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Prune Drying in Australia—A Reappraisal of Methods

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Martin W. Miller, Associate Professor of Food Technology at the University of California, Davis, spent from December 1964 to June 1965 in Australia as a Senior Fulbright Fellow. Professor Miller and collaborators had carried out investigations on more efficient methods of drying prunes in California, and with officers of the Division of Food Preservation he planned pilot-scale and commercial trials to test whether the advantages evident in California could be extended to Australia.

PRUNE plums are grown in Australia primarily for drying, the annual production of the dried fruit being 3000–5000 tons, of which about half is exported. This output is only a small part of the world production of prunes, but represents an annual value to the growers of about a million dollars.

Most Australian prunes are grown in New South Wales, where production is centred in irrigated orchards around Griffith and in non-irrigated orchards in the Young district. The main plum variety used in these localities is the d'Agen, but a significant (though decreasing) tonnage of the Robe de Sergeant variety is still dried. These two varieties of plum are ideally suited for the production of dried prunes, because the fruits when mature contain a high percentage of solids (25–30%) and consequently give high yields of dried prunes.

Australian System of Drying Prunes

In recent years, the production of prunes from plums by sun drying has become obsolete in Australia, where the fruit are now invariably dried with hot air in tunnel dehydrators operated on the counter-flow principle. The use of the counter-flow method of operation stems from early experiments carried out in California by Cruess (1919) and by Christie and Ridley (1923), which showed that prunes could be efficiently dried by passing them through a tunnel against a flow of heated air. Mrak and Perry (1948) later recommended that when prunes are dried by this method the air leaving the cooler end of the tunnel, where the fresh fruit enters, should have a humidity of 65% R.H., since under such conditions maximum heat economy is obtained.

The counter-flow system of drying is characterized by slow drying of the prunes in the early stages, followed by faster drying as the fruit is moved through the drying tunnel towards the hot end. In practice, trucks holding trays of fresh plums successively enter one end of the drying tunnel and according to a fixed time schedule are moved towards the opposite end, into which a continuous stream of hot air is blown. The maximum temperature to which the prunes are exposed as they approach the outlet end of the tunnel, where they encounter the hottest, driest air, is 160°F. It is generally considered that near-dry prunes suffer little heat damage at this temperature, and under the conditions described the total drying time is from 24 to 30 hr, depending mainly on the size of the fruit.

New Californian System

An alternative system that might be adopted with tunnel dehydrators is the 'parallel-flow' system, wherein the trucks of fruit enter the tunnel at the hot end and progress through it in the same direction as the air stream. This system of drying is

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characterized by rapid water removal in the early stages of drying, followed by slower drying as the fruit approaches the cooler or outlet end. As the air is relatively moist at the outlet end of the tunnel, an important limiting factor determining the final rate of drying is the relative humidity of this air.

The parallel-flow procedure was investigated by Christie (1926), who tried this method for drying prunes of the Imperial variety. He reported unfavourably on the procedure, because he found that the fruit split severely during drying, with resultant 'bleeding'. It was not until many years later that Gentry, Miller, and Claypool (1965) re-examined parallel-flow methods for the drying of prunes, and some of the advantages of parallel-flow drying then became more fully apparent. By this time much less emphasis was being placed on heat economy, because relatively cheap fuel (natural gas) was readily available in California. Indeed, owing to the large capital costs involved in erecting new dehydrators, greater emphasis was being given to increasing the drying capacity of existing plants even at the cost of greater fuel consumption.

In their investigations on the parallel-flow method Gentry, Miller, and Claypool (1965) used the d'Agen variety in a commercial prune-drying plant. They found that with the parallel-flow method inlet air temperatures up to 195°F could be used without heat damage to the prunes, because evaporative cooling during the earlier stages of fast drying maintained the flesh temperature of the fruits appreciably below that of the inlet air. Moreover, the throughput of prunes could be increased by 35–40% over that attainable with counter-flow operation, even though the fuel costs per dry ton rose only by about 13%. For these reasons, the parallel-flow system is now favoured in California.

This article describes some experiments recently conducted in Australia to ascertain whether comparable improvements in drying capacities of existing tunnel dehydrators could be attained in this country, where hitherto the parallel-flow system has not been used on the commercial scale. As shown below, parallel-flow operation of the tunnel dehydrators does offer considerable economic advantages over the counter-flow methods now generally used in this country.

EXPERIMENTAL COMPARISON OF TWO SYSTEMS

As described in detail later, preliminary pilot-scale drying trials were carried out in an experimental cabinet dehydrator in which temperature and other conditions could be adjusted to simulate the successive stages of drying that would occur in a tunnel dehydrator. These trials were later followed by other comparative trials carried out under full-scale conditions in conventional tunnel dehydrators.

The plums used in the experiments were all of the d'Agen variety. They had been grown in non-irrigated orchards in the Young district and, despite an exceptionally dry season, were fully mature when harvested. The criteria used to assess maturity were specific gravity of the whole fruits, soluble solids content of the juice, and softness of the flesh.

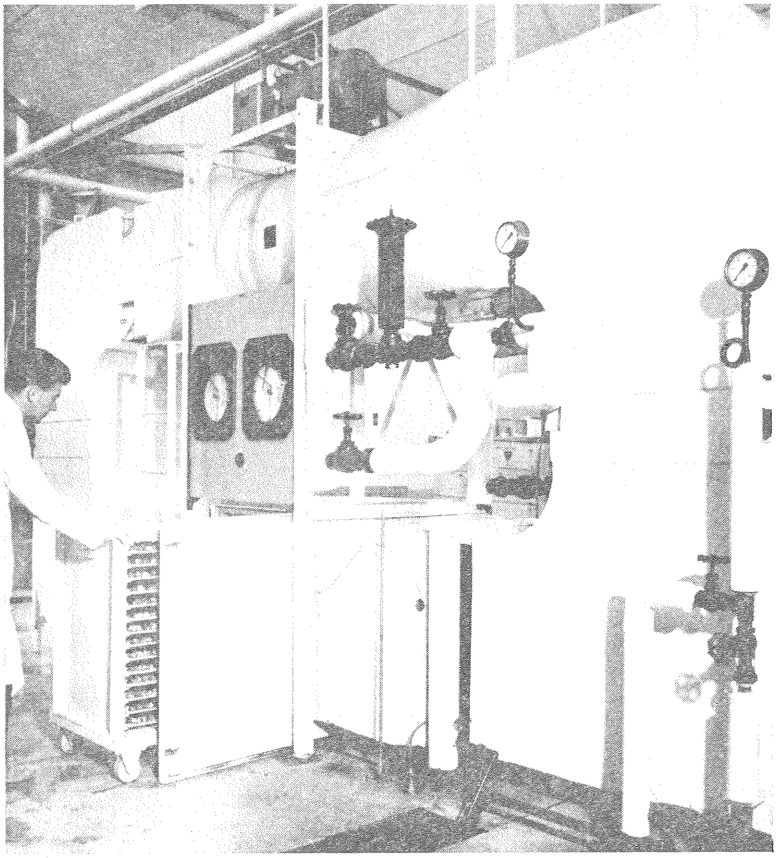
For the determination of total solids contents of the plums before drying and the moisture contents of the dried prunes, standard oven-drying techniques were used (Association of Official Agricultural Chemists 1960). The average weight of the pits (fruit stones) of the fruit used in the pilot trials was also determined, in order that losses in weight noted during the course of drying could be interpreted in terms of loss of moisture content of the flesh alone. For this purpose, it was assumed that no significant change in dry weight of the pits occurred during drying, this assumption being warranted by data obtained from earlier experiments.

