enormous catches, and at the same time reduce the incidence of physical damage and the other defects discussed.

ACKNOWLEDGEMENTS

I am indebted to Mrs Betty Stewart of the CSIRO Division of Food Research, North Ryde, for assistance with bacterial analyses. The CSIRO Division of Fisheries and Oceanography kindly provided facilities at their field station at Karumba. This work was partly financed by a grant from the Fishing Industries Research Trust Account.

REFERENCES

AHMED, E. M., MENDENHALL, V. T. & KOBURGER, J. A. (1973) *J. Fd Sci.*, **38**, 356.

ANON. (1973a) *An Economic Investigation of the Northern Prawn Fishery. Costs and Earnings of Trawlers, 1968/69 to 1970/71. Department of Primary Industry. Govt. Printer, Canberra.*

ANON. (1973b) *Aust. Fish.*, **32** (1), 2.

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS (1965) *Official Methods of Analysis*, 10th Ed. A.O.A.C., Washington.

COLLINS, J., SEAGRAN, H. & IVERSON, J. (1960) *Comml Fish. Rev.* **22** (4), 1. DASSOW, J. A. (1954) *Comml Fish. Rev.*, **16** (7) 1.

MONTGOMERY, W. A., SIDHU, G. S. & CHRISTIE, E. M. (1970), *CSIRO Fd Preserv., Q.*, **30**, 44.

NATIONAL HEALTH & MEDICAL RESEARCH COUNCIL (1967) Report 64th Session, p. 25. Govt. Printer, Canberra.

SHIPTON, J. (1954) *CSIRO Fd Preserv. Q.*, **14**, 54.

THATCHER, F. S. & CLARK, D. S. (1968) *Micro-organisms in Food: Their Significance and Methods of Enumeration.* University of Toronto, Press, Toronto.

WILLIAMS, O. B. & REES, H. B. (1952) *Tex. J. Sci.*, (1), 55.

PRINTED BY C. & E. IRONMONGER PTY. LIMITED, GOSFORD

How to handle and process the prawn catch

by Judith H. Ruello*

Prawns have an undeserved reputation of being difficult to preserve. Although they do not have the keeping qualities of meat and fish, fresh prawns can be kept in excellent condition for many days under particular circumstances before they begin to lose quality (i.e. before their appearance changes and their eating quality deteriorates). However once certain defects develop, it is impossible to restore them to the eating condition of freshly-caught prawns.

IT is well known that raw prawns are more difficult to keep fresh than boiled prawns, and that large catches of raw prawns are difficult to handle and preserve. These problems face the tropical prawn fishery of Australia and are being overcome by 'double freezing' the catch (i.e. freezing the whole prawns at sea and then thawing, heading and re-freezing them into export packs at shore processing plants).

What is not often fully appreciated by processors is that the manner in which prawns are handled aboard the trawlers irreversibly affects the quality of the final product. Sometimes further deterioration is caused by trying to mask spoiled prawns, but there is little a processor can do to restore quality. Fishermen usually know when prawns have lost quality because they observe a slow deterioration in the prawns aboard the trawler. However it is often difficult for a processor, who only sees the catch when it is unloaded, to assess how much the quality of the prawns has deteriorated when they are unloaded.

---

* Ms Ruello, an Experimental Officer with CSIRO Division of Food Research, North Ryde, NSW, has been doing research into prawn handling and processing under a grant from the Australian Government's Fishing Industry Research Trust Account. This article is based on a paper she gave to the 1975 Winter School for Seafood processors at Hawkesbury Agricultural College.

Far too often processors depend upon the opinion of the trawler skipper, who after all aims to sell the product as 'export quality'. Processors should be well informed about how raw prawns should be handled and stored aboard a trawler, and what can happen to them during brine and/or frozen storage. The manner in which the processor handles the prawns is important because they are mostly several days old when he receives them, and may be near the end of their storage life. This calls for expeditious handling.

Handling at sea

At sea the cod end of the net should be emptied on to the sorting tray large enough to hold the entire catch from each trawl, not on the deck, otherwise the prawns may be contaminated with bacteria, trodden on or damaged by shovels. Trash fish should be sorted from the catch and the prawns thoroughly washed with clean water to remove mud, sand and fish slime which contain bacteria.

Refrigerated sea water

Preserving raw prawns in refrigerated sea water (RSW) is a satisfactory method aboard trawlers that are not at sea for more than a week.

The sea water should be chilled to between 0°C and —1.5°C — i.e. at a temperature just above the freezing point of sea water and prawns. Fishermen often lower the freezing point of RSW by adding salt to their brine; this reduces the build up of ice on the refrigeration coils in the tank. When held in these 'super cooled' brines prawns rapidly take up salt. When the salt content exceeds 2.5 per cent they are too salty for most consumers; the flesh becomes increasingly firm and is unacceptably tough when the salt content exceeds 4 per cent.

Many fishermen prefer to store their catch in 'super cooled' brines at —4°C because under these conditions the prawns retain the appearance of freshly caught prawns for at least seven days. When prawns are stored in normal sea water at about 0°C for more than two or three days their appearance deteriorates. Black spot develops and the flesh softens and the head partially separates from the abdomen, giving the prawns an 'old' look. The appearance of these prawns contrasts sharply with that of those stored in 'super cooled' brines at about —4°C because the latter retain their freshly caught appearance. However appearance is no guide to quality because the flavour and texture of prawns held in 'super cooled' brines is irreversibly impaired by their high salt content. Nevertheless many processors tend to think, wrongly, that these prawns are fresher, and prefer them to prawns held in normal RSW at 0°C which actually have an eating quality almost identical to fresh-caught prawns.

The saltiness of prawns cannot be significantly reduced by washing during processing, and the textural changes are irreversible. The processor cannot tell if the salt content exceeds 2.5 per cent unless he eats the prawns, measures the salt content of the prawn flesh (simple test strips are available) or

measures the salt content of the brine. If the salt content of the brine exceeds 6 per cent it is more than likely that prawns stored for three days or more will have a salt content of at least 3 per cent.

It is preferable to store prawns in tanks equipped with a recirculating RSW system, as this gives better temperature control and prevents ice formation. Exposed refrigeration coils quickly ice-up, are difficult to clean, may corrode or rust and leave brown stains on the prawns' shell; sometimes the refrigerant may leak into the brine. In addition prawns become wedged behind the coils and are easily squashed and broken.

Black spot is a problem in raw prawns. It is caused by an oxidative enzymatic process which occurs rapidly in dead prawns. Its occurrence is not related to 'quality' or bacterial contamination or cleanliness of the brine or brine tank. The enzymes that form black spot are found naturally in prawn tissues; they are water soluble and with time will leach into the RSW or melting ice which will blacken. The rate at which prawns blacken will depend upon a number of factors: storage temperature; length of time stored; handling before RSW storage; condition of prawns (soft shell, and frozen/thawed prawns blacken faster than freshly caught hard shelled prawns); length of time in trawl; exposure to air; species of prawn.

Black spot can be effectively controlled by briefly dipping prawns in a dilute sulphite solution. A 30-second dip in a 3 000 parts per million (p.p.m.) sulphite solution will control black spot formation for up to eight days for most species if the prawns are subsequently stored in RSW at 0°C to —1°C. To be successful, the dip solution must have the correct concentration of sulphite; Merck* sulphite test papers can be used to check this. Furthermore, it is important that the sulphite powder is stored in a sealed drum and kept in a dry cool place to ensure that it remains potent.

When carefully used, sulphite causes no noticeable effect on the eating quality of prawns. However haphazard application can result in an unnecessarily high sulphite uptake which causes changes in color, flavour and texture. It is common for trawler skippers to add sulphite directly to the RSW; this method is ineffective unless high concentrations of about 500 p.p.m. are used. However if this high concentration is used the sulphite content of the prawn flesh will exceed 30 p.p.m., the permitted Australian limit. One simple way to detect sulphite is to check the RSW, using Merck test strips which measure sulphite directly up to concentrations of 500 p.p.m. Processors should be prepared to reject prawns stored in RSW containing 500 p.p.m. or more sulphite.

Contrary to popular belief, bacterial spoilage has not been found to be a problem in the tropical fishery of Australia. This is probably because many of the bacteria found naturally on prawns in these warm waters quickly die when they are chilled at 0°C. There are a number of other factors which are responsible for the low numbers of bacteria on the prawns. These include: clean brine tanks; most chemicals used to stop black spot also kill bacteria; the catch is usually well chilled; the catch is usually disposed of before large numbers of bacteria can grow at the low storage temperatures. The spoilage that does occur is caused by enzymes in the prawn tissue. It becomes noticeable after about eight days of RSW storage, depending upon storage temperature. After about eight days, bitter off-flavours begin to develop, and these can only be detected by tasting the flesh. Bacteriologically spoiled prawns will have a distinctive 'off' odour, and the flesh will begin to whiten.

Freezing at sea

Regardless of whether immersion brine freezing or blast freezing methods are used, it is important that the internal temperature of the prawn is reduced to at least —15°C as quickly as possible. Blast freezing at sea is becoming increasingly popular because it requires less handling of the catch, and the vessels can remain at sea for several weeks. The prawns must be well wrapped before being placed in the freezer to prevent dehydration and freezer burn. It is important not to overload the freezer, and it should be remembered that cold storage rooms are not designed to be used as blast freezers.

Frozen prawns may be kept at —15°C for less than one month, but for longer storage, they should be kept below —20°C. Freezer burn will develop in unwrapped, unglazed prawns; this causes the flesh to dry out and toughen, and 'white patches' will appear on the shell. Freezer burn can be controlled by: glazing and wrapping prawns; maintaining the temperature of the cold storage room constant (i.e. no 'hot spots'); making sure that the temperature of the storage room does not fluctuate between a day/night cycle or cut out when some other equipment comes into use. The worst way to store prawns is to expose them to a cold current of air. This occurs when Individually Quick Frozen (IQF) prawns are stored in net bags.

Unloading

The processor is often faced with the problem of unloading a catch of prawns from a trawler quickly without the prawns warming up or becoming damaged when removed from the RSW. Prawns should not be allowed to warm up to 5°C, particularly if they are several days old. Sudden rises in temperature accelerate black spot formation. Prawns should be kept in a rigid perforated container during RSW storage. This containerisation facilitates RSW storage and unloading. Net bags are commonly used, but they do not protect the more delicate parts of the prawn from breaking; furthermore the bags do not support the prawns, and they often get squashed.

After prawns are unloaded they should be placed in an insulated container for transport to the factory. Ideally the prawns should be immersed in chilled sea water as this reduces contact with air. Frozen prawns are usually simpler

*Registered trade name

and faster to unload because they are already in some sort of a container. IQF prawns loose in net bags must be handled carefully otherwise they readily damage.

Storage for processing

It would be ideal if fresh prawns were held in containers in tanks of recirculating RSW chilled to between —1.5° and 0°C. The RSW not only chills the prawns, but reduces contact with air and development of black spot. This method is preferable to icing, because the latter is labor intensive and the extra handling involved in icing damages many prawns. Iced prawns are also more exposed to air which enhances development of black spot. Some processors prefer to ice prawns, and add large quantities of salt and sulphite to extend storage life. This is an ineffective way of treating prawns because no control occurs until the ice melts and washes the prawns with a concentrated sulphite solution. Also, if sulphite powder comes in direct contact with the prawn the shell tends to be 'burnt' by the acidic conditions which cause white patches on the shell. Furthermore the flesh in these localised areas also becomes white and tough. As the ice melts, it slowly dissolves the salt and sulphite and bathes the prawns at the bottom of the bin in a salty, acidic solution of high sulphite concentration. This causes high salt and sulphite uptake (and the acidic conditions toughen the flesh); these prawns often contain 3 per cent salt and 300 p.p.m. sulphite.

Processing facilities

The area in which export prawns are processed must meet Department of Primary Industry requirements. Although some of these conditions seem unnecessarily harsh to processors they are based on sound hygienic principles. Some aspects which are not covered in the Exports (Fish) regulations which are important to clean, efficient processing are listed. They include:

Air conditioning. This is desirable in factories operating in tropical Australia for many reasons. It helps keep prawns cool; means windows and doors can be closed thus keeping out flies and dust; makes working conditions more pleasant and protective clothing more comfortable and tolerable for staff.

Protective clothing for staff. Staff at the processing tables should be encouraged to tie their hair up and wear rubber gloves, rubber aprons and boots. This helps to ensure minimal bacterial contamination of prawns.

Processing equipment. In addition to meeting standards for cleanliness etc. the equipment should be aligned so that prawns do not spill on to the floor.

Mixing stale and fresh prawns. Some staff place a few spoilt prawns in a pack of good quality prawns, hoping that the inferior prawns will not be noticed. This should not be encouraged.

Storage of frozen prawns before processing. Unprocessed prawns should be held under the same conditions as the final product — i.e. at below —20°C and well wrapped to prevent freezer burn. Sometimes processors keep prawns for months until the market improves so it is essential that they are stored under ideal conditions.

Processing for export and domestic market. Any establishment which processes prawns, either for the export market or the domestic market should meet the minimum hygiene standards set by the Department of Primary Industry. At present only establishments that process prawns for export are required to meet Department of Primary Industry standards.

Quality assessment

Guidelines listed below may help processors evaluate raw prawns by their appearance and smell:

1. Well-handled prawns should not be damaged or squashed; prawns may be heavily contaminated with bacteria if handled excessively or poorly.
2. The flesh should be firm and a pale, olive green colour, depending upon species. Firm, dry flesh may be found in prawns with high salt content.
3. Prawns with loose heads should not be regarded as spoiled, they are just 'old', they may not look good, but may still be of excellent eating quality.
4. Prawns with 'milky' flesh should not be processed. This defect is frequently caused by certain parasites. Some fungal infections cause pigmentation changes.
5. The presence of a thin white skin only millimetres thick may indicate spoilage. Spoiled prawns also have a lot of pink pigmentation, particularly along the 'back'. Prawns that have an 'off' odour are definitely spoiled. Remember to smell them when they have warmed up slightly — the odour is difficult to pick at 0°C.
6. The presence of some black spot should not mean that the prawns are spoiled. If it is confined to the shell, simply remove it and process the prawn as cutlets or meat.

Chemical treatment to mask spoilage

Unfortunately some trawler skippers and processors have been known to treat prawns with chemicals to mask certain defects. Prawns are commonly bleached to remove black spot or soaked in chemical solutions to remove the 'off' odour of spoilt prawns. These chemicals change the appearance, colour and eating quality of the prawns, and when thawed, an offensive smell immediately indicates spoilage; chlorine bleaches react with the flesh to produce particularly offensive odours which are only noticeable when the prawns are thawed. These practices should be stopped.

Commonwealth of Australia
Commonwealth Scientific and Industrial Research Organisation

Division of Food Research

Reprinted from *Australian Fisheries 35 (2): 10-12*

Commonwealth of Australia
Commonwealth Scientific and Industrial Research Organisation

Storage of prawns in refrigerated sea water

by Judith H. Ruello

Metabisulphite dipping machine

by Alister K. Sharp

Reprinted from *Australian Fisheries,* Vol. 33 No. 2 February 1974

These reprinted articles are based on papers presented at the National Prawn Seminar at Maroochydore, Queensland, in November 1973.

Judith Ruello is an experimental officer and Alister Sharp is a research scientist at the CSIRO Division of Food Research, North Ryde, N.S.W.

Storage of prawns in refrigerated sea water

oy Judith H. Ruello

Recent research has shown that in certain circumstances eastern king prawns (Penaeus plebejus) can be held in refrigerated sea-water for up to six days and still retain the eating qualities of freshly caught prawns.

DURING the past five years the Australian prawning industry has expanded spectacularly, and the technology for handling and storing prawns on board fishing vessels has undergone dramatic changes. Mechanically refrigerated sea water (RSW) has replaced ice as the cooling and storage medium on most of the large prawning vessels.

There are many advantages in using RSW instead of ice. Not only are prawns cooled more rapidly when immersed in RSW, but the tedious and sometimes difficult task of icing prawns at sea is eliminated. In addition longer trips are possible as fishermen do not have to store large quantities of ice.

It has also been reported that prawns stored in RSW look more appetising and have a more acceptable flavour and texture than ice-stored prawns[1, 2]. The spoilage rate in RSW at —1°C is slower than in ice at 0°C because bacterial growth is reduced by half[1].

Prawns have a limited storage life in RSW, since substantial physical and chemical changes can occur. Deterioration may be brought about by enzymatic changes (principally the development of black spot), uptake of the chemicals which are added to the RSW to extend storage life, or by bacterial spoilage or physical damage.

Our research has been concentrated on finding economic ways of checking black spot, on investigating the uptake of salt (which occurs in prawns stored in 'super-cooled' brines), on evaluating methods for assessing quality and determining the importance of bacterial growth.

Control of black spot

Black spot or melanosis is characterised by a blackening of the head, the abdominal shell segments, and the tail fan. It is caused by the action of enzymes present in prawns which, through a series of reactions, oxidise certain compounds to produce black melanin pigments.

Black spot readily develops in dead prawns especially when they are held under dry refrigeration. Storing them in RSW delays the development of black spot, principally because the amount of oxygen available to the prawn is reduced[3]. Unless special precautions are taken black spot will develop in prawns held in RSW at or below 0°C if they are stored for more than two or three days.

Although prawns with black spot are not necessarily unfit to eat, their unattractive appearance makes them unacceptable to consumers, and its presence also suggests that the prawns have been poorly handled and stored. A traditional method of preventing this discoloration is to boil the catch soon after landing, but now that the export market demands raw prawns other measures must be considered. The following methods of preventing black spot were investigated by the author.

Use of carbon dioxide and nitrogen gases: It should be possible to displace the dissolved oxygen (O_2) from the RSW by bubbling carbon dioxide (CO_2) or nitrogen gas (N_2) through the water, and in this way prevent the formation of black spot. The addition of N_2 to the RSW in a laboratory-scale brine tank delayed the development of black spot for only one day, and after seven days' storage at 0°C the prawns were extensively blackened.

Prawns held in RSW to which CO_2 gas had been added did not develop black spot after seven days. However this was not due to the displacement of dissolved O_2 but to the acid conditions produced when CO_2 dissolved in the RSW. RSW to which CO_2 was added became acid (pH 5.8) after one day, whereas normal RSW (i.e. control) and RSW with N_2 added became increasingly alkaline (pH 8.2).

Although the addition of CO_2 to the RSW prevented black spot, prawns stored in this medium were unacceptably tough after cooking, whereas the texture of both the control prawns and prawns stored in RSW to which N_2 was added was indistinguishable from freshly caught prawns. The acid conditions also partly dissolved the shell, giving the prawns a 'soft shell' appearance. These results suggest that adding CO_2 to RSW is not a desirable method of extending storage life.

Buffered sea water: Prawns stored in RSW buffered with citric acid and sodium phosphate were held at —1.5°C for six days, and the pH of the RSW was adjusted daily to approximately 6.2. After six days all the prawns stored in normal sea water had black head and 50 per cent had abdominal black spot. Two-thirds of those stored in buffered sea water had black head but none developed abdominal black spot (Fig. 1).

After cooking, the colour of the prawns stored in buffered sea water was slightly duller than that of the control prawns, but the former was nevertheless acceptable. Although the flavour of the control prawns was preferred to those stored in buffered sea water, the firmer texture of the latter was preferred.

This method of preventing black spot could have commercial application, as it is a simple procedure to add chemicals to the

recirculating RSW and to check the pH daily. Prawns stored in this medium showed no deterioration in flavour, texture or appearance (other than black head) after six days.

Sodium metabisulphite as black spot control

Of the many chemicals that have been tried sodium metabisulphite is probably the cheapest and the most effective means of controlling black spot[4, 5]. The standard treatments[4, 5] require immersion of prawns for 2-10 minutes in dilute solutions of sodium metabisulphite. These relatively long dips are impractical in prawn fisheries where large quantities have to be treated quickly. Our investigations were therefore aimed at finding the minimum immersion time which would prevent the development of black spot for at least eight days at —1.5°C. Experiments were also conducted to ascertain the suitability of adding sodium metabisulphite directly to the RSW.