Pilot-scale Trials

It is normal commercial practice in Australia to spray the fresh plums with a near-boiling, dilute (0·1%) solution of sodium hydroxide before they enter the tunnel dehydrator to be dried. This has the effect of 'checking', or cracking, the wax layer on the skin of the fruit, thereby facilitating the escape of moisture from the flesh and consequently accelerating drying in the tunnel.

Accordingly, in preliminary studies in a pilot dehydrator an attempt was made to simulate the effect of spraying by dipping the fruit in boiling solutions of caustic soda. Thus in each of the three trials conducted, one on the counter-flow principle and two on the parallel-flow system, batches of fruit were included that had been dipped for 10 sec in either 0·1% or 0·2% solutions of sodium hydroxide, at the boil; for comparison, other batches were given no pretreatment. In one of the two parallel-flow drying runs, fruit dipped similarly in 0·4% boiling caustic soda solution were also included; another batch in this run had been previously exposed to the vapour of boiling petroleum ether until all surface wax was removed.

These various pretreatments were given in order to ascertain the extent to which the drying rate was affected by modification, or complete elimination, of the surface wax layer on the fruit. It was also of interest to determine whether anything was to be gained from the lye pretreatments when the parallel-flow system of drying was used, for in California such pretreatments are no longer considered necessary. Further details of the equipment and procedures used in both the preliminary trials and full-scale trials follow.



Model dehydrator used in the pilot-scale trials.

The ripe plums for the pilot-scale trials were transported to the North Ryde laboratories of the CSIRO Division of Food Preservation, and there sorted for size. Only those weighing between 12 and 20 g were utilized. The various pretreatments previously mentioned were applied to batches of such fruit.

The prunes were dried in an experimental cabinet dehydrator, which has been described by McBean, Pitt, and Johnson (1965). The cabinet section of this dehydrator housed a tray-carrying trolley over which the drying air was passed. The speed of the drying air and its wet-bulb and dry-bulb temperature could be controlled and recorded. The first drying run was carried out on a schedule corresponding to the counter-flow system, and for the second and third runs a schedule simulating the parallel-flow system was used. In all cases the air speed was maintained at 1000 lin ft/min. The moisture lost during drying was estimated by periodically weighing the tared trays, each of which carried an initial load of 2000 g of fresh plums.

Counter-flow System

The temperature schedule used for the counter-flow trials was based on measurements taken in previous years in Australian commercial tunnel dehydrators operating on this principle, and is given in Table 1.

Table 1

Time and Temperature Schedules

Counter-flow Drying				Parallel-flow Drying			
Time (hr)	Dry Bulb (°F)	Wet Bulb (°F)	R.H. (%)	Time (hr)	Dry Bulb (°F)	Wet Bulb (°F)	R.H. (%)
3	130	95	28	1	195	115	10
3	136	95	24	1	178	115	17
3	141	95	19	1	171	115	19
3	146	95	17	1	168	115	22
3	151	95	14	1	166	115	24
3	155	95	12	1	165	115	25
3	158	95	11	Till dry	160	115	27
Till dry	160	95	10				

The plums that showed the slowest loss of water were those which had not been given a preliminary caustic dip before being dried (Fig. 1, curve C_1). Under the same drying conditions the plums dipped in 0·2% caustic soda solution dried somewhat more rapidly (curve C_2); while those dipped in 0·1% caustic soda dried at an intermediate rate, their drying rate curve (not shown in Fig. 1) being closer to C_2 than to C_1.

Calculations based on the solids content of fresh and dried fruits, assuming that the pit weights were not affected, indicated that the prunes dried in the cabinet dehydrator under conditions simulating counter-flow drying would have had a moisture content of 20% (wet basis) when the weight of the 2000-g load of each tray had been reduced to 820 g. For the undipped prunes, this weight would have been obtained in 27 hr, while for the fruit dipped in 0·2% caustic soda the time would have been 25 hr.

For the fairly small prunes used in these trials, the drying times obtained were much longer than can be obtained under commercial conditions of counter-flow drying. Gentry, Miller, and Claypool (1965), for instance,

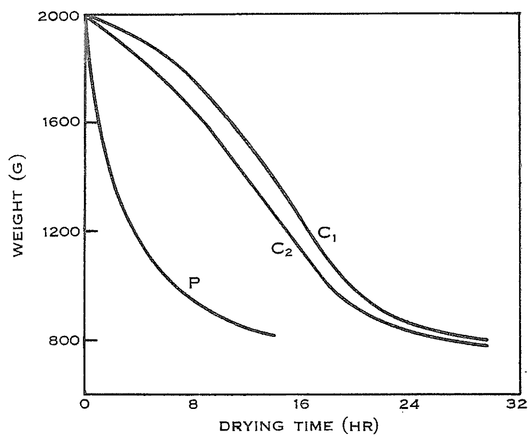


Fig. 1.—Weight losses of prunes during drying.
C_1, *Untreated fruit, counter-flow drying.*
C_2, *Lye-treated fruit, counter-flow drying.*
P, *Pretreated and untreated fruit, parallel-flow drying.*

dried prunes of similar size and solids content to a moisture content of 20% in little more than 15 hr. These investigators used a higher dry-bulb temperature, and the relative humidity of the air passing over the fruit during the first 9–12 hr of drying was lower than that in the present tests (Table 1).

The observed differences in drying rates for the undipped and lye-dipped fruits (Curves C_1 and C_2, Fig. 1) confirm what has already been established from many previous observations, but it is possible that the effect of the lye pretreatment may be relatively small where the conditions of drying, even by the counter-flow method, produce more rapid water removal. In the present work there was a relatively heavy layer of wax on the skin of the fresh fruit, probably due to the fact that the fruit matured under near-drought conditions. Such a layer might be expected to exert its maximum effect in retarding loss of moisture from the flesh of the fruit during the earlier stages of drying, especially when, as in the present instance, the drying temperature is not very high.