As prawn flesh readily takes up sulphite the success of these treatments depended on having a residual sulphite level of less than 10 mg/kg (wet weight) — the Australian export limit.

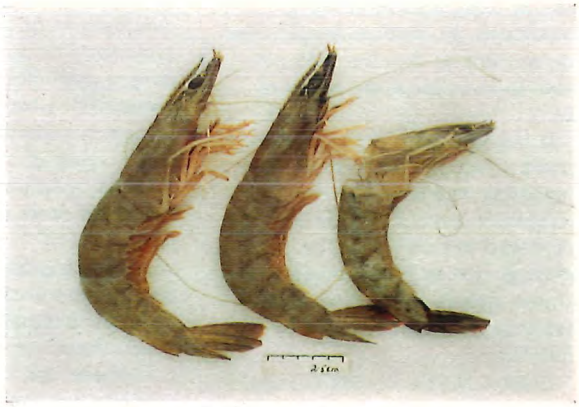
As a dip: Immersion for 30 seconds in a 5 grams per litre (5 g/l) solution of sodium metabisulphite provided complete protection against black spot during eight days' storage in RSW at —1.5°C. Although the sulphite level for raw prawns was high (15 mg/kg), this was reduced to 0-10 mg/kg after cooking or washing for 30 minutes. Using more concentrated dips for a shorter time did not prevent the development of black head, even though a sulphite uptake of between 50 and 100 mg/kg occurred.

Added to RSW: The addition of sodium metabisulphite to RSW is a simple way of preventing black spot, and is the method commonly used on Australian vessels. However our experiments have shown that this method is ineffective in preventing black spot unless high concentrations of sulphite are used.

Initial sulphite concentrations of 100 mg/l or less in the RSW were ineffective in preventing black

1

3



2

4

1. Only black head distinguishes prawn (lower) stored for six days in buffered sea water at 0°C from a freshly-caught prawn (upper).

2. Common and easily recognisable defects — freezer burn in prawn (upper) and excessive bleaching with sodium metabisulphite in prawn (centre) — contrast with a freshly-caught prawn (lower).

3. Prawn (left) stored in brine at —4°C for seven days cannot readily be distinguished from a freshly-caught prawn (centre). Both contrast sharply with prawn (right) stored in normal sea water at —1.5°C, which shows black spot and a partially-detached head.

4. Other physical defects which exclude prawns from export include physical damage (upper) and soft shell (centre), and are obvious when compared with a freshly-caught prawn (lower).

spot for six days at —1.5°C. With an initial concentration of 500 mg/kg no abdominal black spot developed, but 50 per cent of the prawns developed black head. If the concentration was maintained daily at about 500 mg/l (by adding more sulphite to the RSW as it was used up), black head did not develop, but the sulphite level in the flesh after cooking and washing was high (26 mg/kg).

When sodium metabisulphite is added to RSW the water becomes acid (pH 4.5), but will revert to alkalinity (pH 7.7) if the concentration of the sulphite is below 500 mg/kg; if it is maintained at 500 mg/kg or higher, the RSW remains acid (pH 5.5). The texture of the prawns stored in acid RSW was slightly firmer than that of prawns stored in normal sea water, and the firmer texture was preferred by most tasters.

The degree of toughness which developed in prawns after the addition of CO_2 to the RSW did not occur here. A low pH alters the texture of prawns, but the pH must drop below 4 for toughness to be noticeable[6].

Disadvantages: Indiscriminate use of sodium metabisulphite results in high uptake by the flesh, and so reduces the prawn's eating quality. Although there is no evidence that it is harmful to eat prawns with high sulphite content, they would be unacceptable because of their bitter sulphite flavour. If prawns are exposed to concentrated solutions high uptake occurs, but in addition the natural pigments and any black melanin pigments are bleached. These bleached areas usually appear pink when the prawn is raw (Fig. 2) and turn white once the prawn is cooked.

The sulphite content of many foods may be reduced by prolonged boiling. However the normal cooking times for prawns are too short to bring about a significant reduction. Washing for 30 minutes in fresh water significantly reduces the sulphite level, but it is not always desirable or possible to wash prawns before processing.

Commercial use: Our experiments strongly indicate that sodium metabisulphite is best used as a dip, because this gives complete protection against black spot and avoids high sulphite levels in unprocessed prawns. The addition of sodium metabisulphite to the RSW is not recommended because most people add too little or too much; furthermore this method would be suitable only for tanks equipped with recirculating RSW, which ensures equal distribution of the sulphite.

In tanks without circulating RSW local concentrations can occur, and this leads to a high uptake by some prawns. Chemical test papers are now available which can be readily used to estimate sulphite concentrations in the RSW.

If the sulphite is continually maintained at 100 mg/l (by adding more sulphite each day as it is used up) it is most probable that abdominal black spot will be prevented and sulphite uptake will be negligible; however black head may still develop.

'Super-cooled' brines

It has become common practice to store prawns in a partially frozen state in strong brine solutions. The principal reason why fishermen use this storage method is that the prawns retain their freshly caught appearance for at least seven days (Fig. 3).

When prawns are stored in normal sea water at 0°C or —1.5°C for more than two-three days their appearance deteriorates. In addition to the development of black spot the flesh softens and the head partially separates from the abdomen, giving the prawns an 'old' look (Fig. 3).

Although these prawns may look unappetising, our experiments showed that their eating quality may still be excellent, since their salt content cannot exceed 1.9 per cent.

Considerable quantities of salt must be added to sea water to reduce the freezing point to about —4°C. When prawns are stored for several days in these brines they rapidly take up salt. Uptake of salt is apparently affected by the temperature of the prawn; if it remains at —4 ± 0.5°C the salt content does not exceed 2.8 per cent but if it rises above the freezing point of the prawn (—2°C) salt level exceeds 4 per cent.

Prawns stored in strong brines at about —4°C have an excellent appearance, but this is no guide to quality because their flavour and texture are impaired by their high salt content. If this exceeds 2.5 per cent the prawns are too salty for most consumers[7]. The flesh becomes increasingly firm and is unacceptably tough when the salt content exceeds 4 per cent. Also it appears that the eating quality of salty prawns cannot be improved by processing, as the textural changes are irreversible, and washing for up to 30 minutes in fresh water only slightly reduces the salt content.

It appears that this storage technique is only successful when the temperature of the brine is carefully maintained at —4 ± 0.5°C. Since few vessels can do this, prawns stored for more than three or four days in these brines would have salt contents exceeding 4 per cent. With so high a salt content the prawns would be unacceptably salty and tough.

Quality assessment

Raw prawns destined for export are at present assessed by their smell and their appearance. These evaluations are useful for some defects (Figs 2, 4), but frequently they lack uniformity and are often of little value, because it is possible for spoiled prawns or prawns with high salt and sulphite contents to appear excellent.

Various chemical tests can establish that the prawns have spoiled — for example the estimation of total volatile bases (TVB) and trimethylamine (TMA). These tests however do not indicate at what stage loss of prime quality occurred.

A most useful and simple test for loss of prime quality is the measurement of the pH of the prawn after the flesh has been homogenised in water[8, 9]. The pH of a homogenate of freshly caught *Penaeus plebejus* was 6.9, and our experiments showed that during storage the pH gradually

increased until it reached 7.6. The pH did not rise above 7.6 unless spoilage had occurred. Our experiments indicated that prawns are of prime quality if the pH of a homogenate of the flesh is below 7.5, since this indicated a storage life of less than four days in RSW.

As the pH does not rise above 7.6 during the sixth, seventh and eighth days of storage in RSW other tests are essential to determine the quality. When the pH is greater than 7.5 organoleptic assessment (by taste testing) in conjunction with TMA and TVB estimations should be used to determine if the prawns are acceptable.

Bacterial spoilage: The rapid deterioration of prawns has been attributed to the action of bacteria, but bacterial counts do not necessarily give an accurate index of quality[9, 10, 11]. High and variable bacterial counts have been found in freshly caught prawns[12, 13].

The high variability in the numbers of bacteria was attributed to the presence of mud and fish slime on the surface of the prawns[12, 13]. In addition, it was found that the initial bacterial load was reduced by 45 per cent after thorough washing in clean sea water, and by 90 per cent after removal of the head[12, 13].

Low numbers of bacteria were found in freshly caught and washed *Penaeus plebejus*, and they rose only slightly after six days' storage in RSW at —1.5°C. Similar numbers of bacteria were obtained for the RSW, indicating that the majority of the bacteria were located on the surface of the prawns.

These results demonstrate that bacterial spoilage is not significant during the first week of storage in RSW at —1.5°C if the prawns are thoroughly washed before placing in the storage medium.

Recommended method of storing in RSW

I have described experiments in which prawns were held in recirculating RSW at —1.5° or 0°C and after six days still retained the excellent eating qualities characteristic of the fresh product.

Although these prawns were handled under optimal conditions it should be possible for fishermen to duplicate the results on vessels currently in use. We cannot do much to improve the condition of the prawns as caught, but the techniques used to sort, wash and store the catch will determine storage life and ultimate eating quality.

Prawns should be emptied on to a sorting tray large enough to contain the entire catch. In warm climates a canopy should shade the catch during sorting and washing. Before the catch is placed in the RSW it should be dipped into a solution of sodium metabisulphite to stop black spot.

It would be preferable to store the catch in perforated containers to prevent damage occurring during RSW storage at sea and during unloading. The most suitable type of storage tank is one in which the RSW is recirculated through an external heat exchanger because some degree of temperature control is possible and 'icing-up' is avoided.

If the catch is emptied directly into the RSW without sorting or washing rapid bacterial growth may occur, since not only are the prawns contaminated but the trash fish carry heavy bacterial loads. Because these prawns have not been dipped black spot will develop after one to three days' storage.

Prawns that are sorted and washed and then treated for black spot as described above should retain the eating quality of fresh prawns for as long as six days if stored in normal sea water chilled to —1.5° or 0°C. Prawns held in this way will not be salty or tough, and extensive washing with fresh water before processing will not be necessary.

REFERENCES

1. ROACH, S. M., HARRISON, J. S. M., and TARR, H. L. A. (1961). — Storage and transport of fish in refrigerated sea water. Bulletin No. 126, Fish. Res. Bd, Canada.
2. NAYAR, M. R., IYER, K. M. and APPAKULTAN, P. N. (1962). — *FAO Indo-Pacific Fisheries Council 10th Session, Seoul.*
3. FIEGER, E. A. (1951). — Ice and Refrig. **120**(4), 49-50, 64.
4. FAULKNER, M. S., WATTS, B. M., and HUMM, J. M. (1954). — *Food Res.* **19,** 302-310.
5. ESTABLIER, R. (1969). — *Investigación pesq.* **33,** 55-68.
6. AHMED, E. M., KOBURGER, J.A., and MENDENHALL, V. T. (1972). — *J. Texture Stud.* **3,** 186-193.
7. MONTGOMERY, W. A., SIDHU, G. S., and CHRISTIE, E. M. (1970). — *CSIRO Fd Preserv. Q.* **30,** 44-50.
8. BETHEA, S., and AMBROSE, M. E. (1962). — *Comm. Fish. Rev.* **24**(3), 7-10.
9. VANDERZANT, C., and NICKELSON, R. (1971). — *J. Milk Fd Technol.* **34,** 115-18.
10. CAMPBELL, L. L. Jr., and WILLIAMS, O. B. (1952). — *Fd Technol.* **6,** 125-126.
11. CARROLL, B. J., and REESE, G. B. (1968). — Microbiology of iced shrimp; excerpts from the 1965 Iced-Shrimp Symposium, Circular 284, Fish Wild. Serv., Wash.
12. GREEN, M. (1949). — *Food Res.* **14,** 372-83.
13. WILLIAMS, O. B., REES, J. H. B., and CAMPBELL, L. L. (1952). — *Tex. J. Sci.* **4,** 49-58.

Metabisulphite dipping machine

by Alister K. Sharp

A prototype dipping machine which will enable an operator to treat 5000 kg of prawns an hour with sodium metabisulphite is being constructed in the workshops of the CSIRO Division of Food Research. It was designed by the author.

FRESHLY caught prawns have a limited storage life in refrigerated sea water because of a variety of biochemical changes, the most obvious of which is the enzymatic reaction that results in black spot.

It has been shown (Ruello, 1974) that the development of black spot can be controlled by dipping the prawns for 30 seconds in a 5 kg/m^3 (5 grams per litre) solution of sodium metabisulphite before storing them in refrigerated sea water.

The main deterrent to adopting this procedure is the amount of labour and time required to dip and drain the prawns, one basket at a time. The dipping machine reduces the labour required for the job to such an extent that one deck hand can dip the entire catch and still have time to help with the sorting.

It is envisaged that after sorting and washing the prawns will be emptied into standard perforated plastic lug boxes (approx. 0.6 m x 0.4 m x 0.3 m), each of which can hold approximately 43 kg (95 lb) of prawns. If necessary, sorted prawns can be washed as they move down a perforated chute; jets of water, both from above and below, remove sand, mud and fish slime, and also provide sufficient buoyancy to flume the prawns into the lug box. When full the box is pushed along a slide to the prawn dipper.

The prototype prawn dipper (see illustration) comprises a drum capable of holding four lug boxes which revolves in a tank containing the dipping solution. The overall dimensions of the dipper are approximately 1.4 m (4 ft 6 in.) high, 1.5 m (5 ft) long and 0.9 m (3 ft) wide, excluding the loading and unloading ramps. Continuous rather than intermittent rotation of the drum was chosen for the prototype in view of cost and reliability.

The drum is driven from an electric gear-motor which has an output speed of one revolution very two minutes (i.e. ½ RPM). The drive to the drum is taken by a chain and sprockets, allowing the drum speed to be set at ¼, ½ or 1 RPM. The lengths and slopes of the loading and unloading ramps can be adjusted to suit the particular installation.

When the machine is in operation a box of fresh prawns is pushed from the loading ramp into a vacant position in the drum. As the drum revolves the box slowly submerges in the solution. The rotary motion of the drum ensures that all air is displaced, and no part of any prawn escapes contact with the solution, as might happen if the box were merely lowered into a bath.

After being immersed for approximately a quarter of a revolution (30 seconds at ½ RPM) the basket emerges and drains for a similar period before reaching the discharge position, when it is pushed from the drum on to the unloading ramp. The unloading ramp slightly precedes the loading ramp to allow time for the dipped basket to be removed from the drum before a fresh basket is loaded.

In the prototype dipper loading and unloading are performed manually, but it would not be difficult to mechanise these actions. In either case intermittent rotation of the drum might be preferred to continuous rotation, and could be arranged either by switching off the motor or by the use of a mechanical linkage such as a Geneva-movement.

With time the concentration of the active ingredient of the solution will fall because of uptake by the prawn flesh and dilution by sea water adhering to the fresh prawns (approx. 5 per cent of the weight of drained prawns). Therefore fresh chemicals must be added to the dip tank from time to time.

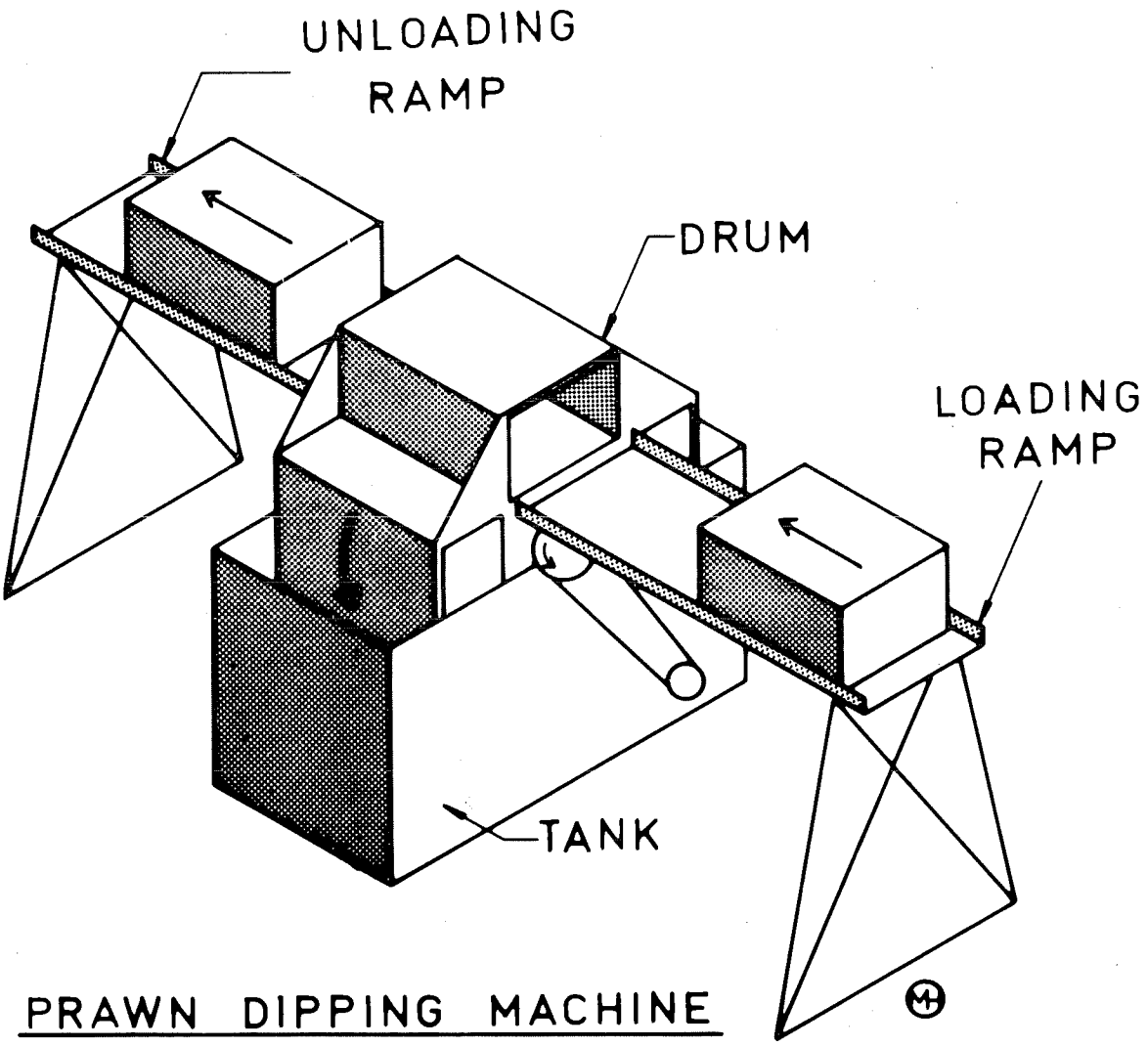
In the prototype, in which sodium metabisulphite is used as the preservative, a concentrated solution is added manually whenever chemical test papers show this to be necessary. However for long-term use it would probably be feasible to drive a metering pump from the drum shaft, and thus add a concentrated make-up solution continuously whenever the dipper is in use. The operator would then need only to ensure that the make-up tank always contained a supply of concentrate.

Both the drum and the tank of the prototype are constructed of marine plywood and finished with an epoxy resin. The loading and unloading ramps are also made of marine plywood, and have nylon rubbing strips to reduce friction. Because the solutions used are acidic all metal parts in contact with the solution, including the support shaft and all fastenings, are made from 316 stainless steel. The shaft is hollow, to save both money and weight, and runs in plain bearings machined from nylon blocks.

Drive from the 200 watt (i.e. ¼ HP) gear-motor is by mild steel pintle chain running on cast iron sprockets. Although liable to corrosion by salt water the chain used has adequate clearance to cope with the harsh marine environment. The drum of the prototype dipper can be easily withdrawn from the tank for ease of transport.

It is envisaged that when the tank is mounted on deck it would be secured to the side of the vessel's sorting tray. A large diameter drain plug is provided for cleaning, and a small overflow pipe prevents over-filling while avoiding excessive loss which might be caused by surging in rough weather.

When operated at ½ RPM, giving a 30 second dip, this machine will dip two lug boxes of prawns each minute, which is equivalent to 5,000 kg (11,000 lb) of prawns an hour, an adequate rate for most fisheries.



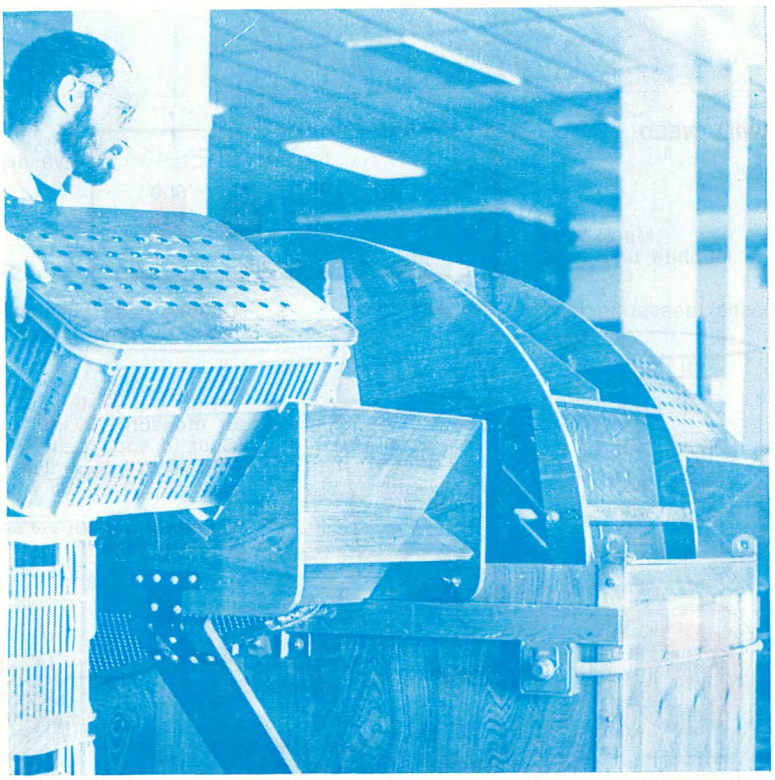
PRAWN DIPPING MACHINE

REFERENCES

Ruello, J. H. (1974).—
Aust. Fish. 33, 6-9.

Control of black spot in prawns

How fishermen and processors can use sulphite to control the development of black spot in raw prawns.



CSIRO prawn dipper undergoing tests at the Queensland Fish Board's Processing Division at Colmslie, Brisbane.

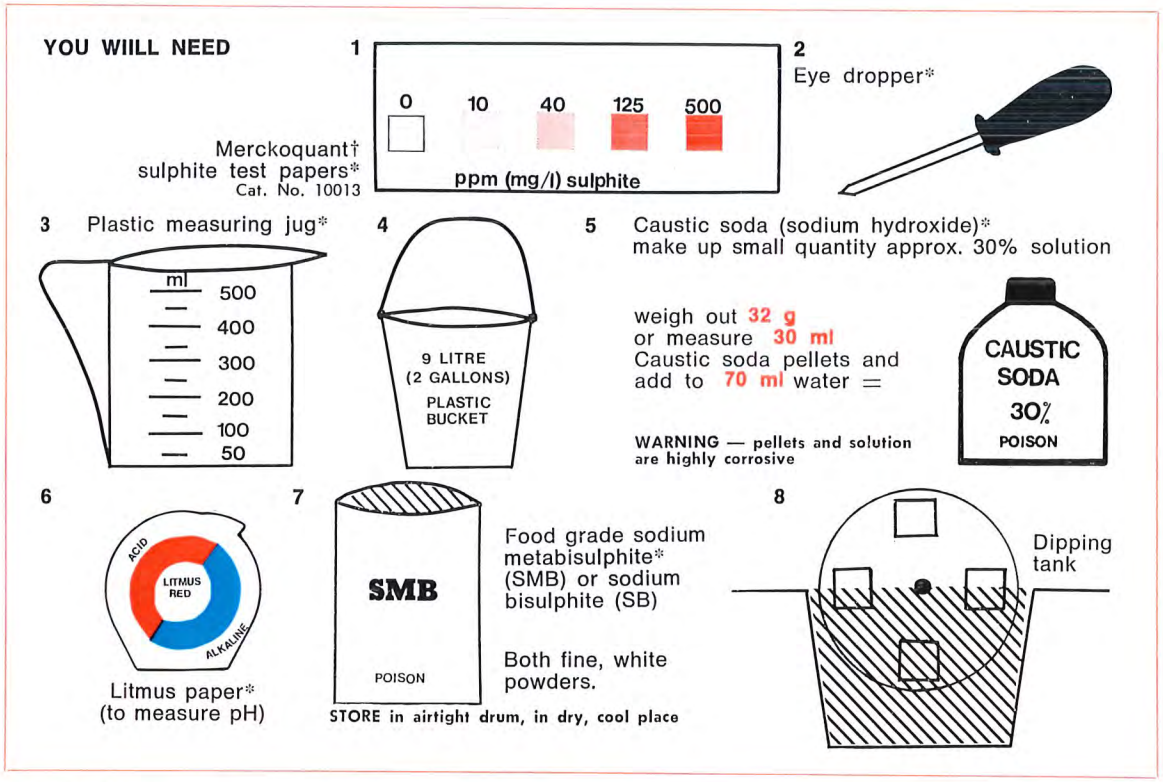
This leaflet was prepared by Judith H. Ruello and Vivien G. Beilby of the CSIRO Division of Food Research, Ryde, NSW.

Equipment, mixtures and methods

Black spot is an enzymatic defect which may develop in raw prawns. Black spot can be controlled if prawns are dipped for 30 seconds in a 3 000 ppm sulphite solution.

One way this can be done is demonstrated in a film *Treatment of Raw Prawns to Control Black Spot.* A copy of this film may be borrowed from the CSIRO Division of Food Research.

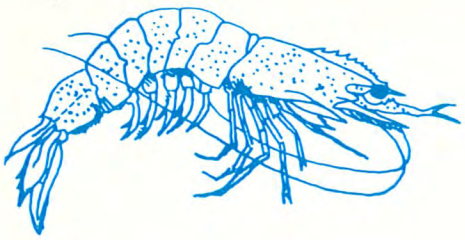
This pamphlet describes the procedures shown in the film.



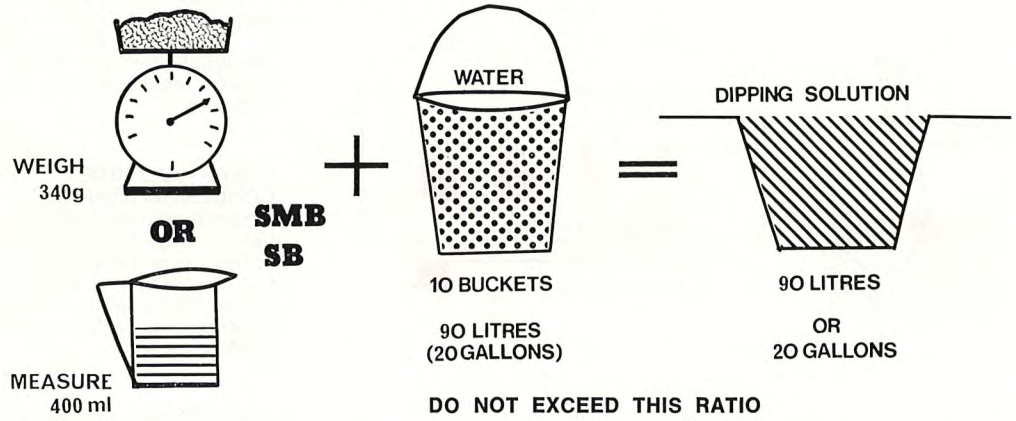
DIPPING TANK — You can build your own tank to fit your vessel's deck space. Materials must be resistant to acid solutions.

VOLUME of dipping tank is measured first by filling the empty tank with water using the 9 litre (2 gallon) plastic bucket. Count the number of buckets needed to fill the tank. (If the tank holds 10 buckets or 90 litres, you will need to add 340 g (or 400 ml) of SMB or SB powder.

* These items should be available from any scientific or chemical supplier.
† Registered trade name.



TO MAKE A DIPPING SOLUTION of 3 000 ppm sulphite



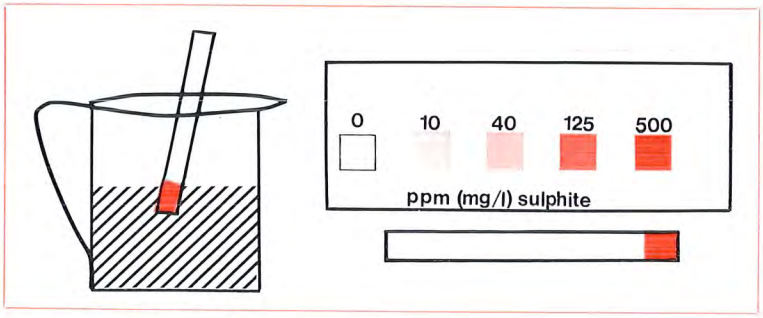
DO NOT EXCEED THIS RATIO

TESTING THE DIPPING SOLUTION. Because the MERCK sulphite test papers are accurate only with alkaline solutions and measure only up to 500 ppm, THE TEST SAMPLE of the dip has to be DILUTED and made ALKALINE to get an accurate reading.

Having filled the dipping tank with the sulphite solution, take **50 ml** sample in the measuring jug and make up with water to **300 ml** . Dilution is therefore **1 in 6** for test purposes.

ALKALINITY. When checking alkalinity of the test sample using litmus paper, 2 or 3 drops of caustic soda solution may be needed so that litmus paper turns blue. (Instead of red for acid solutions.)

SULPHITE LEVEL TESTING with MERCK sulphite test papers
When the litmus paper shows that sample is alkaline then immerse a SULPHITE TEST PAPER and compare the color with the standard colors on the MERCK SCALE while the test strip is still wet. If the color matches the red **500 ppm** color, then your original dipping solution has a concentration of **500** x **6** = **3 000 ppm** .



Sulphite level too low. If the color of the wet sulphite test strip indicates a concentration between **125** and **500 ppm** you will need to make ANOTHER DILUTION in a different proportion to get a nearer reading. This time take another **50 ml** of the original dip and make up with water to **250 ml** . Dilution is therefore **1 in 5** for test purposes.

If the test paper again shows a sulphite concentration of less than **500 ppm** (or less than **2 500 ppm** in the original dipping solution) you will have to add more SMB or SB to the original dipping solution until its sulphite concentration is between 2 500 and 3 000 ppm. Measure out all extra additions of SMB or SB so you will know how much was added.

Take another sample, check alkalinity with litmus paper then measure sulphite concentration with MERCK paper as described before.

ROUTINE PREPARATION. Once you know how much SMB or SB you must add to your dipping tank to give a sulphite concentration of 2 500 to 3 000 ppm, you can routinely add this amount in future.

CAUTION Dipping procedures specified in this lift-out apply only to the control of black spot in whole (head on) raw prawns. Prawns should only be treated ONCE with sulphite. Repeated treatments can result in HIGH SULPHITE UPTAKE. Other styles of prawns (headless raw tails, prawn meat, etc.), may be dipped in sulphite, but it is advisable first to consult your nearest Department of Primary Industry inspector for advice.

FOOTNOTE Sulphur dioxide (SO_2) gas may be used instead of metabisulphite or sodium bisulphite powder. Gas is easier to store, easier to handle, does not decompose during storage and dissolves quickly in water.

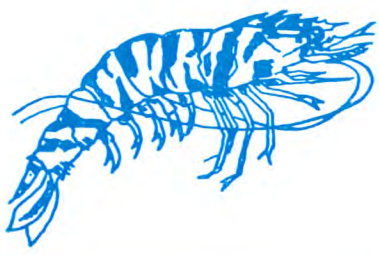
DIPPING METHODS. Rotate prawns in dipping solution for 30 seconds, or, pump the dipping solution over the prawns for 30 seconds. (Dipping and immediate removal of the prawns results in poor chemical contact.)

CHECK SULPHITE CONCENTRATION of the dipping solution (as described before) after large amounts of prawns (e.g. about 5 000 kg) have been dipped. You must add more SMB or SB if the sulphite concentration falls below 2 500 ppm.

NOTE: Sulphite is a permitted additive for use on prawns EXPORTED from Australia. However, the sulphite residue in the flesh of EXPORT PRAWNS should not exceed 30 ppm.

If you want more information, or wish to see a film showing how to dip prawns, contact:

Technical Secretary,
CSIRO Division of Food Research,
PO Box 52,
North Ryde, NSW 2113
Australia.



Reprinted from Australian Fisheries, July, 1976 1976—AMBASSADOR PRESS, 51 Good St., Granville 2142—34405

Determination of the drained weight of individually quick frozen prawns

By JUDITH H. RUELLO†
and
ALISTER K. SHARP
CSIRO Division of Food Research, North Ryde, N.S.W., 2113

A new method for determining the drained weight of individually quick frozen (IQF) prawns is presented in which prawns are thawed in air in a sealed draining unit. Thawing time was found to be related to ambient temperature and can be predicted for routine determinations using the data presented. The proposed method is compared with AOAC methods 18.006 and 18.007 in which prawns are thawed in water. The results show that an accurate measurement of drained weight cannot be obtained if prawns are thawed in water because the prawns take up water and consequently increase in weight. The proposed method overcomes this objection and is recommended for the routine determinations of the drained weight of IQF prawns.

There is a need for a new method of determinating the drained weight of thawed individually quick frozen (IQF) prawns because the following investigations show that standard methods, such as AOAC methods 18.006 and 18.007 (Official Methods of Analysis, 1970), which recommend thawing in water, are inaccurate owing to the uptake of water by the prawns. The prawns take up water while thawing even if sealed in a plastic bag before immersion, as the thaw drip and melted glaze accumulate at the bottom of the bag in contact with the flesh. There is also the danger that the bag may be punctured by the prawns and so allow entry of water.

The AOAC specify four methods of determining the final weight of frozen prawns, depending on whether or not the *drained weight* (Official Methods of Analysis, 1970, sec. 18.006 and 18.007) or the *net contents* (Official Methods of Analysis, 1970, sec. 32.003 and 18.001) are to be measured. To determine *net contents*, glazed and unglazed prawns are treated differently. If unglazed, the final weight is measured simply by weighing the frozen prawns, whereas if they are glazed, the glaze must be first removed. During the removal of the glaze the prawn flesh will be partially thawed, and the resulting drip loss will reduce the final weight. As the degree of thawing is not specified in AOAC Method 18.001, the amount of drip lost from each pack may vary considerably. To avoid this source of error, Werren and co-workers (Werren & Week, 1967; Werren, Johnson & Week, 1967) in their critical appraisal of AOAC Method 18.001 concluded that glazed frozen prawns must be completely thawed if accurate, reproducible measurements are to be obtained. They use the term *drained weight* rather than *net contents* to describe the final weight of the drained thawed prawns. Their recommendations have now been incorporated into the official AOAC methods, 18.006 and 18.007. Because 'unglazed' IQF prawns are never completely free of 'glaze', we feel that they too should be completely thawed before a measurement of the drained weight is attempted.

This paper is presented in two sections: the first section described the development of a new method for the determination of the drained weight and thawing time of IQF prawns thawed in air in a sealed draining unit. The second section describes a comparison of the new method with standard AOAC methods and comments on the use of the new method in routine determinations of drained weight of IQF prawns.

DEVELOPMENT OF NEW METHOD

It was proposed that IQF prawns should be thawed in air, sealed within a draining unit (Fig. 1) so as to avoid problems associated with water uptake and dehydration. Since the prawns were to be sealed within the draining unit, the thawing time could not be accurately determined by sensory means (sight and touch); therefore the temperature of the prawns was to be continuously monitored as it rose from -20°C to 0°C.

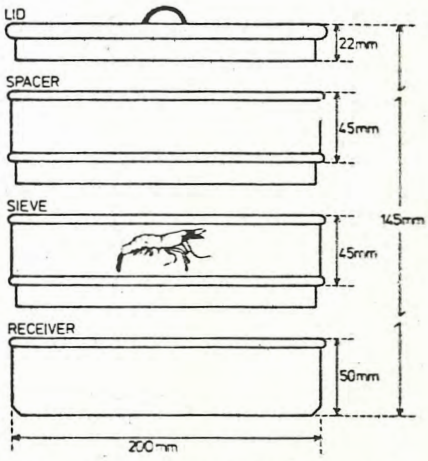


Fig. 1. — Sealed draining unit.

† Present Address: Ruello & Associates, Fishery Consultants, 1 Terrell Ave., Wahroonga, NSW 2076.

Material

The thawing time was measured for several grades (reckoned as number per kilogram) of two species of whole boiled prawns. These were western king prawns *(Penaeus latisulcatus)* and brown tiger prawns *(Penaeus esculentus)*, both taken from Shark Bay, Western Australia.

Measurement of thawing time

To determine the time required for prawns in the sealed draining unit to thaw in air, the temperatures of representative prawns in a one-kg pack were measured as they rose from an initial uniform temperature of -20°C to 0°C. The sealed drained unit, shown in Figure 1, was made from a 200-mm diam. No. 16-mesh Endecott* sieve, lid and receiver with a spacer added to increase capacity to 1 kg. The temperatures were measured with thermocouples attached to a measuring circuit as shown in Figure 2. During thawing the draining unit was placed on a laboratory tripod 25 cm from a desk fan.

Preparations were made in a -20°C room at the temperature of the frozen prawns, the sieve and receiver were weighed on a balance (with an accuracy of 1 g) giving weights W_1 and W_2 respectively. The contents of a one-kg pack of prawns were emptied onto the sieve and weighed (W_3). For each determination of thawing time, 0.18-mm diam. copper/0.32-mm diam. constantan thermocouple wires were inserted into 12 prawns from each pack as follows: a 1.0-mm diam. hole was drilled transversely through the widest part of each prawn, and the thermocouple wire was drawn through the hole to place the thermocouple junction halfway inside the prawn; the hole was filled with water by means of a syringe, thus providing when the water froze good thermal contact between the thermocouple junction and the flesh and also fixing the position of the junction. Then the thermocouple wire was wrapped several times around the prawn to secure it. These 12 prawns were placed in the centre of the draining unit and surrounded by the remaining prawns from the pack. The unit was assembled and all three joints were sealed with adhesive tape.

The sealed draining unit was placed in an insulated carrier, leaving the thermocouple wires protruding, and transferred from the -20°C room to the room held at the test temperature. The thermocouple wires were then connected to the measuring circuit (Figure 2), the insulated box was removed and the desk fan started. The temperature of each of the 12 prawns was monitored continually until it became apparent which would be the last to thaw, and the temperature of this prawn was then recorded continuously until it reached 0°C.

Measurement of drained weight

The sealed draining unit was dismantled, and the adhesive tape and the thermocouple wires were removed and discarded. The sieve containing the thawed prawns was weighed (W_4), as were the receiver and its contents (W_5). The drained weight of the prawns was determined as (W_4-W_1) and the drip loss and melted glaze was determined as (W_5-W_2). The percentage change in weight was determined as

$$\text{Percentage weight change} = 100[(W_3-W_4)/(W_3-W_1)][(1)$$

* Registered Trade Name.