Parallel-flow Drying

In contrast to the results obtained under simulated counter-flow drying, parallel-flow drying of similar fruit in the same equipment gave much faster drying, especially in the early stages (Curve *P*, Fig. 1). The time–temperature schedule used for this system is indicated in Table 1, and was based on experience gained by one of the authors (M.W.M.) in the earlier studies in California. Two successive runs were made on the parallel-flow principle and, as indicated previously, each run included batches of fruit that had been subjected to various treatments designed to modify the wax layer to a greater or lesser degree.

The fruit used in the parallel-flow schedule were somewhat more mature than those used in the counter-flow trials, and had a slightly higher solids content, so that a residual weight of 840 g corresponded to a moisture content of 20%. This weight was attained after only 12 hr of drying, and there was no evidence of case-hardening of the fruit at this stage, despite the higher temperatures to which they had been exposed throughout the drying period. In Figure 1, Curve *P* (which represents the average drying curve for the two successive runs) shows that the rapid initial rate of water removal did not adversely affect the drying rate as the moisture content approached 20%.

The influence of 0·1% or 0·2% caustic dips on the drying rate was negligible in this system of drying, and even when the lye concentration was 0·4% the weight-loss curve still coincided with Curve *P* in Figure 1. Complete removal of wax from the fruit by means of petroleum ether vapour also apparently had no effect on the drying rate. These findings suggest that under parallel-flow conditions the wax layer does not significantly retard water transmission through the skin. It is probable, therefore, that under these conditions of drying the chief factor limiting the rate of water loss is the rate of diffusion of water through the flesh of the fruit. It follows also that in the parallel-flow system, preliminary treatment of the fruit with sodium hydroxide sprays or dips offers no advantages in regard to drying rates.

Full-scale Trials in Tunnel Dehydrators

When it had been established that the parallel-flow system of operation offered advantages in reducing drying times, further tests were conducted under commercial conditions in the prune processing areas.

Before being used in the tunnel drying trials all fruit had after harvesting been stored at 36°F for seven days. These fruits were larger (16–24 g) than those used in the pilot-scale trials in the Ryde laboratories. The total solids contents and final moisture contents were determined, as before, in order to provide data for the drying curves.

All fruit used in the tunnel drying trials were given the normal spray pretreatment with hot 0·1% caustic soda solution.

Equipment and Procedures

For the drying trials in which the two systems of operation were compared on the commercial scale, two adjacent tunnel dehydrators were used. Each tunnel was 35 ft long, with space for seven trucks loaded with fruit. Used to convey the fruit through the tunnel dehydrators, these trucks each accommodated 40 trays (3 ft by 2 ft), which were arranged in tiers in two stacks such that the distance traversed by the air flowing over each tier was 4 ft. Air entering the tunnels was heated indirectly by means of oil burners, with thermostat regulation (on or off) to effect temperature control. Calibrated jets on the burners permitted estimation of the total fuel consumed during the course of each drying run. Air speed over the fruit was 700–1000 lin ft/min.

One of the tunnels was operated on the counter-flow principle in accordance with current commercial practice in Australia, the fruit being sprayed with 0·1% lye in the usual way before entering the dehydrator. To improve uniformity of drying at the end of the drying process, after each truck had reached

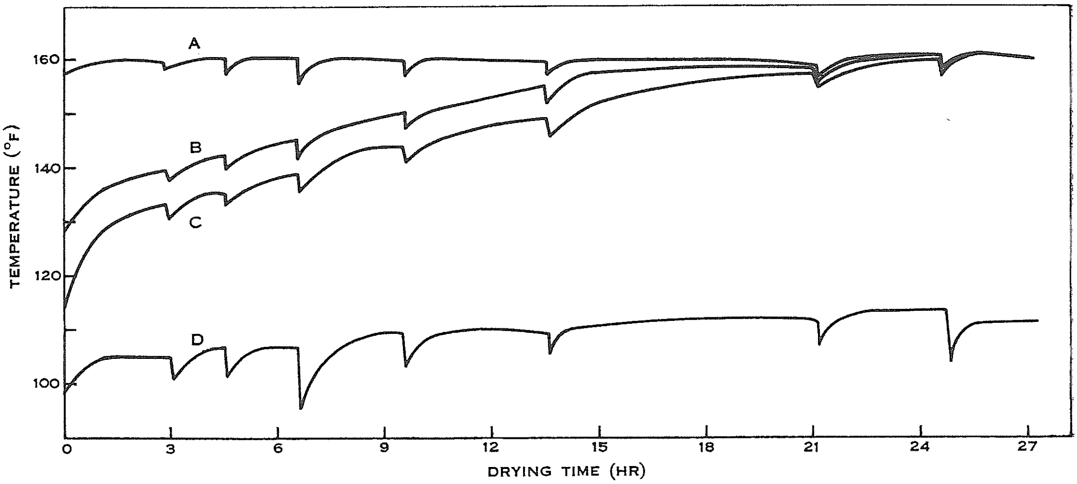


Fig. 2.—Air temperatures during commercial counter-flow dehydration of prunes.

A, Dry-bulb temperature, hot end of tunnel. *C, Rear end of test truck.*
B, Front end of test truck holding fruit. *D, Wet-bulb temperature, hot end.*