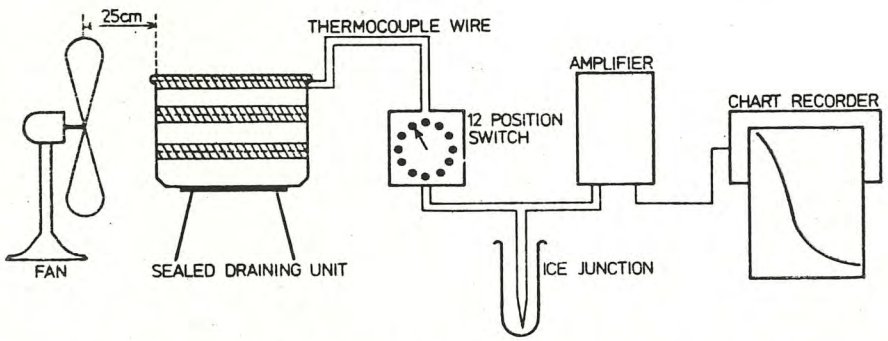


Fig. 2. — Schematic drawing of experimental measuring circuit.

Measurement of continued drip loss after completion of thawing

To determine if there was a change in weight following thawing as a result of continued drip loss, the weights of samples of prawns, both boiled and raw, were measured during thawing in air and for 24 hr after thawing with ambient temperatures of 20°C, 25°C and 30°C.

Approximately 200 g of frozen prawns was placed in a No. 16 mesh basket suspended within a 5-l beaker, the top of which was sealed by a cover plate having a central hole. Except while weighing the sample on a balance accurate to 1 mg, the hole was sealed by a rubber stopper from which the basket was suspended. To weigh the sample the stopper was lifted slightly and hung from the balance. During weighing there was no interference between the sample-suspension system and the cover plate.

ASSESSEMENT OF NEW METHOD

Thawing time

In common with most other foods prawn flesh was found to thaw over a range of temperature, as shown in Figure 3. Below -20°C the curve is

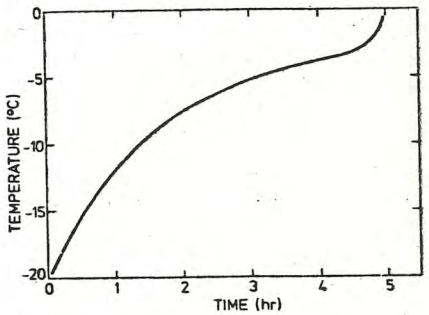


Fig. 3 — Thawing curve of a whole, boiled prawn in the sealed draining unit (measured at an ambient temperature of 31.5°C).

essentially linear, showing the flesh to be fully frozen, while above -2°C it again becomes linear and the flesh is fully thawed. For the purpose of determining the drained weight, the thawing time is defined as the time required for the temperature of the centre of the prawn to rise to 0°C. This ensures that any ice will have melted.

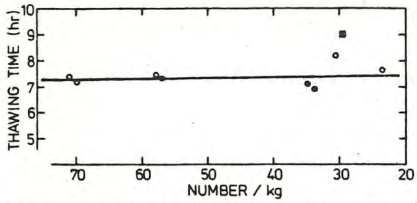


Fig. 4. — Effect of grade and species on thawing time at 20°C of one-kg packs of whole IQF boiled prawns. The line was determined by linear regression — ● Western king, with fan (air velocity = 4 m/s). ■ Western king, without fan (air velocity = 0.1 m/s). ○ Brown tiger, with fan (air velocity = 4 m/s).

In Figure 4 the measured thawing times are plotted against the grade for one-kg packs of prawns, initially at -20°C, thawed in the sealed draining unit at an ambient temperature of 20°C. It can be seen that while neither the species nor the grade appreciably affected the thawing time, omitting the fan increased the thawing time by about 20 per cent.

The effect of ambient temperature on the thawing time is illustrated in Figure 5, again for a one-kg pack. For prawns initially at -20°C, the thawing time can be described by line A. The scatter of points about this line can be attributed to variations in the ambient humidity, which was not controlled. (During the initial part of all determinations dew was observed to form on the outside surface of the sealed draining unit. Sharp (1973) has shown that such condensation greatly increases the rate of heat transfer to a body.) To allow for this scatter, a second line (line b) is given as a recommended time to ensure complete thawing.

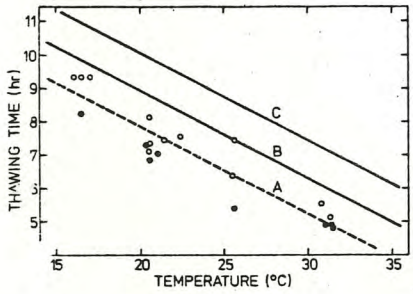


Fig. 5. — Effect of ambient temperature on thawing time of one-kg packs of whole IQF boiled prawns — ● Western king, ○ Brown tiger. Line A experimental results (by linear regression). Line B recommended thawing time for initial temperature of -20°C. Line C recommended thawing time for initial temperature of -30°C.

At temperatures below -20°C, the rate of temperature increase at the centre of the prawns in the sealed draining unit was approximately linear, with a value of 9 deg. C/hr. Therefore the thawing time for a product with an initial temperature below -20°C can be calculated by adding this allowance. Line C has been drawn for an initial temperature of -30°C by adding to the time given in line B 1.1 hr, the time required for the temperature to rise from -30°C to -20°C.

Drip Loss

Average values of the drip loss accompanying thawing are given in Table 1 for one-kg packs of both western king and brown tiger prawns thawed in the sealed draining unit.

Table 1
Average percentage change in weight of IQF whole, boiled, unglazed prawns thawed in air in a sealed draining unit

Species	*One kg samples* (No.)	*Average change in weight* (%)
Western king prawns	9	−2.95 SD*=0.53
Brown tiger prawns	12	−3.23 SD=1.105

*SD=Standard Deviation

The drip loss includes both melted glaze and thaw drip. The ambient temperature during thawing was found to have no effect on the total drip loss at the completion of thawing, and the values given in Table 1 include determinations with ambient temperatures from 16°C to 31°C. The variability is attributed to variations in the degree of glazing rather than in the extent of thaw drip. Although these prawns were described as *unglazed*, fragments of ice were observed adhering to their surface.

Continued drip loss after completion of thawing

The weight of a sample of prawns held in a sealed enclosure after the completion of thawing was found to decrease approximately linearly with time over a 24-hr period. The rate of this continued drip loss is shown to increase with temperature (Figure 6) and increases more quickly with raw than with boiled prawns. The curves in this figure have been extrapolated to temperatures lower than those measured by plotting this data on logarithmic co-ordinates.

If prawns are allowed to drain beyond the recommended thawing time (given in Figure 5), a correction derived from the data in Figure 6, must be made to the measured drained weight to take account of the continued drip loss.

If the recommended thawing time = t_r (hr) (Fig. 5)

actual thawing time = t_a (hr)

estimated continued rate of drip loss = r (% per hr) (Fig. 6)

measured drained weight = W_m (kg)

true drained weight = W_t(kg)

then the fractional correction to be *added* to the measured drained weight is given as

$$r(t_a - t_r)/100 \quad \ldots\ldots (2)$$

The true drained weight is found from

$$W_t = W_m[1 + r(t_a - t_r)/100]\text{kg} \quad \ldots\ldots (3)$$

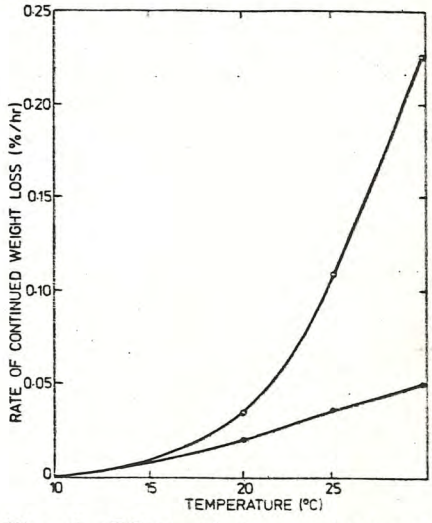


Fig. 6. Effect of temperature on continued weight loss measured over a 24 hr period after completion of thawing — ○ whole raw prawns, □ whole boiled prawns.

Routine determination of drained weight

Because the thawing time was found to be linearly related to temperature, it is not necessary to measure the rate of thawing for each determination. Instead, the thawing time can be predicted from the data in Figure 5 when using the method described in this paper.

If prawns are left to drain beyond the recommended thawing time a correction to account for continued drip loss must be added to the measured drained weight, as discussed above. For prawns left to thaw at ambient temperatures above 15°C this value is significant. However, at ambient temperatures below 15°C and for short periods in excess at higher ambient temperatures, the correction will be below 1 g for a one-kg pack. This figure is below the accuracy of the balance recommended for the proposed method and the correction can be disregarded.

COMPARISON OF THAWING METHODS

The new thawing method based on the investigations described above is proposed as a standard method for determining the drained weight of IQF prawns and is compared with the AOAC methods 18.006 and 18.007 (Official Methods of Analysis, 1970). The method proposed by the authors recommends thawing in air in a sealed draining unit and differs from the AOAC methods in which the frozen prawns are thawed in water. The following comparison was undertaken to evaluate both methods for their accuracy, reproducibility and for their ease of use in routine determinations.

Materials

Approximately 16 kg of freshly caught raw eastern king prawns, *Penaeus plebejus*, and approximately 16 kg of freshly cooked eastern king prawns, both from Sydney Harbour, N.S.W., were blast frozen. Half of these were then weighed to give eight packs, each containing approximately 1 kg of *unglazed* IQF raw and eight packs each containing approximately 1 kg of *unglazed* IQF cooked prawns. The remainder were then glazed by hand dipping the *unglazed* frozen prawns in chilled water. When glazed, these were then weighed to give eight packs each containing approximately 1 kg of *glazed* IQF raw prawns and eight packs each containing approximately 1 kg of *glazed* IQF cooked prawns. These one-kg packs were then thawed by each of the two methods. Each determination was made in quadruplicate.

Thawing in air in a sealed draining unit

For each determination a one-kg pack was weighed into the draining unit as already described. The unit was assembled, sealed with adhesive tape and transferred in an insulated carrier to the test room in which the temperature was maintained at either 25°C or 30°C. The sealed draining unit was then placed on a tripod 25 cm from a desk fan and left for the recommended thawing period obtained from line B of Figure 5. Following this thawing period the draining unit was dismantled and weighed to determine the weight change and the drip loss. In each case the weighings were made immediately following the recommended thawing period, and no correction was required for continued drip loss.

Thawing in water

One-kg packs of IQF prawns prepared as described above were placed in a No. 16-mesh wire basket and thawed according to AOAC methods 18.006 and 18.007 (Official Methods of Analysis, 1970). The basket containing the IQF prawns was immersed in a 20 ℓ container of fresh water at 28°C and water at the same temperature was introduced at the base of the container at a rate of 10 ℓ/min. The thawed prawns were drained for 2 min on a No. 8 sieve inclined at 30° to the horizontal.

Table 2

Comparison of the authors' thawing method for the determination of drained weights of whole individually frozen eastern king prawns *(Penaeus plebejus)* with the AOAC method

Note: Determinations were made in quadruplicate

State of sample	*Raw*				*Cooked*			
	Unglazed		*Glazed*		*Unglazed*		*Glazed*	
Thawing method	*A**	*B**	*A**	*B**	*A**	*B**	*A**	*B**
Weight of frozen prawns (g)	1022	1025	1041	1076	1032	1015	1033	1108
Standard deviation	8.8	7.7	20.5	16.5	18.7	8.7	21.2	10.8
Weight of thawed prawns (g)	1044	998	1013	973	1072	997	992	988
Standard deviation	15.1	7.3	19.3	21.2	21.1	6.6	25.6	18.2
Drip loss (g)	—	27	—	103	—	18	—	120
Standard deviation	—	1.0	—	17.7	—	2.4	—	18.2
Change in weight (%)	+2.1	−2.6	−2.7	−9.6	+3.9	−1.8	−4.0	−10.8
Standard deviation	0.7	0.1	1.8	1.7	1.0	0.3	2.2	1.6

* Thawing methods: A—according to AOAC 18.006 and 18.007, Official Methods of Analysis (1970); B—in air in a sealed draining unit.

SUPERIORITY OF NEW METHOD

The two techniques are compared in Table 2. It can be seen that unglazed IQF prawns thawed in water gained weight due to water uptake, and that the increase in weight was greater for boiled prawns than for raw prawns. Moreover, the standard deviation of the average percentage change in weight of unglazed prawns during thawing is greater when thawed in water than when thawed in air. It can also be seen that glazed prawns lose weight during thawing with both methods due to the removal of the ice glaze. However, the weight loss of boiled glazed prawns thawed in the sealed draining unit was greater than that of boiled glazed prawns thawed in water, because of water uptake by the latter. It should be remembered that the degree of glazing depends on the temperature, size and shape of the prawn, the time of immersion and the temperature of the glaze water (Torry Research Station, 1971). These parameters control the reproducibility of results obtained with any thawing technique.

Thawing in air in a sealed draining unit allows an accurate measurement of the drained weight of IQF prawns to be determined because the thaw drip drains continuously. Therefore there is little chance that either incompletely drained prawns or uptake of drip can effect the final weight. Also, because the prawns are sealed in the draining unit while thawing in air, the drip cannot evaporate and the prawns cannot dehydrate. Thus it is possible to determine accurately the amount of thaw drip and melted glaze.

The main advantage of thawing in water is that the determination can be completed relatively quickly, whereas with the proposed technique the thawing time is dependent on ambient temperature and even at temperatures as high as 30°C, a period of 6½ hr is required for thawing. In some circumstances the long thawing time required for this method at an ambient temperature of 25°C or less may be considered a disadvantage. However, once started, the determination can proceed unattended, and if more convenient, the prawns may be thawed overnight.

CONCLUSIONS

This paper describes a new method for determining the drained weight of IQF prawns. The prawns are thawed in air in a sealed draining unit to avoid problems associated with water uptake and dehydration. The time required to thaw a given weight of prawns using the apparatus described does not vary with the species or the size of the prawns, and therefore the thawing time can be predicted simply from the ambient temperature.

The results indicate that if IQF prawns are thawed in water according to existing AOAC methods 18.006 and 18.007, an inaccurate measure of drained weight is obtained. The proposed method gives an accurate measure of the drained weight of IQF prawns and also gives better reproducibility, while still requiring only simple rugged equipment.

ACKNOWLEDGEMENTS

This work was partly financed by a grant from the Australian Fishing Industries Research Trust Account.

REFERENCES

Official Methods of Analysis (1970) 11th Ed., AOAC, Washington, D.C., sec.

Sharp, A. K. (1973) *Fd Technol. Aust.* **25**, 18. 18.001, 18.006, 18.007, 32.033.

Torry Research Station (1971) *Ann. Rep., Aberdeen, 1970*, 12.

Werren, J. C., Johnson, A. R. & Week, R. W. (1967) *JAOAC* **50**, 278.

Werren, J. C. & Week, R. W. (1967) *JAOAC* **50**, 275.

NEW METHOD FOR THE DETERMINATION OF THE DRAINED WEIGHT OF IQF PRAWNS

(1) Weigh sieve ..... W_1

(2) Place frozen prawns on sieve and weigh ..... W_3

(3) Assemble draining unit and seal joins with adhesive tape.

(4) Place sealed draining unit on a tripod 25 cm from a desk fan and leave for recommended thawing period (Fig. 5).

(5) Discard adhesive tape and dismantle draining unit.

(6) Weigh sieve containing thawed prawns ..... W_4

(7) If prawns were allowed to stand in excess of recommended draining period, find rate of continued drip, r, loss from Fig. 6.

(8) Calculate:

Frozen weight = $W_3 - W_1$

Drained weight = $W_4 - W_1$

If recommended thawing period was exceeded,

True drained weight = $(W_4 - W_1)\,[1 + r(t_a - t_r)/100]$

where t_a = actual thawing period

t_r = recommended thawing period.

Mobile laboratory visits dairy factories

Taking the Dairy Research Institute out to dairy factories is the purpose of a new mobile laboratory reports *Food Technology in New Zealand*. The brain-child of research officer M. F. Parkin, the 19 ft (5.8 m) caravan has been designed to help dairy factories to solve effluent disposal problems. It was built at a cost of between $NZ22 000 and $NZ25 000, with a similar amount spent on equipment.

Specialised equipment in the caravan enables the staff to monitor the characteristics of the effluent from the factories, and to carry out chemical and biochemical analyses, over a period of about six weeks. The equipment includes an oven for total solids determination and for drying and sterilising glassware, an ice-making machine which supplies ice used to chill the effluent, a pH meter and titration equipment, a refrigerator-freezer, an incubator, a weighing bench, distillation units for Kjeldahl nitrogen analysis, a spectrophotometer, fume cupboards, electric heating plates and a muffle furnace

Vol. 37 No. 1 March 1977

CSIRO Food Research Quarterly

CSIRO Food Research Quarterly

ISSN 0310-9070

Front cover

Honey bee gathering nectar—see article on the 'Quality of Australian Honeys'.

Printed by CSIRO, Melbourne

77.165-3325

Quality of Australian honeys

By B. V. Chandler

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

This paper presents in more general terms a summary of the Division of Food Research Technical Paper No. 38 (Chandler *et al.* 1974)

With an annual honey production of about 20 000 000 kg, which exceeds local consumption by about 8 000 000 kg, Australia not only ranks as one of the four leading honey-producing countries of the world, but also as one of the three leading exporters of honey. Its honey markets overseas, principally in the United Kingdom, South-East Asia and Japan, return about $A15 000 000 annually. However, the honeys produced in Australia vary widely in flavour, colour, texture and other quality characteristics because its vast hardwood forests and extensive pastoral areas provide literally hundreds of floral sources, each with the potential for producing its individual characteristic honey. Although this variety can be an asset in the marketing of uniquely Australian honeys, the range of characteristics may also present problems in meeting the rigid standards set by the importing countries. Moreover, since most is sold as blended honey, blenders need to know which honeys, if any, to avoid in blending because of their unfavourable quality characteristics. Besides, the apiarists themselves would often like to be able to apply the same principles in order to exclude their bees from harvesting nectar from undesirable floral sources.

Nevertheless, apart from work on the diastase activity, colour, pH and amino-acid contents of some Victorian honeys (Langridge 1966; Petrov 1971) and the sucrose contents of some Western Australian honeys (Smith 1965), there was until recently a dearth of published information on the composition of Australian straightline honeys, i.e. honeys of identified floral source. Some studies had been made on the composition of commercial blended honeys (Langridge 1971) in relation to European standards set by the Codex Alimentarius Commission (FAO/WHO 1969) but, while defining those quality factors in which our honeys could be improved, the information obtained did not indicate those straightline honeys or nectar sources whose avoidance could lead to such improvements.

Accordingly, at the request of and with financial support from the Australian Honey Research Advisory Committee, a program to study the composition of Australian honeys was undertaken in this Division under the supervision of Dr T. M. Reynolds. Chemical analyses were carried out on almost 100 straightline honeys from all six honey-producing States and representing over 60 different floral sources. The program, which was based on a similar study made of American honeys by White *et al.* (1962), led to the publication of a technical bulletin on this subject (Chandler *et al.* 1974). This article summarizes that bulletin. It will discuss the results recorded for each quality characteristic for each of the three honey types into which Australian honeys may be divided according to their floral source: eucalypt honeys, honeys from non-eucalypt Australian flora and honeys from exotic floral sources.

The discussion will also relate these results to the three main sets of standards operating for Australian honeys: those of the Codex Alimentarius Commission (FAO/WHO 1969), the Australian Defence Force Food Specifications (1972), and the Australian Export Standards (Australian Statutory Rules 1964, 1966). These comparisons are summarized in Table 1. Attention will be given to circumstances where these standards, though developed in good faith to reject adulterated or maltreated honeys, appear to be unfairly penalizing an Australian honey whose natural composition is such that the standards could not be met by pure samples

Table 1. Summary of analytical results for Australian honeys

Compositional criteria[1]		Range	Eucalypt	Other Aust. flora (Number of samples)	Non Aust. flora
Granulation					
0 = no crystals		0	19	1	1
2 = very few crystals		1–3	5	2	3
6 = semi-crystalline		4–6	7	3	5
9 = completely crystalline		7–9	29	12	12
Colour (Pfund value in mm)					
AES*:	Extra white	0–17	2	0	7
	White	18–34	20	0	5
	Extra light amber	35–50	16	5	4
	Light amber	51–65	10	1	1
	Pale amber	66–75	7	2	0
	Medium amber	76–90	4	7	2
	Dark amber	91–114	1	3	1
Manufacturing		> 114	0	0	1
Moisture (%)					
CAC†:	Max. 21%	< 14·5	10	2	4
AES:	Max. 18·5%	14·5–15·9	32	9	8
ADFFS‡:	Max. 20%	16·0–17·4	16	5	8
		⩾ 17·5	2	2	1
Ash (%)					
AES:	Max. 0·5%	<0·20	38	5	21
CAC:	Max. 0·6%	0·21–0·50	21	13	0
ADFFS:	Max. 0·75%	> 0·50	1	0	0
Free acid (m-equiv/kg)					
CAC:	Max. 40	6·0–9·0	19	1	0
		9·1–20·0	35	7	13
		20·1–40·0	9	10	7
		> 40·0	0	0	1
Reducing sugars (%)					
CAC:	Min. 65%	54·0–59·9	0	1	0
AES:	Min. 60%	60·0–64·9	0	3	0
ADFFS:	Min. 60%	65·0–71·9	15	0	0
		72·0–79·0	45	14	22
Apparent sucrose (%)					
CAC:	Max. 5%	0·0–1·5	37	9	8
ADFFS:	Max. 5%	1·6–5·0	18	5	11
		5·1–10·0	4	0	2
		10·1–19·3	1	4	0
Diastase number					
CAC:	Min. 3 if HMF < 15·0	9–15	24	10	1
	Min. 8 if HMF > 15·0	16–20	11	6	4
		21–30	21	2	10
		31–44	7	0	6
HMF (mg/kg)					
CAC:	Max. 40;	0·0–10	51	16	18
	Max. 15 if DN < 8	10·1–15·0	3	0	0
		15·1–24·0	5	0	0
		24·1–40·0	1	0	2
		40·1–90·0	0	2	1

*AES, Australian Export Standards (Australian Statutory Rules 1964).
†CAC, Codex Alimentarius Commission (FAO/WHO 1959).
‡ADFFS, Australian Defence Force Food Specifications (CFS-8-3-10).

of the honey which had been subjected only to the best possible processing and storage conditions. Finally, a comparison will be made of the results from these authentic straightline honeys and from 28 commercial straightline honeys, 30 commercial blended honeys and 32 imported honeys.

Moisture content

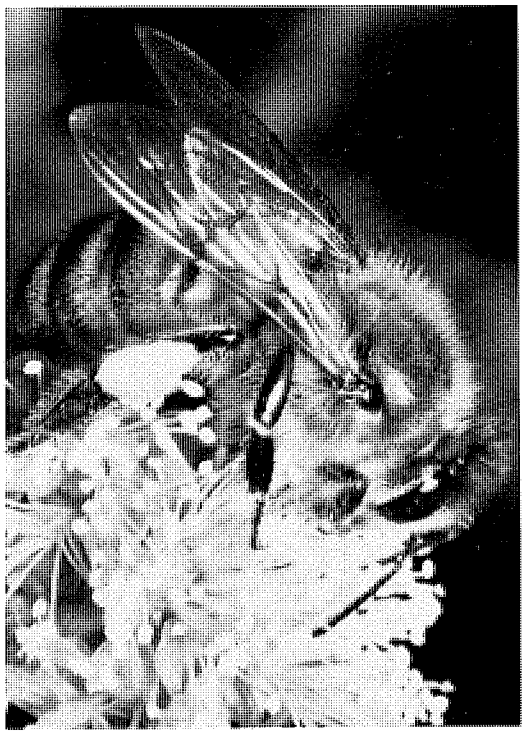
Dilution of honey was sometimes practised in earlier times, either to overcome granulation problems or to assist in the recovery of honeys during transfer and processing, and a maximum value for the moisture content of honey is set in all honey standards, e.g. 21% by the Codex Alimentarius Commission (CAC), 20% by the Australian Defence Force Food Specification (ADFFS) and 18·5% by the Australian Export Standards (AES); honeys with moisture contents less than 18·5% are very unlikely to ferment under normal circumstances.

Australian honeys should have little difficulty meeting these standards since only three of the 99 examined failed these specifications: two honeys (a mulga eucalypt and a natural banksia blend) exceeded the AES maximum, the lowest of the limits, and a broad-leaved tea-tree honey exceeded the CAC maximum, the highest of the limits. The generally low moisture content of Australian honeys is shown by the fact that these three honeys plus four other eucalypt honeys (South Australian blue gum, mallee, dusky-leaved iron bark, long-leaved box) were the only ones to exceed the *average* moisture content of 17·2% recorded by White *et al.* (1962) for U.S. honeys. Particularly low moisture contents ($<14·5\%$) were recorded for three eucalypt honeys (yorrell, sugar gum, yellow box), two non-eucalypt Australian flora honeys (loudonia, red bell) and two exotic honeys (Lincoln weed, Paterson's curse).

The results from the commercial honeys confirm these findings, with mean moisture contents of 17·8% and 16·1% in foreign and Australian honeys respectively and at least 30% of the foreign honeys would have failed the AES specifications. Moreover, although there was statistically a very highly significant difference between the mean moisture contents of commercial blended and non-blended honeys (16·6 and 15·8%, respectively), only one of the 30 blended samples tested would have failed the AES specification.

Ash content

Although most honeys are derived from blossom nectar, bees will forage nectar excreted by plants elsewhere than in the flower, and there is no basic difference between the compositions of floral and extra-floral nectars or between the compositions of the honeys derived therefrom. However, when bees forage on honeydew, the syrup excreted by certain plant-sucking insects, the product obtained, though similar to blossom honey, is inferior to it in quality, being darker in colour, lower in glucose and fructose contents and higher in polysaccharide, acid and ash contents. Such foraging, though rare in Australia, can be prolific overseas, especially in pine, cedar and oak forests, and the honeydew honeys produced have different properties according to the plant and insect that provide the excretions. Standards for honeydew honey are laid down by the CAC which allow, for example, a maximum ash content of 1·0%, compared with 0·6% for blossom honey. Honeys containing more than 0·6% ash



A honey bee foraging for floral nectar which it packs mixed with pollen into 'baskets' on its hind legs for transport back to the hive where the bees 'process' it into honey.

could therefore be labelled and sold as honeydew honey, finding their own value in the market place for commercial use in manufactured honey products.

Since contamination by metal corrosion, particularly of iron-based containers, leads to darker honeys and since dark honeys have a higher ash content than light honeys, it may be thought that a limit set to the ash content provides a barrier to metal-contaminated honeys. However, the principal difference between the metal content of average U.S. light and dark honeys lies in their potassium content (205 and 1676 ppm respectively) and not in their iron content (1·4 and 9·4 ppm respectively), and ash contents bear no direct relation to metal contamination. Similarly, the addition of alkali to reduce the titrable acidity of a honey (see below) would not be detectable by its ash content because of the low amounts of alkali required.

With ash contents of $0 \cdot 18 \pm 0 \cdot 12$, $0 \cdot 22 \pm 0 \cdot 07$ and $0 \cdot 08 \pm 0 \cdot 05$ for honeys from eucalypt, non-eucalypt and exotic flora respectively, current standards are unlikely to offer any undue restriction to Australian honeys. Only one sample exceeded the CAC and CES maxima (a spotted gum honey with 0·67% ash) and only two other honeys exceeded 0·36% ash. Consideration of other quality characteristics of these honeys does not indicate contamination by honeydew honey, and it seems unlikely that insect exudates constitute an important source of food for bees in this country. Australian commercial honeys and imported honeys also all gave ash values well below the level set by local and overseas standards.

Acidity and pH

Though the acidity and pH of a honey will affect its flavour characteristics to some extent, the wide range of flavours exhibited by honeys do not make these factors important in the definition of honey quality. Nevertheless, natural enzymic processes occurring in stored honeys lead to the production of free acids and extremely high acid contents may indicate excessive storage. However, only the CAC specifications set a limit on the free acid content of honey with a maximum permitted level of 40 m-equiv./kg. Of the 99 straightline honeys studied, one Paterson's curse sample (and not five others from this floral source) gave an acidity above the CAC maximum. Eucalypt honeys, in particular, had very low acid contents, with a mean value of 12·2 m-equiv./kg compared with 20·0 m-equiv./kg for honeys from other sources.

Though the total acidity (free acid plus lactone contents), lactone: acid ratio and pH value of honeys are sometimes measured, these parameters are not used in honey specifications because of their complicated relation to honey quality. The pH is related not so much to free acidity as to ash content which determines the buffering capacity of the product, while the pH itself determines the degree of natural hydrolysis of gluconolactone to gluconic acid that has occurred and hence the lactone: acid ratio. For the reasons given above, all these parameters will change with storage, but the changes are not always in the same direction, hence their absence from honey specifications.

Carbohydrates

Until regulations defining honey quality were established, one of the commonest methods of adulterating honey was by the addition of sugar syrups containing glucose, sucrose and particularly invert sugar. Such adulterations, when carried out at a commercially profitable level, can be detected by analysis of the carbohydrate content of the honey and hence the setting of permissible sugar contents by all honey standards: the minimum apparent reducing sugar content as 60% by both the ADFFS and AES and the higher figure of 65% by the CAC, while the CAC and the ADFFS set 5% as the maximum sucrose content.

All eucalypt honey and honeys from exotic floral sources had reducing sugar contents above the minimum values set by all three standards, but honeys from blackboy (54·2%), grand banksia (60%), Menzies banksia (63·3%), and red bell (63·2%) would have failed two or more of the specifications as well as the sucrose standard, with contents of 19·3, 15·3, 13·8 and 10·1% respectively. White stringybark honeys with reducing sugar contents of 66–68% were well below the average in this respect, and would have failed all sucrose specifications because of their high sucrose contents of 6–12%. One yellow box (5·1%) and one yellow gum (5·7%) among the samples of eucalypt honeys, and one Paterson's curse (6·0%) sample among the honeys from exotic floral sources also failed the standards for maximum sucrose content, but other samples of these honey types did not.

The CAC standards make a special allowance for the high natural sucrose

contents of Menzies banksia honeys by accepting 10% as the maximum sucrose content for such honeys. The present work indicates that such a dispensation should be extended to other honeys, in particular to white stringybark honeys which have potential economic value as non-candying honeys. Other honeys with high sucrose contents listed above, especially blackboy honeys, should be avoided by both apiarists and honey processors. None of the commercial honeys tested, either from local or overseas sources, failed any of the specifications relating to the carbohydrate content of honeys.

Diastase number and hydroxymethylfurfural content

The diastase number is a measure of the activity of starch-hydrolysing enzymes naturally present in honeys and is used in honey specifications to exclude honeys that have been damaged by overheating during processing or by overlong storage at unfavourable temperatures. Under these conditions, enzymic activity is reduced and, as a guard against such abuse, honeys with a low diastase number are rejected by the European market. Heat and prolonged storage also initiate discoloration reactions involving sugars and amino acids by promoting the formation of hydroxymethylfurfural (HMF), and a high level of this compound is also the basis for the exclusion of a honey from the EEC.

It is recognized, nevertheless, that some honeys have a naturally low diastase number, and a system with a triple standard is therefore followed by the EEC. This system effectively places an embargo on:

- all honeys with HMF content greater than 40 mg/kg;
- all honeys with HMF content greater than 15 mg/kg and a diastase activity of less than 8 on the Gothe scale; and
- all honeys with a diastase activity of less than 3 on the Gothe scale.

Eucalypt honeys easily met those criteria: no honeys had an HMF content greater than 40 mg/kg or a diastase number of less than 3, and although six samples, including three blue gum honeys, exceeded the 15 mg HMF/kg level, their diastase numbers were well above 8, enabling them to pass the standards. The honeys from all other sources gave diastase numbers well above 8 and HMF contents well below 15 with the exception of two natural broad-leaved tea-tree blends and one natural blue heliotrope blend, all of which had exceptionally high HMF contents (over 40 mg/kg), although their diastase numbers (over 13) demonstrated they had not been grossly heat-abused. These three honeys came from the same general area of Queensland where blue heliotrope presents a serious weed problem. Authentic blue heliotrope honey is unique in having a distinctly bluish cast in its pale amber colour and it has an HMF value (6·5) above average even when fresh, while storage for a few months, even of natural blue heliotrope blends, leads to an HMF value approaching 15. The three samples mentioned above had been stored for over 12 months and while there is no certainty that in each case the bees foraged on pastures contaminated by blue heliotrope, the evidence suggests that apiarists should avoid areas where this weed is prevalent if they want their honeys to meet CAC specifications.

Generally speaking, although they give much the same diastase numbers, Australian commercial honeys have an HMF content higher by about 6 mg/kg than the test honeys, but this is to be expected as a result of the additional handling and processing the commercial honeys would have received. However, despite their higher HMF contents, they would all pass the CAC specifications because their diastase numbers were high enough, though just high enough in a couple of samples. On the other hand, of the 32 foreign-produced honeys examined, six would have been rejected outright by the CAC for their high HMF content and two outright for their low diastase number. A further three would have been rejected for having an HMF content greater than 15 mg/kg *and* a diastase number less than 8 on the Gothe scale. Nevertheless, Australian honey processors should not become complacent on this matter and should take care to prevent over-heating in their operations, especially where blending is involved, and to ensure that temperatures above 50°C (preferably 45°) are avoided during processing, transport and storage.

Colour

Freshly extracted honeys vary in colour from nearly colourless to dark amber according to floral source, and with abuse during processing and storage they will darken at a rate which also varies with the

floral source. Since HMF is the precursor to the pigments formed under these conditions, the HMF content provides a basis for the rejection of such discoloured honeys under CAC specifications, and honeys passing this standard are allowed to find their own market value. However, because consumer demand for honey is largely dependent on colour, lighter coloured honeys being preferred, this quality characteristic is a prime determinant of the price paid for honey at each marketing level. Consequently, the AES specifications incorporate a grading system which separates honeys into seven groups according to their colour as determined by the Pfund Colour Grader: Pfund readings 0–17, extra white; 18–34 white; 35–50 extra light amber; 51–65, light amber; 66–75, pale amber; 76–90, medium amber; and 91–114, dark amber.

Compared with the 490 American honeys examined by White *et al.* (1962), Australian honeys are darker, but the differences are not related to geographical differences directly but to the available floral sources. Honeys from the same floral source fall into the same colour grade irrespective of the country of origin, and the major difference in the colour of honey from the two countries originates in the particularly darker colour of honeys from non-eucalypt Australian flora (Table 2). Because of the commercial importance of colour grading, the lightest and darkest honeys within each classification of floral source have been listed in Table 3. Particularly notable are honeys from wireweed, messmate, blackbutt and blue heliotrope; the presence of the latter in pastures foraged by bees led to natural blends that were medium to dark amber in colour, and the two Queensland honeys mentioned above as possibly naturally contaminated with blue heliotrope honey were also medium to dark amber.

Because a premium price is paid for lighter honeys, most commercial Australian straightline honeys are lightly coloured (< light amber) while blended honeys are light amber to medium amber. Generally speaking, Australian honeys would be disadvantaged by colour comparison with foreign honeys. Except for four extremely dark samples from Mexico and China, all the foreign honeys tested fell into the white to extra light amber range.

It is recognized, as indicated above, that the colour of honey gradually deteriorates on storage and the discolouration process can be regarded superficially as another example of non-enzymic browning since both the reactants, reducing sugars and amino acids, are present in honey, the former in very high concentration. Because of the higher pH of Australian honeys and the higher temperatures at which they are frequently stored, the deterioration in colour would be expected to be a bigger problem in Australia than in Europe or the United States.

In these studies, of all the chemical criteria that could be associated with colour development (acidity, pH, ash content,

Table 3. Australian honeys notable for their colour

Lightest	Darkest
Eucalypt honeys	
pink gum	messmate
dusky-leaved ironbark	blackbutt
green mallee	bloodwood
yellow box	river red gum
yorrell	jarrah
napunyah	mallee
Honeys from exotic floral sources	
Paterson's curse	wireweed
orange blossom	blue heliotrope
Honeys from other floral sources	
Menzies banksia	blackboy
grey mangrove	tea-tree
leatherwood	wallum oak

Table 2. Colour ranges for Australian and foreign honeys

Source of honey	Standard deviation in colour of test samples	Standard deviation in colour of commercial samples
Australian eucalypt honeys	White–light amber	White–light amber
Australian honeys from exotic flora	Extra white–pale amber	White–light amber
Other Australian honeys	Light amber–medium amber	Extra light–light amber
American honeys	Extra white–extra light amber	—
Foreign commercial honeys	—	White–medium amber

reducing sugar content), the closest relationship was between colour and pH. This association can be expressed best by a simple empirical relation: the Pfund reading of a honey will always be greater than 30 times its pH less 107. This relationship would mean that a honey less than 6 months old must have a pH of 4·13 or less before it can fall into the 'extra white' grade, and that for other colour grades the maximum pH would be: white, 4·70; extra light amber, 5·23; etc. Of course, not all honeys with a pH less than 4·13, for example, would be graded extra white, and there is a storage factor operating such that the above pH values would be reduced by 0·3–0·4 pH units for honeys stored for a year.

The above formula held for all but 10% of the honeys studied in this work and to all but 2% of the honeys examined by White *et al.* (1962). (The better correlation in the American studies may have been due to the fact that their storage conditions could be controlled better than was possible in this work.) Moreover, the general light colour of U.S. honeys would be expected from the above relation since only 3% had pH values higher than 4·70 and only 1% had values higher than 4·13.

Finally, on the colour question, the ability of certain flower pigments to pass through into the honey, as indicated by our experience with blue heliotrope honeys, suggests that flavonoids and other phenolic constituents of flowers may do likewise. Such compounds have the ability to form coloured complexes with many of the metals that can become incorporated into the honey as a result of corrosion of the container. (Corrosion is partly related to the acidity of the honey and to the duration and temperature of storage.) Clearly, honey colour is a complicated question, and more than one mechanism is likely to be involved in colour changes as indicated by the apparent anomaly that, in these results, both high pH and high acidity are associated with high Pfund readings, although normally a high pH means a low acidity and a high acidity means a low pH.

Granulation

Although honey granulation is not covered by any regulatory standards, it is an important factor in determining the acceptability of honeys on both a personal and a regional basis. Such granulation occurs on storage because fresh honey, predominantly a mixture of fructose, glucose and water, is frequently supersaturated at normal temperatures with respect to glucose, the least soluble of its major sugar constituents. In simplest terms, whether a honey will granulate or not depends on the proportion of glucose to other components of the mixture. Three formulae have been suggested (White *et al.* 1962) for predicting the susceptibility of honey to granulation:

- the ratio of glucose to water contents (G/W)
- the ratio of fructose to glucose contents (F/G)
- the ratio of the difference between glucose and water contents to the fructose content [(G-W)/F].

Of these formulae, White *et al.* (1962) found G/W the simplest to determine and the most reliable in use. They associated a G/W of 1·7 or less with non-granulating honeys and a value of 2·1 or more with rapidly granulating honeys.

These three formulae can be assessed for their usefulness in classifying honeys according to their susceptibility to granulation on storage by comparing the number of samples of liquid (or solid) honeys after storage with the number of such samples indicated by the formula to be liquid (or solid), or by comparing the number of samples predicted to be liquid (or solid) by the formula with the number of such samples that actually were liquid (or solid) after storage. The application of such comparisons to the honeys examined in the present work gave the results recorded in Table 4.

The formulae (G-W)/F appears to be the most satisfactory of the three for predicting honey granulation, though only marginally more satisfactory than F/G, and its application would have predicted the continued liquidity of about half the honeys that remained liquid after 6 months' storage at 20°C. To obtain more successful formulae for the prediction of honey granulation, further work would be needed on the compositional factors controlling the tendency of honeys to granulate, e.g. on the importance of high molecular weight components in the stability of the supersaturated system.