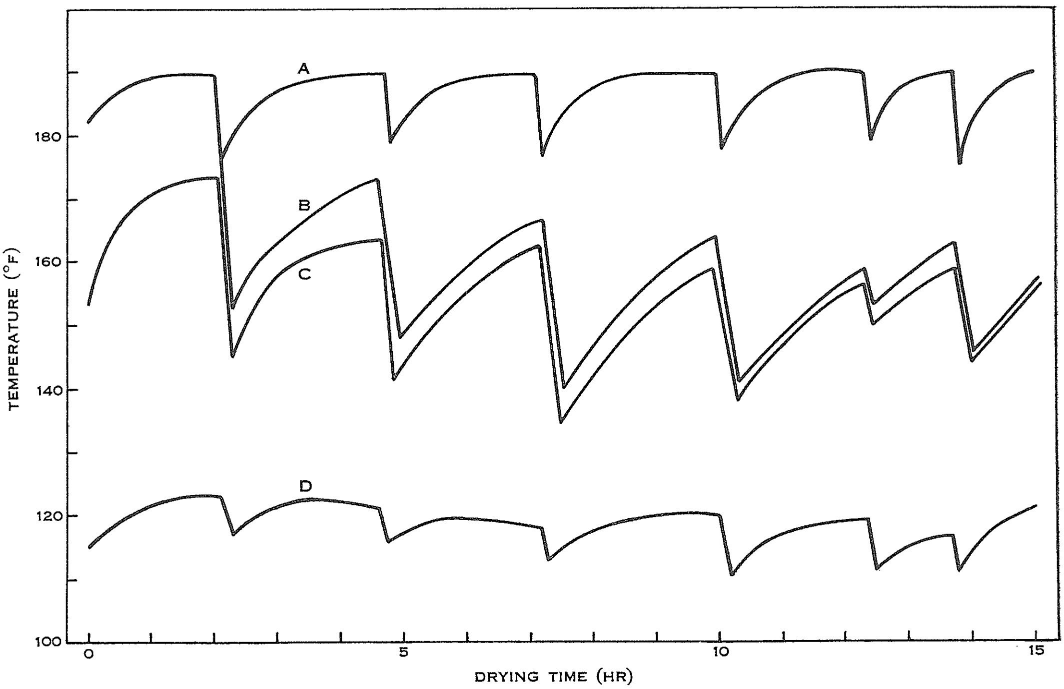


Fig. 3.—Air temperatures during commercial-scale parallel-flow dehydration of prunes.

A, Dry-bulb temperature, hot end of tunnel. *C, Rear end of test truck.*
B, Front end of test truck holding fruit. *D, Wet-bulb temperature, hot end.*

the final drying position it was removed from the tunnel, turned around, and replaced in its former position for a further period.

In operating the parallel-flow system, only six trucks of fruit were used, and they occupied 24 ft of the tunnel. However, after each truck had traversed this distance it was moved to the seventh, vacant position, and kept there as long as was necessary to complete the drying. The temperature and loading schedules were derived from data obtained in the Californian trials of Gentry, Miller, and Claypool (1965).

During the course of the drying runs by either system, dry-bulb and wet-bulb temperatures were measured at the hot end of each tunnel, and also at several positions on the front and rear ends of each test truck. These temperatures were measured by means of thermistors and registered on a recorder through an automatic switching device, thus permitting calculation of the average gradient in dry-bulb temperature throughout the tunnel and across each loaded test truck.

Temperature Gradients

Typical curves showing the recorded dry-bulb and wet-bulb temperatures during the drying runs in the commercial tunnels are given in Figures 2 and 3, the former relating to the counter-flow system of operation and the latter to the parallel-flow system. Each step in these curves corresponds to the removal of a truck of dry fruit from one end of the tunnel and the entry of a new truck-load of fresh fruit into the other end; this resulted in a temporary drop in both the dry-bulb and wet-bulb temperatures at the hot end of the tunnels (curves *A* and *D* respectively in Figs. 2 and 3). As is to be expected, this effect is more marked in the parallel-flow system (Fig. 3), where air and fruit entered the tunnel at the same end.

The entry of trucks was less uniform when drying was carried out by the counter-flow method, as is evident from a comparison of Figure 2 with Figure 3. The dry-bulb temperature of the air at the hot end of the tunnel operated on the counter-current system was 160°F, and during the course of a drying run (about 28 hr) the general level of the wet-bulb temperature rose from about 105 to 115°F, these data corresponding to a range of about 17–26% R.H. at the hot end of the tunnel.

At the cooler, exhaust end where the fresh fruit entered, the relative humidity was about 45% R.H. as compared with a value of about 25% R.H. obtained in the Californian counter-flow trials previously mentioned (Gentry, Miller, and Claypool 1965). In the Californian trials also, the temperature drop across a 3-ft-wide tray of prunes was only 3–4°F after 2 hr, whereas the tests under Australian conditions showed a drop of 5–6°F across the 4-ft layers of fruit even after drying had proceeded for 14 hr in the tunnel.

Relative Drying Efficiency

Whereas in the present counter-flow tunnel drying trials the prunes dried to a moisture content of 20–21% in about 27½ hr, the somewhat larger prunes dried on the same principle in the Californian trials discussed above required less than 21 hr to bring them down to a moisture content of 20%.

On the other hand, our results with the parallel-flow system showed that in tunnel dehydrators an average moisture content of 19% could be obtained in 15 hr, this period being the same as that required in California to dry slightly larger prunes to 20% moisture content.

In the local trials it was also found that in the counter-flow system fruit sampled from near the top of the test trucks after drying were slightly drier than those sampled from the bottom. In the parallel-flow system, however, top-to-bottom variations were insignificant, and the prunes were more uniformly dried.

Economics of Operation

Table 2 summarizes the factors of economic significance recorded during the tunnel drying tests.

During counter-flow drying, the burner operated on full flame for 11 hr, i.e. approximately 40% of the drying time. As the burner nozzle delivered 3 gal/hr, the fuel required to dry seven truck-loads of prunes was 33 gal, or 4·7 gal/truck.

In operating the parallel-flow system, a dry-bulb temperature of 190°F was selected, for it seemed unlikely that the capacity of the oil burner would be adequate to maintain a higher temperature. This decision appears to have been vindicated by the relatively long temperature-recovery times after the entry of each fresh truck (Fig. 3). The burner was 'on' for 12 hr, or 80% of the parallel-flow drying time, and hence used 36 gal of fuel, or 6 gal/truck. Thus the parallel-flow system involved the use of 28% more fuel per truck than was utilized in counter-flow drying.

marized in Table 3 and are discussed below.

Skin Colour.—The amount of brown pigmentation in the high-moisture prunes was measured by the method of Nury and Brekke (1963), as well as being assessed by the taste panels. In contrast to the dark brown to black colour and glossy character of the prunes dried by the counter-flow method, those dried by the parallel-flow method had a distinct red component, besides being dull in appearance. This reddish colour was presumably due to anthocyanin pigments, which either did not develop or were masked by darker pigments in the counter-flow prunes. After the fruit had been stored at a temperature of 60–80°F, the reddish colour became less noticeable, and was scarcely apparent after 4 months, possibly also because of masking by pigments formed during the storage period.

Table 2

Factors that influenced Fuel Costs during Dehydration of Prunes

Drying Conditions	Time (hr)	Loading Interval (hr)	% Drying Time Burner 'On'	Fuel Consumption (gal)	Estimated Fuel to dry 1 Truck (gal)
Counter-flow	27·5 (7 trucks)	3·9	40 (11 hr)	33	4·7
Parallel-flow	15 (6 trucks)	2·5	80 (12 hr)	36	6·0

In terms of handling and operation times the advantages clearly lay with the parallel-flow system. The truck-loading interval in counter-flow drying averaged 3·5 hr, but was only 2·5 hr for the parallel-flow system of operation. Moreover, whereas in the counter-flow system six truck-loads of trays were dried every 24 hr approximately, nearly ten truckloads could be dried in the same time by the parallel-flow system. These differences represent an increase of about 60% in drying capacity for the parallel-flow system as against the counter-flow procedure.