The question of granulation is, of course, of major importance in those markets where consumers display a preference for fully liquid honeys, and Table 5 shows how

Table 4. Effectiveness of formulae for predicting granulation in honeys

	Predictor		
	G/W	F/G	(G-W)/F
Range of values for liquid honeys[A]	1·36–2·17	1·64–2·88	0·12–0·37
Range of values for solid honeys[B]	1·70–2·46	0·92–1·56	0·28–0·70
Most suitable limit for predicting liquidity	$\leqslant$ 1·70	$\geqslant$ 1·64	$\leqslant$ 0·27
Most suitable limit for predicting solidity	$\geqslant$ 2·20	$\leqslant$ 1·25	$\geqslant$ 0·42
Number of liquid honeys[A] predicted to be liquid	10/31	13/13	14/31
Number of solid honeys[B] predicted to be solid	8/42	11/42	12/42
Number of successful predictions of liquidity	10/11	13/14	14/14
Number of successful predictions of solidity	8/10	11/17	12/14

[A] Honeys showing no or extremely few crystals; [B] honeys completely or almost completely crystalline.

Table 5. Extent of granulation in Australian and foreign honeys

Source of honey	Standard deviation in granulation of test samples
Australian eucalypt honeys	extremely few crystals–completely solid
Australian honeys from exotic flora	moderate crystallization–completely solid
Other Australian honeys	moderate crystallization–completely solid
American honeys	no crystals–sample semi-crystalline
Foreign commercial honeys	extremely few crystals–moderate crystallization

Australian honeys, especially those from non-eucalypt sources, would be at a disadvantage on such markets overseas. Eucalypt honeys varied greatly in their tendency to granulate, with an abnormal distribution showing population peaks corresponding to both completely liquid and completely solid honeys. Regional factors, rarely important in honey quality apart from defining floral source, also come into play. Thus none of the five Queensland honeys examined showed more than very few crystals, while all but six of the 24 Western Australian honeys were at least semi-crystalline. Australian honeys notable for their liquidity or solidity are listed in Table 6.

Table 6. Australian honeys notable for their liquidity or solidity

Liquid	Solid
Eucalypt honeys	
messmate	comet vale mallee
white stringybark	swamp yate
jarrah	napunyah
coastal blackbutt	river red gum
grey box	S.A. blue gum
dusky-leaved ironbark	long-leaved box
stoney mallee	yorrell
spotted gum	karri
pink gum	marri
	forest blackbutt
Honeys from exotic floral sources	
blue heliotrope	most other sources
Honeys from other floral sources	
blackboy	most other sources
grand banksia	

Conclusions

Most Australian honey should be able to pass the standards for quality demanded by overseas markets providing they are properly processed, stored and transported. A strong case could be made for the introduction into the AES of specifications based on HMF content and diastase number and designed to reject honeys that have been maltreated. Since Australian honeys apparently do not present problems of naturally low diastase content as encountered in foreign honeys, scrupulous honey processors would have little to fear from the introduction of such specifications.

However, in addition to Menzies banksia honey, which is already allowed a special dispensation by the CAC, certain Australian

honeys could face rejection under CAC specifications for their unusual natural carbohydrate composition, particularly white stringybark honey, noted for its light colour and limited granulation. Acceptance of such honeys on the European market could partially compensate for the disadvantage Australian honeys generally suffer on account of their natural dark colour and strong granulating tendency.

Although there is still a market for granulated and dark coloured honeys, apiarists and processors at present attempt to eliminate or reduce these potential quality defects by avoiding honeys from certain identifiable floral sources. This recent work will assist in such selective activities along the lines indicated in Tables 3 and 6. Such selections could also extend to the avoidance of honeys from the following sources: broad-leaved tea-tree (high in moisture), spotted gum (high in ash), white stringybark (high in sucrose), blackboy, grand banksia and red bell (low in reducing sugars), and blue heliotrope (with high HMF values). In blending operations, consideration can now also be given to the incorporation of honeys specifically selected to boost the properties of the blend with respect to one or more of the important quality characteristics.

References

Australian Statutory Rules (1964). No. 154. Exports (honey) regulations.

Australian Statutory Rules (1966). No. 52. Exports (honey) regulations.

Chandler, B. V., Fenwick, D., Orlova, T., and Reynolds, T. (1974). Composition of Australian honeys. CSIRO Aust. Div. Food Res. Tech. Pap. No. 38.

Australian Defence Force Food Specifications (1972). Honey. CFS 8-3-10. (Dep. Primary Ind.: Canberra.)

FAO/WHO Codex Alimentarius Commission (1969). Recommended European regional standard for honey. CAC/RS 12–1969.

Langridge, D. F. (1966). An investigation into some quality aspects of Victorian honey. *J. Agric. Victoria* **64,** 81–90, 119–26, 139.

Langridge, D. F. (1971). Australian honey in relation to European standards. *Food Technol. Aust.* **23,** 116, 118.

Petrov, V. (1971). Qualitative determination of amino acids in some Australian honey, using paper chromatography. *J. Apic. Res.* **10,** 153–7.

Smith, F. G. (1965). The sucrose content of Western Australian honey. *J. Apic. Res.* **4,** 177–84.

White, J. W., Jr., Reithof, M. L., Subers, M. H., and Kushnir, I. (1962). Composition of American Honeys. U.S. Dep. Agric. Tech. Bull. No. 1261.

Book notice

'Guide to Refrigerated Storage.'

International Institute of Refrigeration, 177 bd. Malesherbes, 75017, Paris; 1976; pp. 190, 50 F (hard cover).

This book is an up-to-date and enlarged version of the publication 'Practical Guide to Refrigerated Storage' which appeared in 1965. The new book, which is bilingual (English and French), has been compiled by an international team of qualified experts on refrigerated storage.

Summary of contents:

- design and construction of cold stores;
- handling of merchandise;
- the merchandise in the refrigerated warehouse;
- the cold store and its customer;
- safety precautions; and
- personnel working in cold stores.

The book collates and reviews many documents on refrigerated storage. It will assist and guide professionals concerned with the design, construction and operation of cold stores.

Device for measuring small weight changes in carcasses during chilling and chilled storage

By J. Anderson and R. R. Weste

CSIRO Division of Food Research, Cannon Hill, Qld.

Introduction

Chilling in batch chiller rooms, where cold air is blown over carcasses or sides hanging on elevated rails, is an important step in the hygenic production of meat. As the carcass cools, water evaporates from its surface and the resultant weight loss is a direct monetary loss to the industry. Efforts are being made to ascertain the conditions permitting satisfactory rates of cooling in the chiller while causing minimum losses of weight.

Fifty devices for measuring weight loss were required for an investigation of chiller performance by the Physics and Engineering Section of the CSIRO Meat Research Laboratory. Commercially available load cells and experimental weight loss devices (Lovett 1973) were not suitable because of their high cost, instability or inability to withstand conditions in an abattoir. A new device was therefore developed which was:

- Compatible with rail systems of abattoirs, easy to clean and sterilize, and able to withstand rough handling and adverse conditions.
- Portable, simple in mechanical and electronic design, and cheap to manufacture.
- Capable of measuring weight changes of ± 7 g in carcasses weighing about 30 kg, and of ± 25 g in carcasses up to 200 kg, stable with time, preferably unaffected by temperature variations, and with an electrical output suitable for an existing data logger.

Design and construction

The final form of the device is shown in Fig. 1 and diagramatically in Fig. 2. Basically, the device is a spring balance, with a hook for carrying the carcass attached to a lower, moving plate. This plate is

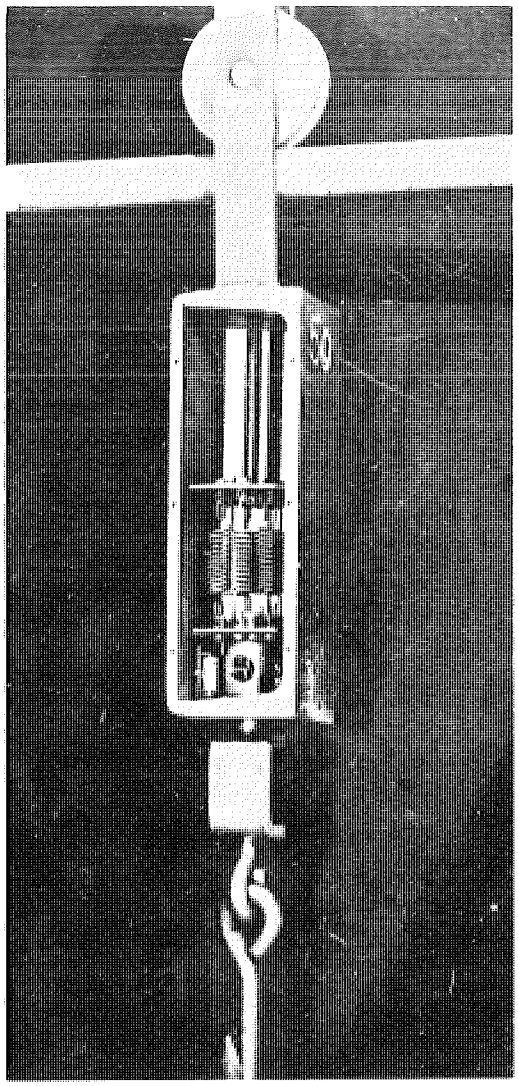


Fig. 1. Photographic illustration of the weighing device

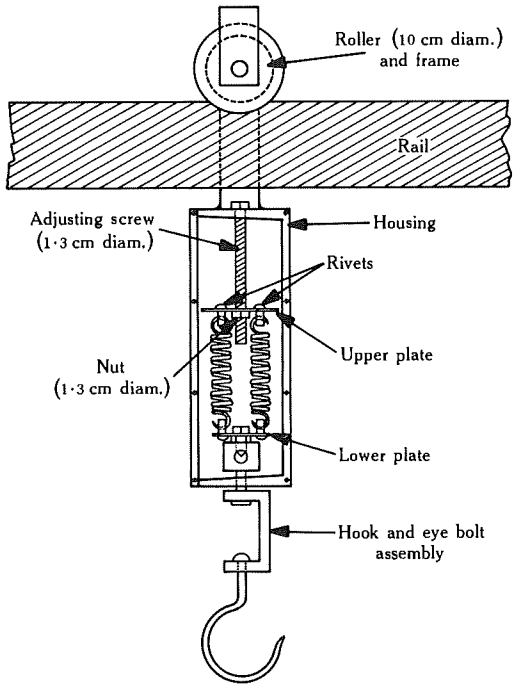


Fig. 2. Weighing device shown diagramatically.

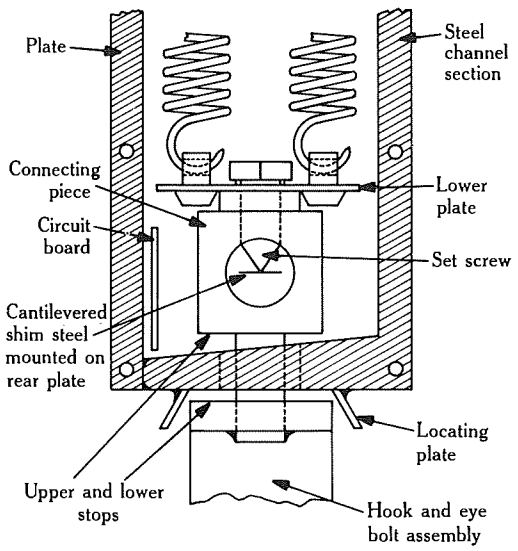


Fig. 3. Detailed view of displacement transducer.

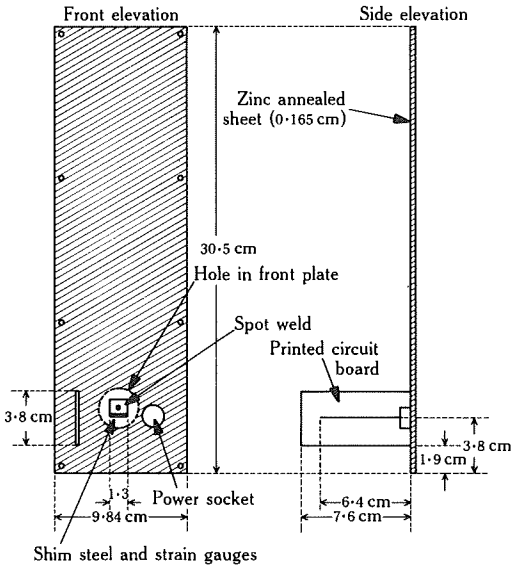


Fig. 4. Front and side elevation of rear plate.

suspended by six springs from an upper plate connected by a vertical adjusting screw to the housing and to the roller on the meat rail. The position of the upper plate is adjusted to vary the tension in the springs so that measurements may be made on carcasses that differ widely in weight.

Two sets of tension springs are used. Light springs for small stock (10–40 kg) are made from galvanized spring wire (wire diam. 1·6 mm, mean coil diam. 15·8 mm, 13 coils in each spring and slightly enlarged hooks). The heavier springs used for beef sides (50–160 kg) are similar but the diameter of the wire is 2·8 mm, the mean coil diameter is 19 mm and there are 20 coils. All other materials and components used in the device are readily obtainable or easily fabricated in a small workshop.

Loss of carcass weight causes the lower plate to rise (Fig. 3) and this in turn changes the shape of a strip of shim steel which is fixed to the electronic panel (Fig. 4) and makes contact with the lower plate through the specially machined set screw. Changes in shape of the shim steel are detected by changes in output of two strain gauges cemented to the shim. One gauge is in compression on the lower surface and the other in tension on the upper surface; their combined output is double that of a single gauge. The strain gauges and two resistors forming a bridge circuit (Fig. 5) are carefully selected to have very similar values of resistance and temperature coefficients, with the result that the bridge output is virtually unaffected by temperature changes.

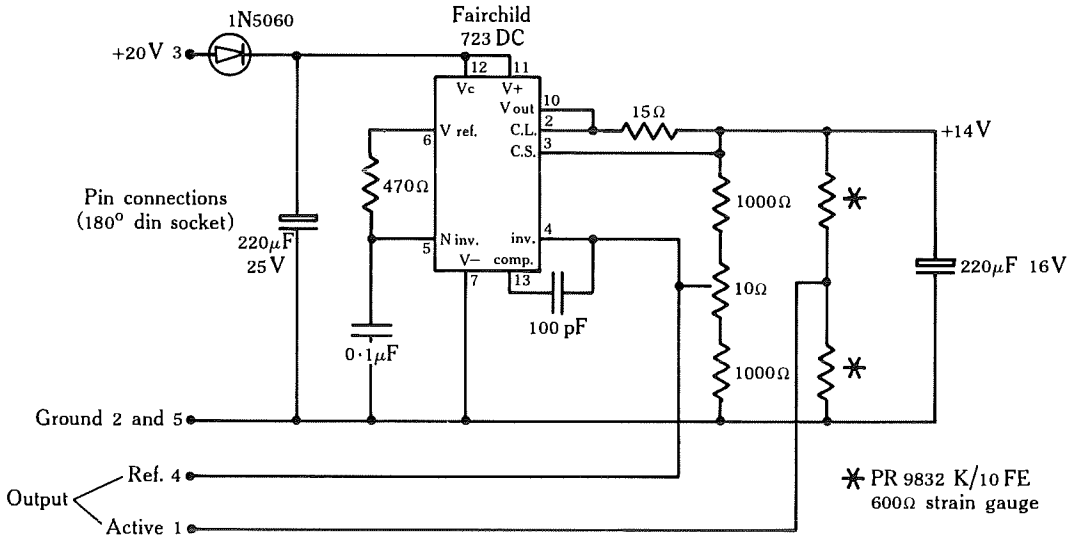


Fig. 5. The electronic circuit.

With the carcass hanging on the hook, the position of the upper fixed plate is altered with the adjusting screw (Fig. 2) until the bottom plate is 'floating' approximately half way between the upper and lower stop positions (Fig. 3). Changes in output from the bridge circuit resulting from changes in the weight of the carcass are then recorded by means of a scanner and data logger.

Calibration and performance

The instruments were calibrated with a base load of 24 kg when fitted with small springs, and 135 kg when fitted with springs for measuring weight changes in beef. The change in electrical output with change in weight was linear being about 0·7 g/μV for small springs and 2 g/μV for the heavy springs (Fig. 6). The instruments were calibrated at 0°C and 10°C and temperature coefficients were found to be reproducible and in the range 0–2 μV per Celsius degree. Corrections can therefore be made for changes in ambient air temperature. Drift of output with time was negligible over the calibration period of 2 to 3 days and there was negligible change in sensitivity or temperature coefficients when the instruments were calibrated at intervals during a period of several months.

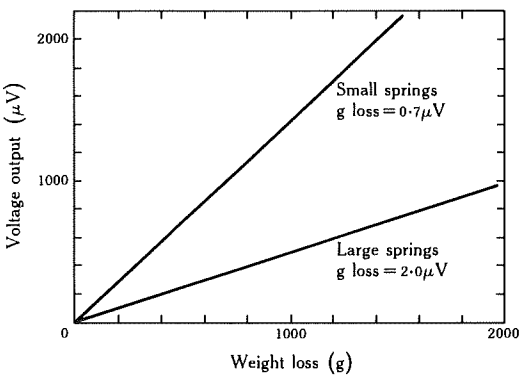


Fig. 6. Calibration of the weighing device.

The devices have been used for 16 investigations of weight loss in two mutton, one pork and four beef chillers. Electrical outputs, as well as other electrical signals from thermocouples, relative humidity and air velocity instruments, were measured and recorded at regular intervals throughout the chilling cycle by a 100-point data logger. Measurement discrimination in the logger was ±10 μV, so that weight losses could be measured with an accuracy of about ±7 g for small stock, and ±20 g for beef. Useful results were obtained in all investigations and typical curves of weight loss *v.* time of chilling are shown in Fig. 7. Any unsatisfactory results could generally be attributed to extraneous factors such as the presence of water on plug connections or contact between the test carcass and adjacent carcasses. Poor results were obtained when the bottom plate was not adjusted to be approximately midway between the upper and lower stop positions at the beginning of a measurement. This adjustment was

particularly difficult in beef chillers where it must be done from the top of a ladder three metres above the floor of the chiller. Regular inspections and calibrations showed that some errors of measurement resulted from the breakdown of the strain gauge. Twenty sets of strain gauges have been replaced during the 18 months that the 50 devices have been in use.

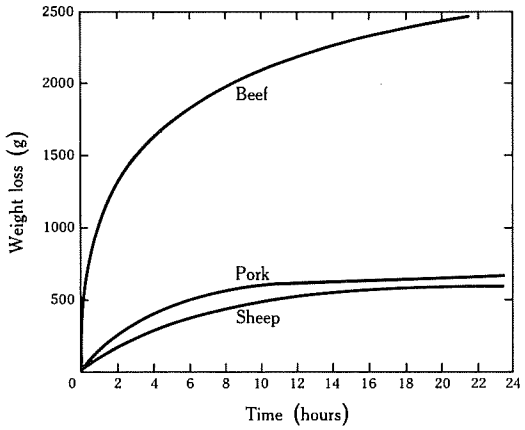


Fig. 7. Typical curves of weight loss *v.* time of chilling.

Reference

Lovett, D. A. (1973). Load cell for measuring small weight changes in carcasses. *CSIRO Food Res. Q.* **33,** 40–3.

Tropical and subtropical crops in Hawaii

By E. K. Akamine

Department of Botany, University of Hawaii, Honolulu, Hawaii 96822

A review of postharvest problems and handling methods. Professor Akamine recently spent 6 months as a guest worker at the Food Research Laboratory, North Ryde

Because crops are grown under much the same environmental conditions in Hawaii as in tropical and subtropical Australia, they are similarly subjected to attacks from insects and diseases that influence the quality of shelf life of the stored commodity. There are three species of fruit fly in Hawaii, the Mediterranean fruit fly, the melon fly and the Oriental fruit fly. Nearly all fresh commodities must be disinfested before shipping to continental United States or wherever fruit flies do not exist. The Queensland fruit fly poses a similar problem in Australia, whilst the problem of control of storage diseases is universal. In addition, there is a need to extend shelf life by regulation of ripening and senescence, and this is basically associated with respiration and the production of ethylene by the crop.