Quality Evaluation

The quality of the prunes dried according to the methods described was judged subjectively by several growers, dehydrator operators, and processors. Some of the tunnel-dried prunes were canned commercially as 'high-moisture' prunes about 1 month after drying; after a further 2 months these cans were opened and skin colour, flesh colour, and flavour of the prunes were assessed by 50 tasters. For these assessments the paired-comparison technique was used; the flavour assessments were made under masking lights in order to eliminate possible bias through differences in prune colour. A consumer-type test involving 40 tasters was also conducted on the samples, to indicate general acceptability. Some of the findings are summarized in Table 3 and are discussed below.

Industry representatives agreed that the red colouration was not a disadvantage, but Table 3 shows that the taste panels preferred the darker-coloured fruit produced by the counter-flow system. There is a possibility that these conclusions have been affected by differences in moisture contents of the two groups of prunes, which, as indicated later, had after drying been processed for high-moisture prunes.

Flesh Colour.—Thin slices of flesh cut from the prunes immediately after they had been dried by the parallel-flow method were golden yellow, but those from the fruit dried by the counter-flow method were from light brown to dark brown. Curiously enough, when ethanolic extracts of the fruits were examined spectroscopically at 440 mμ according to the method of Nury and Brekke (1963), the extracts from the former had a higher absorbance ($\epsilon = 0 \cdot 35$) than those from the latter ($\epsilon = 0 \cdot 25$). Darkening of the fruit occurs earlier in the drying cycle under counter-flow conditions, and because of the relatively lower temperatures at this stage is likely to be due to enzymic rather than to non-enzymic browning. This view is supported by the above finding, since at 440 mμ the pigments arising from non-enzymic browning have a relatively high absorbance.

In the taste panel tests, the two types of prune were regarded as equally acceptable as regards flesh colour (Table 3); though more of the judges preferring the counter-flow-dried prunes regarded the flesh colour of the other prunes as unacceptable, the result was not significant in a statistical sense ($P > 0 \cdot 05$).

Table 3

Tasting Test Results on Counter-flow and Parallel-flow Dried Prunes after Processing to High Moisture Contents

Characteristic	Counter-flow		Parallel-flow		Level of Significance
	1st Preference	Not Acceptable	1st Preference	Not Acceptable	
Skin colour	42	2	8	1	0·001
Flesh colour	25	5	25	13	N.S.
Flavour	35	0	15	8	0·01
General acceptability	27	1	13	4	0·05

Minimum agreeing judgments necessary to establish significant preference:

for 50 tasters: $P = 0 \cdot 05$, 33; $P = 0 \cdot 01$, 35; $P = 0 \cdot 001$, 37.

for 40 tasters: $P = 0 \cdot 05$, 27; $P = 0 \cdot 01$, 29; $P = 0 \cdot 001$, 31.

Flavour and General Acceptability.—The results of the conclusions of the two separate panels are also shown in Table 3. In regard to both flavour and general acceptability the prunes dried by the conventional, counter-flow method were preferred by the tasters ($P < 0 \cdot 01$ and $P < 0 \cdot 05$ respectively). The parallel-flow prunes were less caramelized and more acid in flavour than the counter-flow prunes, and they tasted more like fresh prunes.

It is possible that the tasters' adverse decisions on these prunes were prompted mainly by their unfamiliarity with the new product. It was unfortunate also that owing to the commercial processing of the prunes as high-moisture prunes, the moisture contents of the two types were different, being 39·7% for the parallel-flow prunes and 34·6% for the counter-flow prunes.

DISCUSSION

In appraising the results of these experiments, one major aspect may first be considered. This is that under Australian conditions the counter-flow system does not appear to be operated as efficiently as in the best Californian practice. While higher heat economy was undoubtedly obtained in the Australian trials, the markedly lower drying times that have been reported in counter-flow drying in California suggest that Australian methods could be substantially improved.

To bring these methods into line with modern Californian counter-flow practice, slightly higher dry-bulb temperatures and less recirculation of the air would be advisable. By thus reducing the relative humidity of the air and increasing its total drying capacity, a significant increase in throughput could be obtained in many Australian counter-flow dehydrators.

Lye treatment of the prunes, as presently practised in Australia before drying by the counter-flow system, does cause a small but worth-while reduction in drying time. However, it seems likely that faster counter-flow drying might obviate the need for this treatment (as it does in parallel-flow drying). The consequent saving in labour and fuel costs might well compensate for the lower heat economy which, as indicated previously, is associated with operating the counter-flow system in accordance with current Californian practice.

These laboratory and commercial-scale tests confirm recent American experience and show that Australian prunes can be more rapidly dried on the parallel-flow principle than by counter-flow methods without case-hardening or loss in quality of the product.

It is true that, though the tasting tests showed that differences in flavour were slight, members of the taste panel preferred prunes dried under the counter-flow system. Part of this result was undoubtedly due to the tasters' unfamiliarity with a new product and part would have been due to the known difference in moisture contents of the two types, as a consequence of differences in processing conditions not related to the present investigation. Most prunes are held for much longer than one month in the dry state before being further processed as high-moisture prunes, and this would tend to reduce the differences in flavour and appearance detected by the tasters in these trials.

CONCLUSION

Australian prune driers wishing to increase the capacity of their prune-drying facilities face three possibilities:

- Modifying the drying conditions so as to provide faster drying on the counter-flow system.
- Adopting the parallel-flow system in existing tunnels, at the possible expense of heat economy.
- Erecting more tunnel dehydrators.

The first two possibilities involve a greater fuel cost per unit basis, though some saving could be effected by eliminating the lye pretreatment, especially with parallel-flow drying. The net total cost would still be relatively small, however, as against the high capital costs likely to be involved in the third method.

In choosing between the first two methods, the prune processor would have to consider the advantages of the parallel-flow system in terms of production efficiency. He would also have to take account of the possibility that, at least in the earlier stages of production, the dried product might prove less acceptable to consumers until they became familiar with it. In some instances, where Australian tunnel dehydrators are 70–80 ft long and have inadequate heating and air circulation facilities, difficulty may be encountered in adopting the parallel-flow system.