The primary aim in proper postharvest handling is to maintain the original quality of the commodity as long as possible. A diseased or insect-damaged fruit or fruit physically damaged in the harvesting or handling process cannot be expected to have much shelf life even under optimum storage conditions; it will only deteriorate. Since cultural practices including sanitation (disease and insect control, weed control, disposal of diseased and insect-infested plant materials, etc.) are the main factors determining the quality of the commodity at harvest, it is apparent that the best practices must be maintained in the field in

order to obtain a high quality commodity which will benefit most from proper postharvest handling.

The purpose of this article is to present some aspects of postharvest handling of some Hawaiian crops that may be of interest to growers and processors in Australia. The discussion of different fruits, vegetables and ornamentals is based on the results of research conducted at the College of Tropical Agriculture, University of Hawaii, and on observations in the field and in commercial packing facilities.

Papaw

Disinfestation methods for papaw and other fresh commodities intended for export from Hawaii are developed in a cooperative effort between the College of Tropical Agriculture, University of Hawaii, and the Hawaii Fruit Fly Investigations Laboratory of the United States Department of Agriculture (USDA). The University is responsible for determining the tolerance of commodities subjected to the disinfesting treatments prescribed by the USDA, which also determines the toxic residues of the treatments in the commodities. Three requirements must be met before any treatment is certified for a commodity. They are:

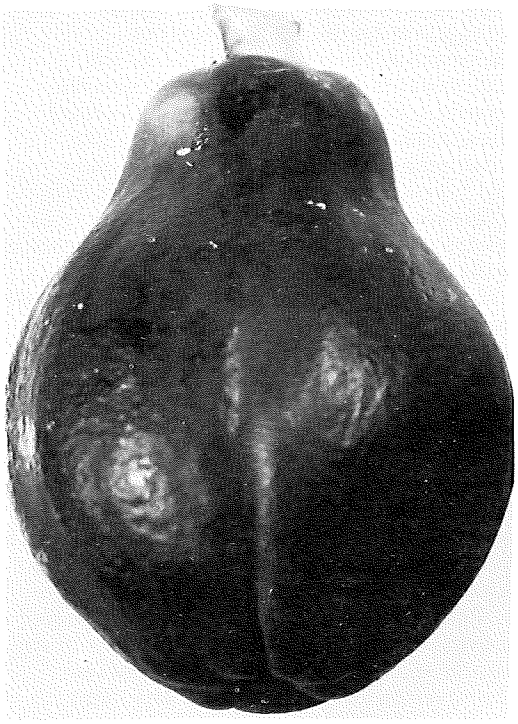
- the treatment must destroy the fruit flies or other insects involved,
- the commodity concerned must exhibit a reasonable degree of tolerance to the treatment, and
- toxic residues of the treatment must be within the safe levels prescribed by health regulations.

Two disinfestation methods are currently approved for export papaws—vapor heat and fumigation. In the vapor heat method, the fruits are initially subjected to dry heat at 43°C and about 40% R.H. for 6–8 h ('conditioning') to improve tolerance. They are then subjected to a saturated atmosphere (100% R.H.) and manipulation of the temperature for 4 h or more until they reach 47°C. The fruit is then cooled with circulating air for several hours before being packed for shipping. In the fumigation treatment, ethylene dibromide is used at the rate of 225 g per 28 m^3 of fumigation chamber space for 2 h followed by airing for 1 h before being packed. The fruit temperature during fumigation should not be below 21°C.

The vapor heat treatment reduces the typical papaw aroma without affecting the taste, but this is not objectionable. In fact, some people prefer fruit with reduced aroma. The treatment also controls storage decay. On the other hand, the fumigation treatment does not affect the aroma or flavour, but since it does not control storage decay, other means have had to be developed to overcome this problem. Primarily because of the shorter period and fewer risks of this treatment (for unless it is properly controlled, papaws can readily be damaged by vapor heat), more fruits for the export trade are fumigated than are treated with vapor heat. However, because the method leaves a relatively high bromide residue in the treated papaws, even though it is within the presently required tolerance limits, some concern has been expressed by growers and shippers over the possibility of ethylene dibromide being eliminated as a disinfestation treatment. If this happens, the industry must use the vapor heat treatment until such time as a substitute fumigant is found. Although research has shown that low dose gamma irradiation (about 25 krad) is also effective for disinfesting papaws, it is not as yet an approved treatment for export fruit, presumably because it may produce carcinogens.

In order to control storage decay in fumigated papaws, a simple hot water treatment was developed at the University of Hawaii in 1952. This was designed initially to control anthracnose, the major storage disease at the time, and the recommended method consisted of dipping the fruit in water maintained at 43–49°C for 20 min. The value of this treatment was proved in extensive trial shipments conducted by the University of Hawaii in projects supported jointly by the then Hawaii Territorial Government, the USDA and the papaw industry. It also proved effective for controlling other diseases which eventually attacked the fruit as the industry expanded. Nevertheless, until recently shippers were reluctant to use the treatment because it was not required by regulation for export fruit and it entailed additional cost. Moreover, in certain periods of dry weather as in the summer months, the incidence of storage decay was low. So the hot water treatment was used only sporadically by the industry.

In 1963, growers were obliged to stop applying certain fungicides in the field because their use on papaws had not been



Solo papaw. Photo: M. Awada.

cleared by the U.S. Food and Drug Administration. Consequently, the degree of field infection increased tremendously. Since the hot water treatment was practically forgotten by this time, the percentage of decay in papaws shipped to the West Coast of the United States was very high, sometimes reaching 75%. Upon the recommendation of the University of Hawaii, the shippers in desperation again began using the hot water treatment in 1964.

The hot water treatment was made an integral part of the disinfestation process in 1972 and since then all papaws for export have been subjected to a combination of both the hot water and fumigation treatments. The hot water treatment enhances the effect of the fumigant in killing fruit fly to such an extent that the standard dose of fumigant could be reduced. This in fact has not been done as the heated papaws can tolerate the treatment. The fruit is first dipped in hot water maintained at 49°C for 20 min (complete immersion), then cooled in a shower of tap water for *c.* 20 min before being fumigated. As the hot water treatment has always been considered an insurance against storage decay when the field infection rate is high, the required combination treatment now affords protection against storage decay at all times in addition to protection against emergence of fruit fly.

Papaws are harvested commercially when slightly yellow, i.e. as much as one-third of the fruit surface showing yellow. After disinfestation treatment (vapor heat or hot water plus fumigation), the fruits are packed in fibreboard cartons with shredded paper to prevent bruising in transit. At present, nearly all papaws are shipped by air. Those shipped by sea are carried in refrigerated containers at *c.* 10°C.

In addition to cold storage and hot water treatment, controlled atmosphere storage (C.A.) was investigated as a means of extending the shelf life of papaws. Fruits that were successively treated by hot water, fumigated and stored under C.A. (1–2% oxygen and 99–98% nitrogen at *c.* 10°C) had their shelf life extended by 1–2 days over that of fruits similarly treated but stored in air. Although trial shipments showed that transport by sea under C.A. conditions was feasible, the industry has opted for air shipment which does not require any special method of storage because of its short duration.

Application of gamma irradiation with a dose of *c.* 75 krad (higher doses are detrimental) delays ripening and senescence, but it does not control storage decay. The hot water treatment used for controlling storage decay in fumigated fruit is also effective for irradiated fruit. Hence if irradiation is approved for export papaws, the recommended treatment would consist of pasteurizing in hot water plus irradiation as this would simultaneously control fruit fly and storage decay while extending the shelf life of the fruit.

Pineapple

At present, pineapples for export do not receive a disinfestation treatment. Although formerly required this precaution was discontinued after it was discovered that while fruit fly may attack pineapples the flies do not survive in this fruit. Pineapples are harvested commercially when the surface of the fruit is up to one-quarter yellow if shipment is to be by sea, and when the surface is one-third to nearly full yellow for shipment by air. The base of each fruit is treated with a fungicide, Dowicide A (7·2 g/l water), to control a storage decay caused by *Thielaviopsis paradoxa*. After being

sorted for size, the fruits are placed in single layers on their sides in fibreboard cartons, each designed to hold 5–8 fruits depending on their size. The packed cartons are loaded directly onto the aircraft, but for shipment by sea they are carried in a refrigerated container at *c.* 7°C.

C.A. storage was found experimentally to be effective for extending the shelf life of pineapples, but the economic feasibility of its use for refrigerated fruit has not been fully established and the industry is not using it routinely. The effect of gamma irradiation on shelf life has not been established.

Probably the only serious obstacle to the expansion of the market in fresh pineapples is the physiological malady, Endogenous Brown Spot, which in its worst form is known as Black Heart in other areas of the world where pineapples are cultivated. In Hawaii, the disease occurs after refrigerated fruits are stored under ordinary conditions; it is rare in unrefrigerated fruit. Hence it is a problem only in pineapples shipped by sea, but as most are shipped by this means, it is a major concern for shippers. The disease can cause 75–100% loss in a single shipment. There are no visible symptoms in the intact fruit and hence roguing as a means of removing whole diseased fruits cannot be used.

Except for low temperatures in the field, no other known factors cause Endogenous Brown Spot. Until preventive measures applicable in the field are found, the only hope of controlling the disease lies in postharvest handling. Laboratory experiments recently conducted at the University of Hawaii have resulted in the discovery of a practical method to control the malady in shipped pineapples. The treatment entails application of dry heat (no humidity control) at 32–38°C for 24 h either just before or immediately after refrigeration; the latter method of application is slightly more effective.

Commercial line in Hawaii: an airgun is used to insert a tag with a brand name into the crown leaves of the pineapple before the fruit is packed and shipped.

In actual shipment, heat can be applied on the first day of the transit period in the shipping container or on the last day of the transit period, with refrigeration applied during the balance of the shipping period. The control of Endogenous Brown Spot in heated fruits after storage under ordinary conditions is 90–100% effective depending on the degree of incidence of the disease; the lower the incidence the better is the control. The only detrimental effect of the treatment is increased weight loss in the fruit, but this is more than offset by the beneficial effect of reduction of disease and improvement in the appearance (golden yellow) and flavour (reduced astringency) of the pulp. The pineapple industry in Hawaii is currently testing the feasibility of this treatment on a pilot scale.

Avocado

Fumigation by ethylene dibromide used to be the required treatment for avocados intended for export but it was subsequently declared ineffective for disinfestation unless administered at such high doses as to cause injury to the fruit. Gamma irradiation is also detrimental as it produces severe injury even at doses below the levels required for disinfestation (about 25 krad). Currently, fumigation with methyl bromide (1 kg per 28 m^3 for 4 h at a minimum fruit temperature of 21°C) is the approved treatment for export. However, only a few varieties can tolerate this treatment, which accelerates ripening. Hence shipment of avocados is very limited and is by air only. Some untreated fruit is also shipped to Canada and Alaska where fruit fly cannot survive because of the low temperatures prevailing. For extended storage, Hawaiian avocado varieties, in general, keep well at 7–13°C.

Lychee

The approved disinfestation treatment for export lychee is fumigation with ethylene dibromide (225 g per 28 m^3 for 2 h at a

Lychee. Photo: W. Yee.

minimum fruit temperature of 21°C). The fruit also tolerates disinfestation doses of gamma irradiation, but this treatment has not been certified for export fruit. Because of the erratic fruiting habit of the species in Hawaii, shipments of fresh fruit are limited and are all by air. Since lychees keep well under refrigeration (4–6 weeks at *c.* 7°C), shipment by sea is feasible when the volume to be exported justifies it.

The only major problem in postharvest handling is darkening of the pericarp (skin) of the fruit. Research has shown that injury to the cells as a result of surface desiccation is the cause of the darkening, and the solution lies in preventing this desiccation. In practice, this is done by packaging the fumigated fruit in a moisture-proof material such as polyethylene or a similar plastic membrane that retains high relative humidity. The package should allow adequate entry of air to prevent fermentation of the lychees. For shipping, the package is then placed in a cardboard carton. (Fresh whole lychees can readily be frozen and stored for as long as one year and retain their quality. This is one of only a few fruits in which freezing and subsequent thawing does not soften the pulp.)

Banana

The approved treatment for bananas intended for export is fumigation with ethylene dibromide (225 g per 28 m^3 for 2 h at a minimum fruit temperature of 21°C). Bananas used to be shipped from Hawaii to the United States mainland, but they are now imported from Central America via California to supplement the short supply on the Hawaiian market.

Research has unearthed varietal difference in the behaviour of bananas when subjected to fumigation. Thus the Cavendish varieties must be prevented from accumulating excessive concentrations of chlorophyll in the peel if the bananas are to tolerate the fumigation treatment, whereas the other varieties—Gros Michel, Apple and Cooking—do not have such a requirement. The Cavendish varieties may be readily safeguarded by covering the bunch in the field for the 2 months preceding harvest with an opaque paper or some similar material. Such shading reduces the accumulation of chlorophyll and prevents darkening of the fruit surface on fumigation. Apparently, fumigation interferes with the breakdown of chlorophyll in the ripening process if it is present in excessive amounts. For extended storage of both green and ripe, fumigated and untreated bananas, 13°C is the optimum temperature (this seems to be the only instance where green and ripe fruits have a similar storage requirement), and the optimum ripening requirement is a temperature of 21°C with *c.* 90% R.H.

Ripening in bananas is accelerated by the required ethylene dibromide fumigation, especially when they are stored under prevailing atmospheric conditions. Consequently, the possibility of using the fumigant as a ripening agent was investigated. Doses of the fumigant at levels below those required for killing insects were found to be just as effective for ripening as pure ethylene. Thus a substitute ripening agent is available when ethylene is unavailable.

Mango

Although mangoes grow well in Hawaii, shipment of the fresh fruit is not allowed because there is no approved treatment for destroying the mango seed weevil without injuring the fruit. Fumigation by ethylene dibromide eliminates any fruit-fly infestation but it is ineffective for killing the seed weevil. Gamma irradiation is effective but has not been approved as a treatment for export fruit. For extended storage, 7–13°C is the optimum temperature range; lower temperatures cause chilling injury.

Anthracnose is the most common cause of poor fruit set in mangoes. Different varieties are more or less tolerant to this disease. In Hawaii, the variety Haden, which is the major commercial variety, is very resistant and is probably more resistant to attack from fruit fly than are other varieties. In general, therefore, fruit set in this variety is heavy. Nevertheless, fruits produced in cloudy or rainy areas invariably succumb to anthracnose decay after the fruit is harvested and stored. The hot water dip treatment (at *c.* 47°C for 20 min) is effective for controlling this storage decay.

Tangerine

Hawaii does not produce tangerines in quantities sufficient for shipment and hence no disinfestation treatment has been developed for this fruit. Since the harvest season is very short (about 2 months in late fall and early winter), there is a tendency for growers to glut the market, with a consequent reduction in price. Moreover, Hawaiian tangerines are very perishable. Under ordinary storage conditions at room temperature their shelf life is only about 1 week. A storage method that would prolong the marketable life of the fruit was therefore needed. From the results of research, storage at *c.* 7°C and 92% R.H. was recommended. This permits tangerines to be stored for *c.* 6 weeks without excessive weight loss, decay or development of off-flavours—the main causes of deterioration in fruit during storage. Dowicide A dip at the same concentration as for pineapple is used routinely by growers immediately after harvest to control storage decay.

Ginger root

No disinfestation treatment is required for the shipment of fresh ginger root (rhizome). Before the advent of competition from Fijian ginger on the mainland market of the United States' West Coast, Hawaii was the major source of this crop for the Oriental population on the mainland. Currently, fresh ginger is shipped only in limited quantities from Hawaii, partly because of price competition and partly on account of decreased production resulting from field diseases and other factors. Today it is not uncommon to see foreign ginger, including some from Australia, on the shelves of supermarkets in Honolulu.

Ginger roots must be dug when they mature. If left in the ground for any extended period, they are subject to attack from insects and disease, and to discoloration and sprouting. When the shipment of this crop was substantial, growers wanted a method to keep the roots in good condition for as long as 6 months in order to prevent glutting the market and lowering the price. Ginger deteriorates in ordinary storage mainly as a result of weight loss caused by desiccation, decay, sprouting, discoloration and senescence. It was discovered at the University of Hawaii that at 13°C and 65% R.H. the rhizomes can be stored for 6 months. This condition minimizes the factors responsible for deterioration. The Hawaii State Department of Agriculture concurred with this finding after an extensive pilot experiment on conditions of storage.

Vanda orchid

Among the orchid blossoms exported from Hawaii, the Vanda orchid (*Vanda Joaquim*) contributes most to total sales. The blooms are shipped by air. Fruit fly are unable to survive on the tiny blossoms and so fumigation, which reduces the life of the blossoms, is unnecessary.

Fading is the major problem in the shipment of Vanda blossoms. It normally occurs at senescence but may happen prematurely as a consequence of pollination, disturbance of the pollinia or exposure to noxious gases such as domestic heating gases, automobile and aircraft exhaust fumes, or industrial and tobacco smoke, all of which may contain ethylene, acetylene and other related gases. Whatever the cause, as the flowers fade they produce ethylene. The Vanda flowers are among the greatest biological producers of ethylene (over 3000 ml/kg/h). If one flower in a package begins to fade, it will produce ethylene which will cause normal flowers to fade also in a few hours. Therefore the utmost care should be exercised during packing in order to avoid including in the package damaged flowers or blooms beginning to fade from other causes. In spite of the care being taken, human errors are unavoidable and shipments may be lost because of fading. An insurance against such losses is necessary.

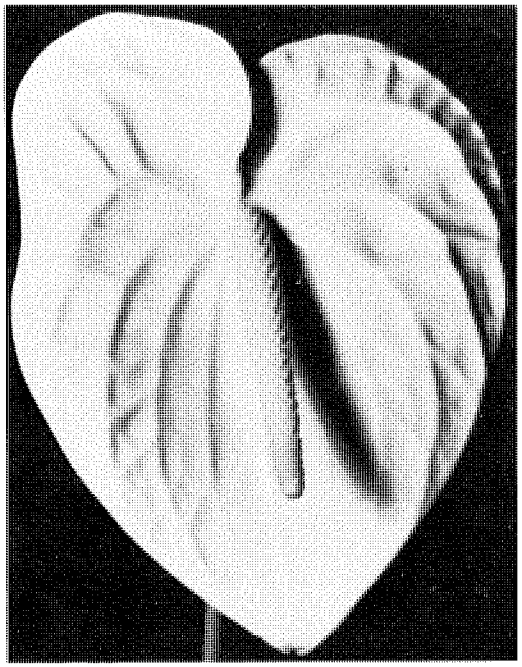
In laboratory experiments brominated charcoal, potassium permanganate and carbon dioxide were found to be effective as ethylene inactivators and therefore controlled fading. Hypobaric storage also seemed effective. The brominated charcoal method has not been adopted by the industry

because of practical difficulties including the need for very close control of the amount of bromine. Potassium permanganate incorporated in a commercial preparation called Purafil was found to be very effective for inactivating ethylene and appears to have commercial application for preventing premature fading. The other methods found effective as ethylene inactivators in the laboratory also need further experiment if they are to become of practical value. In the meantime, care in the packing operation to prevent the inclusion of damaged or fading flowers is the only commercial control measure available for preventing premature fading in Vanda orchid blossoms during shipping.

Anthurium

Flowers of anthurium (*Anthurium andraeanum*) are free from fruit-fly attack and therefore there are no restrictions on shipping them. These flowers constitute the major portion of the Hawaiian export trade in ornamentals. They are packaged in fibreboard cartons with moistened shredded newspaper and shipped by air mostly to the U.S. mainland, but some also go to foreign countries.

The vase life of cut anthurium flowers is long compared with that of other cut flowers. Provided they are packaged so that physical injury and excessive wilting are minimized during transit, anthuriums withstand shipping well. In general, the current demand for these flowers is such that almost immediately after harvest they are packaged and shipped, thereby eliminating the necessity of holding them in storage. However, with increased production from increased plantings, it is speculated that eventually the flowers will have to be held in storage for varying periods before shipment.



Anthurium (*Anthurium andraeanum*). Photo: H. Kamemoto.

A method for maintaining the life of the flowers during this holding period was therefore desirable.

As with most cut flowers premature wilting is mainly responsible for shortening the vase life of cut anthuriums. Wilting follows when water transport is interrupted by vascular blockage of the conducting system. Such an occlusion may be caused by bacterial organisms or by accumulation of products disintegrated by enzymatic or bacterial activities in the exposed (cut) ends of the flower stems. Eliminating the blockage by cutting off a short segment of the stem tip

Production and cash value of Hawaii's main fruit and ornamental crops*

	Total production (tonnes)				Value (US$1000)				Export to U.S. mainland (tonnes)			
	1972	1973	1974	1975	1972	1973	1974	1975	1972	1973	1974	1975
Avocados	461	344	516	460	120	113	187	184	Export very limited			
Bananas	2727	3316	3000	2812	720	773	865	856	Not exported			
Ginger root	227	234	160	360	209	354	218	481	111	139	49	209
Papaws	11 698	14 920	16 920	18 093	3423	4180	4788	5668	5118	7908	9760	10 322
Pineapples	858 929	734 670	638 528	616 760	43 900	39 600	41 100	38 500	27 256	46 735	39 246	42 793
Tangerines	252	132	159	76	83	42	58	34	Not exported			
	Total production (1000 doz.)				Value (US$1000)				Export to U.S. mainland (1000 doz.)			
	1972	1973	1974	1975	1972	1973	1974	1975	1972	1973	1974	1975
Anthuriums	542	556	560	NA	1789	2036	NA	NA	542	556	550	519
Vandas	NA	NA	NA	NA	290	273	NA	NA	NA	NA	NA	NA

* From Department of Agriculture, Hawaii, Statistics of Hawaiian Agriculture 1975.
NA, not available.

every other day or so will maintain normal conduction of water, and the flower does not wilt until natural senescence occurs. This method, of course, is labour intensive.

Research showed that certain preservatives may be added to the water in the vase to prevent vascular blockage and forestall premature wilting without resorting to cutting the tip of the stem. These materials not only extended the vase life of cut flowers held continuously at prevailing ambient temperatures, but they also exerted beneficial carryover effects after shipment. Effective chemicals were benzoic acid (500 ppm) and sodium hypochlorite (7·3 ppm). Vase life after shipping may be extended from 1·4 to 2·7 times by placing flower stems in solutions of the recommended preparation for 5–7 days at ambient temperatures before packaging and shipping. Thus treatments are now available for holding Hawaiian anthurium flowers in storage before shipping if and when holding becomes necessary.

Further reading

Akamine, E. K. (1960). Preventing the darkening of fresh lychees prepared for export. Hawaii Agric. Exp. Stn Tech. Prog. Rep. No. 127.

Akamine, E. K. (1962). Storage of fresh ginger rhizomes. Hawaii Agric. Exp. Stn Bull. No. 130.

Akamine, E. K. (1963). Ethylene production in fading Vanda orchid blossoms. *Science* **140,** 1217–8.

Akamine, E. K. (1965). Fumigation of bananas with special reference to ripening. *Hawaii Farm Sci.* **14**(2), 1–3.

Akamine, E. K. (1967). History of the hot water treatment of papayas. *Hawaii Farm Sci.* **16** (3), 4–6.

Akamine, E. K. (1967). Tangerine storage. Hawaii Agric. Exp. Stn Bull. No. 142.

Akamine, E. K., and Arisumi, T. (1953). Control of postharvest storage decay of fruits of papaya (*Carica papaya* L.) with special reference to the effect of hot water. *Proc. Am. Soc. Hort. Sci.* **61,** 270–4.

Akamine, E. K., and Goo, T. (1975). Vase life extension of anthurium flowers with commercial floral preservatives, chemical compounds and other materials. *Florists' Review,* 30 Jan., 14–15, 56–60.

Akamine, E. K., Goo, T., Steepy, T., Greidanus, T., and Iwaoka, N. (1975). Control of endogenous brown spot of fresh pineapple in postharvest handling. *J. Am. Soc. Hortic. Sci.* **100,** 60–5.

Akamine, E. K., and Sakamoto, H. I. (1951). Brominated charcoal to prevent fading of *Vanda* orchid flowers. *Am. Orchid Soc. Bull.* **20,** 149–52.

Physical data on uncooked prawns

This note summarizes the physical data required by Australian fishermen and processors to calculate, for instance, freezing rates or to determine the quantity of prawns which will fill tanks of chilled sea water.

The data were obtained from measurements on four commercial species of prawns, but the results probably apply to other species as well. The species tested were: tiger prawns, *Penaeus esculentus*; eastern king prawns, *P. plebejus*; school prawns, *Metapenaeus macleayi* and greentail prawns, *M. bennettae.* (Colour illustrations of three of these species—king, tiger and greentail, the latter being formerly known as *M. mastersii*, appeared in *Food Preservation Quarterly*, Vol. 30(2), June 1970, p.23.)

Freshly caught uncooked school, king and greentail prawns were collected from Tuggerah Lakes (N.S.W.) and from the Sydney Fish Centre, Pyrmont. The prawns were packed in ice and transported to the Food Research Laboratory at Ryde. Uncooked tiger prawns and large eastern king prawns were collected in Brisbane, packed in ice and air freighted to Sydney.

Size grades

The prawns were divided into three size grades according to their count per kilogram. Large prawns were those that numbered less than 40 to the kilogram, medium prawns were those that numbered between 40 and

90 to the kilogram and small prawns were those that numbered more than 90 to the kilogram.

Measurements

Samples of at least 50 prawns of each size grade and species were used to determine: the percentage recovery on heading and shelling to 'tail', 'cutlet' and 'meat'; percentage of adhering water; the true density and the load density. Before each determination the prawns were rinsed in water and drained for 20 min on an inclined (30°) No. 16 sieve. There were no samples of the large grade from the school or greentail species.

Percentage recovery after heading and shelling

Prawn 'tails' were prepared by removing the 'head' (cephalothorax) from the 'tail' (abdomen) with scissors. Prawn 'cutlets' were made by removing the shell of the first five abdominal segments by hand from the prawn 'tail' and prawn 'meat' was prepared by removing all the shell from the prawn 'cutlet'. The prawns were weighed before and after being headed and shelled and the recovery was calculated as a percentage of the initial weight.

Percentage of adhering water

Adhering water is defined as the water which fails to drain from freshly immersed prawns after 2 min on an inclined (30°) No. 16 sieve.

The prawns were drained for 20 min and then weighed (W_1). The drained prawns were then immersed in water and tipped onto a previously weighed No. 16 sieve (W_2); the prawns were drained for 2 min. The prawns and sieve were then weighed (W_3) and the percentage of adhering water was calculated as:

$$[(W_3 - W_2 - W_1)/W_1] \times 100$$

True density

The density of each whole, uncooked prawn was calculated by dividing its weight by its volume. The weight was measured after the prawns had drained for 20 min on an inclined (30°) No. 16 sieve. The volume was measured as the difference between the weight of a cylinder of water and the weight of the same cylinder of water containing a fully immersed, freely suspended prawn. If the weight of the drained prawn is W_1, the weight of the cylinder of water is W_2, and the weight of the cylinder of water and prawn is W_3,

the density of prawn $= W_1/(W_3 - W_2)$ g/ml.

Load density

The load density is defined as the weight

Physical data of uncooked prawns

Property	Prawns		
	Large (< 40/kg)	Medium (40–90/kg)	Small (> 90/kg)
Average percentage recovery on heading and shelling to:			
'tail'	57 (2·4)[A]	60 (2·4)	64 (2·7)
'cutlet'	50 (2·5)	52 (2·3)	54 (2·5)
'meat'	46 (2·5)	48 (2·5)	50 (2·6)
Average percentage of adhering water	5·5 (0·02)	7·5 (0·04)	10 (0·14)
Average density (g/ml)		1·08 (0·011)	
Load density in water (kg/m^3)		600	
Water content[B] (%)		70	
Average freezing point[B] (°C)		−2·2	
Specific heat above freezing[B] (J/kg °K)		$3·6 \times 10^3$	
Specific heat below freezing[B] (J/kg °K)		$1·9 \times 10^3$	
Latent heat[B] (J/kg)		$2·8 \times 10^5$	

[A] Values in parentheses are the standard deviations.

[B] 'ASHRAE Handbook of Fundamentals' (1972), page 573. (American Society of Heating, Refrigerating and Air-Conditioning Engineers: New York.)

of prawns which may be randomly packed into a water-filled container so that the water may move freely among the prawns. The load density was measured by means of a perforated plastic box with dimensions $0{\cdot}6\,m \times 0{\cdot}4\,m \times 0{\cdot}3\,m$ ($0{\cdot}072\,m^3$). The box was immersed in water, and then removed and allowed to drain for 20 min and weighed (W_1). It was then filled with drained prawns and immersed in water to ensure that the prawns were packed so that water could just move freely past them. The box and prawns were removed and drained for 20 min and weighed (W_2). The load density = $(W_2 - W_1)/0{\cdot}072\,kg/m^3$.

Results

The results of these measurements and other appropriate data on the physical properties of uncooked prawns are given in the accompanying table. No differences were noted between the species for any of the properties measured, but differences were found for the different grades of prawn for percentage recovery on heading and shelling and percentage of adhering water.

Acknowledgment

This research was financed by a grant from the Fishing Industry Research Trust Account.

JUDITH H. RUELLO

News from the Division

Obituary

Edward Felix Lucien John Anet, 1925–1976

Dr E. F. L. J. Anet was born in Doulcon, France, in 1925 and died suddenly at his home in Lindfield, N.S.W., on 27 December 1976.

Ted Anet joined CSIRO in June 1950 when he was awarded a post-graduate studentship to work for his Ph.D. degree in Lord Todd's laboratory at Cambridge. His scholastic and academic career had been brilliant, first at Sydney Boys' High and then at Sydney University, and he obtained his Ph.D. degree in the shortest time possible, returning to Sydney in October 1952 to join the Division as a Research Officer. Here his interest in the chemistry of natural products, built up at Sydney University in the Hughes-Ritchie school, was maintained by his location in Dr Thelma Reynold's team to work on the chemistry of the non-enzymic browning reaction.

On this project, after initial work on the identification of natural fruit acids, Ted was assigned the task of isolating and identifying the degradation products of carbohydrates believed to be intermediates in the development of brown pigments when sugars are heated with amino acids. In this difficult sphere of carbohydrate chemistry, his experimental work was of an exceptionally high order and, coupled with an acute appreciation of its theoretical aspects, led to significant advances in our understanding of the browning reaction. This work yielded 34 papers in 16 years which, together with four 'outside' papers in this period and eight papers from his university studies, gave Ted an enviable record of 46 research papers in less than 20 years. At the same time, he built up an international reputation as a carbohydrate chemist, resulting in invitations to give talks overseas, prepare reviews, and act as Australian representative on the Editorial Board of the journal *Carbohydrate Research*.

When it was decided to cease the Division's work on the browning reaction, Ted was assigned to take over the late Dr F. E. Huelin's work on the involvement of farnesene in the superficial scald of apples, together with Ili Coggiola, whose sudden death at the early age of 37 preceded Ted's by only four years. This collaboration produced six papers over the period 1969–1972 inclusive until it became apparent that a greater understanding of the physiology of this storage disorder would be required before chemical studies could make a further significant contribution.

With the cessation of the farnesene work, Ted was called upon to investigate the possible usefulness of antioxidants in foodstuffs, the presence of ascorbic acid sulphate in foods, the development of off-flavours in cooked 'polyunsaturated' mutton, and most recently the occurrence in foods of certain amines implicated in migraine. These studies resulted in two publications before Ted's untimely death.

Though regarded as something of a 'loner' in his own research work, Ted was always ready, willing and able to assist his colleagues on the staff with any problems in organic chemistry they might encounter. Thus, though he preferred to work in a narrow, well-defined field, his chemical interests were very broad, and many of his colleagues will remember his willingness to discuss a hypothesis with them and to suggest a new path through their difficulties. His acute brain allowed him to sum up an argument rapidly and to give considered advice that was short and to the point—propounders of unsound or illogical hypotheses found him a severe critic. As a result of such discussions, many of his co-workers were saved the trouble of needless experimentation.

Ted was always willing to employ the latest developments in techniques and instrumentation, his recent interest in electronics allowing him to modify equipment to suit his purposes. In the complex modern fields of conformational analysis and n.m.r. spectroscopy he was a reservoir of information, and his passionate interest in chemical nomenclature and journalistic style was of great assistance to authors compiling manuscripts.

Ted was very much 'a family man'; he met his wife Jennifer when she was employed by the Division at Homebush, and he left one son and three daughters, aged between 13 and 18. His spare time was devoted to fishing and electronics, two activities which greatly broadened his circle of friends within the Division. He will be sadly missed by his family and colleagues; his published work stands as his memorial.

B.V.C.

Congresses

The Fifth International Congress of Food Science and Technology, hosted by the Union of International Food Science and Technology of Japan and sponsored by the Union of International Food Science and Technology, will be held at the Kyoto International Conference Hall, Kyoto, Japan, from 17 to 22 September 1978. The Congress will be a major meeting of professionals for the international exchange of ideas and experience in those scientific disciplines and technology relating to the production, processing, distribution conservation, and utilization of food for adequate nutrition, and related concerns. The steering committee and the program committee are already actively working on plans for the Congress to encompass and call public attention to major progress made in the field of food science and technology since the previous Congress, and to provide opportunity to meet, exchange ideas, obtain stimulation for further work and promote world-wide collaboration on topics of great importance.

For further information and preliminary registration blanks, please write to: Secretariat, Fifth International Congress of Food Science and Technology, c/o Nippon Italy Kyoto-Kaikan, Sakyo-ku, Kyoto, 606 Japan.

The 20th International Horticultural Congress will be held in Sydney from 15 to 23 August 1978, under the direction of the International Society for Horticultural Science. It will also have the support of the Commonwealth and State Governments of Australia, and of the Australian horticultural industries.

The main purpose of the Congress is to facilitate exchange of information in all spheres of horticulture. The Congress is open to all. It will cater for technologists, scientists, practising horticulturists, extension specialists and research workers.

Further information may be obtained from the Secretary, 20th International Horticultural Congress, 157 Liverpool Street, Sydney, 2000, who will also enter names on a mailing list for subsequent information on the Congress.

Visiting workers

Associate Professor E. C. Tigchelaar of the Department of Horticulture, Purdue University, Lafayette, Indiana, is spending the period from October 1976 to May 1977 at FRL, as a Visiting Scientist in PPU. He and Dr W. B. McGlasson are collaborating in a study of the physiology of ripening mutants of tomatoes.

Dr Christa Critchley, formerly of the

Botany Institute of the University of Düsseldorf, Germany, joined PPU for eight months from October 1976 as a Visiting Scientist. Her interests are in temperature regulation and plant growth and development, and in plant growth and chloroplast development.

Professor T. A. Nickerson, Department of Food Science and Technology, University of California, Davis, spent three months from November 1976 at DRL. Professor Nickerson, who is well known for his work on lactose, participated in current studies of lactose crystallization in the whey utilization research program.

Jubilee year seminar

As part of the activities to celebrate the 50th Anniversary of CSIRO, the Division held a seminar entitled 'Science and Technology of Food Preservation by Cold', in September 1976 at North Ryde. Among those invited was a number of distinguished overseas scientists who had come to Australia to attend a joint meeting in Melbourne of the Food Sciences, Refrigeration and Air Conditioning Commissions of the International Institute of Refrigeration.

Appointments

Dr B. A. Cornell was appointed Research Scientist and commenced work in FRL's Physics Section in November 1976. He is studying the physical properties of simple lipid–water–protein systems to elucidate the structure of natural lipid–protein complexes. The project aims at an understanding of the fundamental processes that cause irreversible changes during freezing, drying and heat treatments of foods. Dr Cornell holds B.Sc. and Ph.D. degrees from Monash University and recently spent a year at the University of London under a CSIRO Postdoctoral Studentship.

Miss P. L. Conway, B.Sc., was appointed as an Experimental Officer to work in FRL's Microbiology Section on spore morphology and on the microflora of the human gut. Miss Conway had previously completed an assignment at MRL concerned with the use of microbes from ruminant paunches as inocula for fermentation systems.

Dr C. R. Timms has joined DRL to undertake a research program on the physical and chemical structure of butterfat and of blends of butterfat with other edible fats and oils. After completing his M.A. and Ph.D. degrees at Cambridge, Dr Timms worked for several years on lipid research in industry in Britain.

Miss Helen Dornom has been appointed Information and Liaison Officer at DRL. Miss Dornom graduated in Agricultural Science from the University of Melbourne and has recently completed studies for a Master's degree.

Mr D. T. Kerr, Experimental Officer, was appointed to the Process Development Group, MRL in December 1976, to work on the investigation and practical implementation of new meat processing techniques. Mr Kerr has a degree in Mechanical Engineering from Caulfield Technical College. He was previously employed by M.W.M. Diesel Pty Ltd.

Mr P. Pisansarakit, Experimental Officer, was appointed by the CSIRO Division of Animal Production to the Muscle Growth and Development Section, MRL in December 1976, to work on the preparation of histological sections of muscle and to operate image analysis equipment. He has the degree of Bachelor of Rural Science and was previously a lecturer at Khon Kaen University in Thailand.

Mrs V. Miller, Experimental Officer, resigned from her position with the Biochemistry Section, MRL.

Mr R. D. Redford, Experimental Officer, resigned from his position with the Process Investigation Section, MRL.

General

A joint AIFST/ASM/CSIRO Symposium on 'Food-borne microorganisms and public health' was held at FRL on 13 August 1976. The guest of honour was Miss Betty Hobbs, recently retired Director of the Central Public Health Laboratory, Colindale, London.

AIFST/ASDT/AIP sponsored a seminar on 'Aseptic packaging' at North Ryde on 24 November 1976. More than 100 persons from the three institutes attended.

FRL welcomed a number of high school students for brief periods of 'job experience' late in 1976, under a scheme devised by the New South Wales Department of Education.

Because News from the Division in this issue covers the period since Vol. 36, No. 2 of the *Quarterly*, details of overseas travel and some other items have been omitted to conserve space.

CSIRO Division of Food Research

Technical inquiries may be directed to

Food Research Laboratory

P.O. Box 52, North Ryde, N.S.W. 2113
(Delhi Road, North Ryde)
Telephone: 888 1333 (STD code 02)
Telegrams: Foodresearch Sydney

Dairy Research Laboratory

P.O. Box 20, Highett, Vic. 3190
(Graham Road, Highett)
Telephone: 95 0333 (STD code 03)
Telegrams: Foodresearch Melbourne

Meat Research Laboratory

P.O. Box 12, Cannon Hill, Qld. 4170
(Cnr. Creek and Wynnum Roads, Cannon Hill)
Telephone: 399 3122 (STD Code 07)
Telegrams: Foodresearch Brisbane

CSIRO FOOD RESEARCH QUARTERLY Volume 37 Number 1 March 1977

Contents

1. QUALITY OF AUSTRALIAN HONEYS

10. DEVICE FOR MEASURING SMALL WEIGHT CHANGES IN CARCASSES DURING CHILLING AND CHILLED STORAGE

13. TROPICAL AND SUBTROPICAL CROPS IN HAWAII

20. PHYSICAL DATA ON UNCOOKED PRAWNS

22. NEWS FROM THE DIVISION