ACKNOWLEDGMENTS

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Consumer Reactions to Steak Beef

By H. D. Naumann,* A. Howard,† and P. E. Bouton†

Professor Naumann recently returned to the University of Missouri after spending several months with the CSIRO Division of Food Preservation, chiefly at its Meat Research Laboratory at Cannon Hill, Brisbane. While in Australia he demonstrated new consumer survey techniques which he had developed in association with meat scientists, animal production experts, and agricultural experts in the U.S.A. This article gives some preliminary results of such a survey recently carried out in Brisbane, under Professor Naumann's guidance, by the Meat Research Laboratory.

GRAZIERS and butchers, wholesale or retail, carry out their businesses primarily from profit motives. They thus cannot afford in the long run not to be aware of the consumer's likes and dislikes, for if a potential customer cannot get the type of beef he prefers he may go to another supplier or even turn to other kinds of food.

Although the requirements of the meat consumer are therefore of fundamental concern to the meat trade in general, the Australian meat industry (unlike many other industries in this country) has done little to ascertain, through the application of market research techniques, the basic preferences of the customer. The Australian Meat Board (1962) commissioned a national survey of factors involved in promoting meat sales in 1962, and in the same year the Faculty of Agricultural Science of the University of Sydney completed a survey (Wardrop 1962) of expenditure on meat in the area around Camden, N.S.W., in which the opinions of consumers in this area were sought on the price, presentation, and quality of the meat they purchased. More recently, a survey on meat consumption in Sydney households was undertaken by the Bureau of Agricultural Economics on behalf of the Australian Cattle and Beef Research Committee (1965).

All these surveys were of the questionnaire type in which consumers were asked merely to provide information on their opinions, attitudes, and purchase records, and, as indicated below, this type of information can sometimes be misleading. Preliminary results of surveys recently carried out by CSIRO in the Brisbane area may therefore be of interest. In these new surveys several variables were studied in an attempt to ascertain their influence on consumer reaction, but this was possible only because the techniques used were somewhat more sophisticated than those hitherto used in meat consumer surveys conducted in Australia.

IMPROVED SURVEY TECHNIQUE

It is becoming increasingly apparent that a prior opinion expressed by a consumer cannot be depended upon to predict accurately his actual response to a given, real situation. Hence replies to questionnaires of the simpler kind, in which only general opinions and attitudes towards particular products such as meat are sought, may be suspect. However, investigators at the University of Missouri have over the last decade or so been developing more reliable methods (Naumann *et al.* 1957) whereby, in addition to general information on consumer requirements and other pertinent factors, the consumer's reactions to samples actually cooked and eaten by him are recorded. In this way, investigators are able to compare previously stated opinions of consumers with actual responses, since the consumers have been provided with and have reported upon selected samples of food of known origin and type, the quality and other characteristics of which can be checked independently in the laboratory. Information

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on socio-economic and other possibly relevant factors is obtained simultaneously, in order that the effect of these on the preferences of the consumer public represented by the individuals participating in the survey can be ascertained.

In essence, when applied to a meat consumer survey, the technique referred to above is as follows. A representative sample of the consumer public is decided upon, using accepted market survey sampling techniques (e.g. see Deming 1960), and one or more individuals from each of the several randomly selected groups of consumer households are invited to cooperate. When an adequate number of participants have agreed to serve on the consumer panel they are provided with suitably prepared (but uncooked) specimens of meat representing the class of meat, type of joint, or other meat category under study. At this stage, care is taken to avoid introducing any bias such as may occur through an existing association of particular kinds or cuts of meat with particular strata of the consumer population. The selected consumers then prepare and cook the meat in accordance with their usual practices. After eating it, they note down their reactions by putting a check mark in the appropriate line of each question listed on the report card supplied to them. In addition to the coded replies to these and other questions on the card, the consumers may write down any general comments they may wish to make about the sample or about their own cooking methods. The coded answers on the report card are then analysed by statistical methods appropriate to the method of sampling and to the system of distribution used in the survey.

CONSUMER OPINIONS IN BRISBANE

In our first survey, the meat samples were representative of different cross-breeds of cattle, all the animals having been weaned under uniformly similar conditions. In the second, the meat was from normal commercial carcasses that had been grouped into grades allocated by officers of the Queensland Department of Primary Industries, and in the third, normal commercial carcasses were again used, but the meat was subjected to various treatments that were expected to modify its tenderness. Details of these treatments are given later.

Information gained from the personal interviews with the consumers before they received the meat samples, and preliminary findings based on the results of a statistical breakdown of coded replies to the questions on the report card shown on page 14 after the samples had been cooked and eaten, are given below.

Purchasing Habits and Attitudes

The wife shopped for meat in 95% of the families taking part in the surveys, and over four-fifths of these purchased meat less than one mile away from the home. Over half of the families represented purchased meat two to three times a week.

With regard to the quality of the meat, half of the participants stated that they were satisfied with the beef they bought, and where criticisms were expressed these related to the degree of tenderness, uniformity of quality, and price. The most important characteristics of beef were given as: tenderness (46%); appearance (36%); flavour (14·5%); and price (2·5%). One-fifth of all consumers complained about the price of steak beef, but almost half of them criticized its tenderness. However, despite the emphasis given to tenderness as a desirable feature in steak meat, only one out of four families made any attempt to tenderize the meat they purchased; most of those that did used only pounding methods.

RESPONSES TO SAMPLES PROVIDED

One feature of the results of the surveys was the wide range of responses manifested, even for nominally homogeneous material. Nevertheless, some useful indications were obtained from the three surveys, which are considered separately below.

Survey No. 1

In the first survey, no evidence was obtained from the responses or from the laboratory tests that meat from the various cross-breeds differed in respect of eating quality. Because of this homogeneity the data provided good material for studying variability in response among the consumers. Accordingly, the response data were set out in the form of histograms and distribution charts; they were separated into two separate groups, because approximately half the meat was delivered after preparation and freezing and the remainder was first thawed out, allowed to 'age', and then refrozen before distribution.

BRISBANE BEEF STEAK PANEL
CSIRO MEAT RESEARCH LABORATORY

The steak without a ring is for the wife. Please eat all of the steak and then fill out this schedule immediately.

1. What is your opinion of this steak?

__________Like Extremely
__________Like Very Much
__________Like Moderately
__________Like Slightly
__________Neither Like Nor Dislike
__________Dislike Slightly
__________Dislike Moderately
__________Dislike Very Much
__________Dislike Extremely

2. Check the least desirable eating characteristic of this steak.

__________Juiciness
__________Flavour
__________Tenderness

3. Compared to steaks that you buy how was this steak?

Tenderness

__________Much More Tender than Average
__________More Tender than Average
__________As Tender as Average
__________Less Tender than Average
__________Much Less Tender than Average

Flavour

__________Much Better Flavour than Average
__________Better Flavour than Average
__________As Good Flavour as Average
__________Poorer Flavour than Average
__________Much Poorer Flavour than Average

Juiciness

__________Much More Juicy than Average
__________More Juicy than Average
__________As Juicy as Average
__________Less Juicy than Average
__________Much Less Juicy than Average

4. How cooked?

__________Dry Heat (grilled or fried without liquid other than fat added and with lid off)
__________Moist Heat (liquid added other than fat or with lid on)

5. Doneness?

__________Well (no pink meat)
__________Rare or Under Done (some pink meat)

6. Any flavouring other than salt added (tomato sauce, barbecue sauce, steak sauce, onion, garlic, etc.?)

__________Yes, if so what? ______________________________
__________No.

7. Comments. (Both favourable and unfavourable comments are useful and greatly appreciated.)

Name ____________________ Address ____________________
Date Eaten ____________________ Household ____________________

From the replies to the first group of questions in the questionnaire (No. 1 in the report card reproduced here), it was immediately evident that though the average reactions to both the 'aged' and the unthawed samples were on the 'liking' side of the midpoint of the scale, they were not greatly so. For both kinds of meat, varying degrees of dislike expressed extended to the furthest dislike point of the scale and, for the unthawed samples especially, a disturbingly large proportion of responses lay on this side of the histogram.

The relative importance attached by the consumers to tenderness, flavour, and juiciness in making their overall assessments was elicited by their replies to Question No. 2 (see report card). The results are indicated

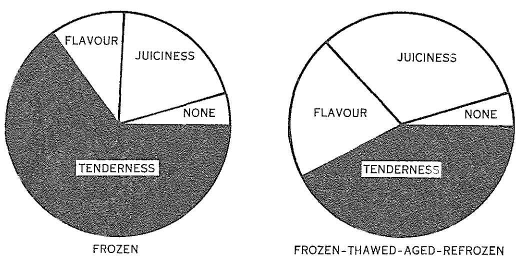

Fig. 1.—Proportion of times that the different attributes of eating quality were reported as contributing most to any feeling of dislike in Survey No. 1.

by the accompanying circular distribution diagrams (Fig. 1), in which the area of each segment represents the relative frequency with which the designated attribute contributed most to any feeling of dislike for the steak eaten, and from this it is evident that for both kinds of meat, tenderness was the most important criterion. This result confirms the majority view expressed by the consumers before the samples were distributed.

A comparison of the two diagrams in Figure 1 indicates that for the thawed and aged meat a lower proportion of consumers listed tenderness (i.e. lack of it) as the chief reason for disliking the meat. Although this suggests that the aging treatment induced a marked improvement in tenderness (as might be expected), a similar trend in the diagrams would be evident if flavour and juiciness had been adversely affected by the aging treatment, because this form of presentation only indicates the *relative* importance of the various attributes under consideration. However, histograms prepared from the replies to the other questions (No. 3 on the card) relating to the same attributes provide positive information on this point. Taken in their entirety, the replies indicated that on the average, consumers regarded the samples as neither better nor worse than meat normally purchased by them. It was clear from histograms separately relating to tenderness, juiciness, and flavour that aging had made a marked improvement and that any change in flavour and juiciness was also in the direction of improvement. This finding was supported by evidence obtained in Survey No. 3 (Fig. 2), which is described more fully below. It will be of interest to ascertain whether reported flavour and juiciness changes are real or result merely from a 'halo' effect, in which all scores tend to move up or down the scales together.

Survey No. 2

In this survey, where the samples were from a number of grades of beef (assessed by the Queensland Department of Primary Industries), statistical analysis suggested that the consumers had been able to discriminate between the grades. Further examination of the data, however, indicated that the discrimination was largely between the yearling and steer carcasses, and that much of the variation arose from the chance allocation of the various carcasses to the different grades. As in the first survey, there was a very large range of responses, and lack of tenderness was most often the least attractive characteristic of the meat.

For both the yearling and the steer meat the animals were selected on each of six different days from fairly large mobs. Data representing the mean scores for each grade and animal-to-animal variation within each grade showed that within each grade there was a pronounced tendency for the meat from animals from the same mob to be ranked equally, this tendency being apparent with both steers and yearlings.

With the meat samples of this survey, animal-to-animal variation within each grade appeared to be greater than that due to differences among grade means. A similar result has been found in overseas studies (Naumann *et al.* 1961), but in the present instance the tendency was even greater than suggested in the literature. The variability was much the same in all grades and, contrary to what might have been expected, was not greater in the lower grades.

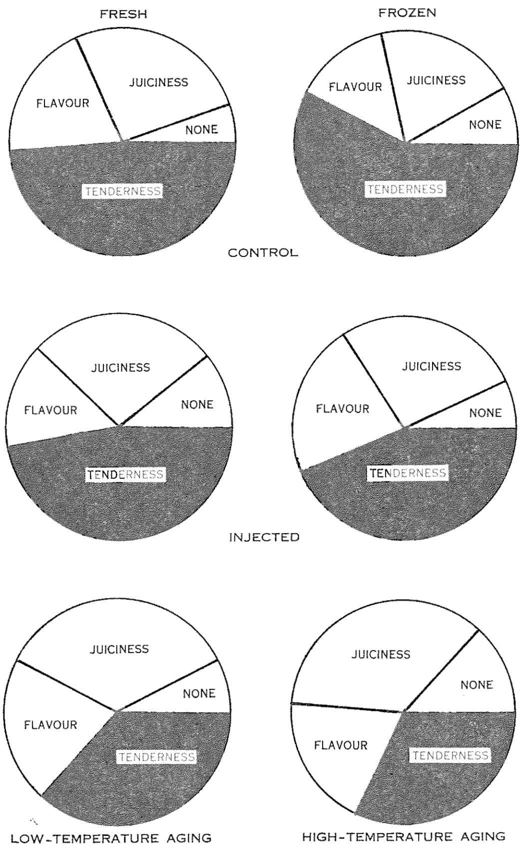

Fig. 2.—Proportion of times that the different attributes of eating quality were reported as contributing most to any feeling of dislike in Survey No. 3.

Survey No. 3

This survey, in which some of the meat was processed to improve the tenderness, was carried out in two parts. In the first, the meat was handled throughout as fresh meat; in the second, the meat was frozen immediately after the tenderizing process had been applied, and then thawed out for delivery. The fresh and frozen samples were tested by different consumer clusters. There was no evidence of any adverse reaction against the frozen meat, though there was little evidence to support the claim that meat is tenderized by freezing (Bouton, Howard, and Lawrie 1958; Hiner and Hankins 1947).

The distribution diagram for least attractive characteristics (Fig. 2) shows that there was a pronounced reduction in unfavourable reports on tenderness. With both the fresh and frozen samples the major effect of the applied tenderizing treatments (as seen in the 'cumulative' curves, Fig. 3) was to reduce the number of highly adverse reports, rather than to increase the number of highly favourable reports. This confirms the suggestion (Bouton, Howard, and Lawrie 1958) that aging brings about greater changes in low-grade meat than in the high grades but still leaves a difference between them. The failure to produce a large increase in proportion of high scores for 'liking' indicates that with the tenderized meat other attributes may have become limiting factors.

FIELDS FOR FURTHER STUDY

The preliminary examination of the data obtained in the three surveys outlined above has thus highlighted the following points:

- An excessively large proportion of normal commercial steak beef available in Brisbane is not liked by the consuming public in that city.

- The attribute mostly affecting consumer reaction to steak beef is its degree of tenderness.

- There were marked variations in the reactions of consumers to beef from animals in the several grades selected by meat inspectors, indicating that these grades, contrary to the commonly held view, do not necessarily reflect the eating quality of the meat.

The emphasis currently being given in meat research to the nature of tenderness and to elucidating causes for its variability seems therefore to be fully justified. But it is also clear that other factors may contribute to the wide variability of consumer responses.

It is proposed to carry out at least one more survey before examining all the data in further detail. In later analyses of survey data it is hoped to clarify further the respective contributions of individual consumer requirements and of individual carcass characteristics to the overall variation in consumer response. An independent study of carcass variation will be possible through reference to the laboratory data from taste panels and from objective measures, since together these should provide the basis for a reasonably reliable eating-quality rating for the sample. Once the variations in the reactions of the

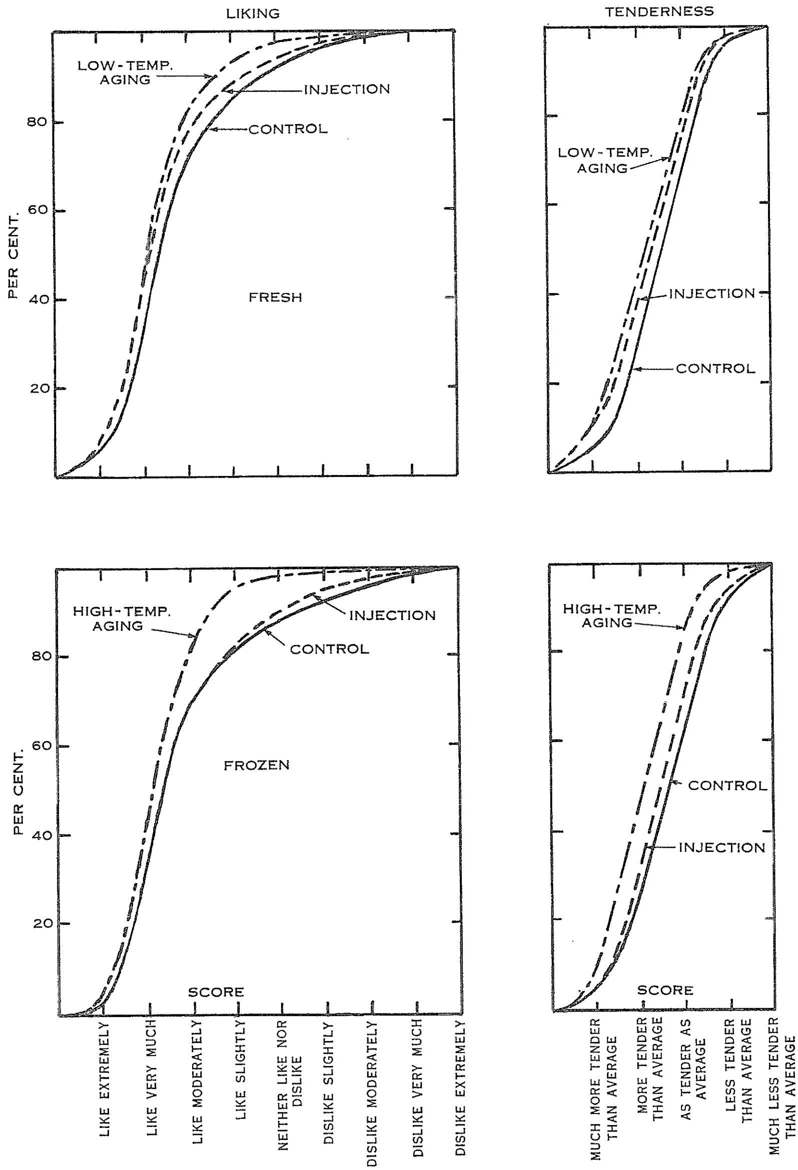

Fig. 3.—Proportion of replies for liking and tenderness which did not score below each point of the scoring card in Survey No. 3.

consumers caused by variability in the material have been eliminated or allowed for, a valid study can be made of the relation of consumer responses to various sociological factors such as age, socio-economic level, profession, education, and so on.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the co-operation of those members of the Brisbane public whose participation as panel members made the surveys possible. They are particularly grateful to Mrs. E. V. P. Kennett, who interviewed and selected all panel members and undertook delivery of samples. Thanks are due also to members of the staffs of the University of Queensland, the Queensland Department of Primary Industries, the Commonwealth Bureau of Census and Statistics, and the Bureau of Agricultural Economics, whose advice and assistance helped materially in designing and carrying out the surveys.

The meat used was obtained from the CSIRO National Cattle Breeding Station, Belmont, and from Messrs. Thos. Borthwick & Sons Ltd. and T. A. Field Pty. Ltd.

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A NOTE ON THE COMPOSTING OF CANNERY WASTES

In 1964, Kefford* described successful composting of pear canning wastes using procedures developed by the National Canners' Association, Berkeley, California, and mentioned that the NCA had scaled up its operations from bins to wind-rows. The wind-rows, confined between vertical walls, are 9 ft wide, 40 ft long, and 6 ft high.

In *Research Information* No. 108, November 1965, the NCA reports that the study on disposal of solid cannery wastes by composting is nearing completion. In the 1965 season, a machine to turn the compost pile while simultaneously adding and mixing in fresh waste solids was evaluated. This machine runs on a track on top of the wind-row walls and has an inverted triangle configuration supported at three points with shafts. Buckets are attached to chains passing over sprockets mounted on each of the shafts. The machine traverses in either direction. Through most of the season, ground cannery waste was added to a composting wind-row and turned every day. Approximately 2 tons per day was added to the 40 cu yd of rice hulls in the wind-row. The rice hulls were the same material as was used in 1964, thus indicating that the absorbant can be used for many waste additions without inhibiting the breakdown of the cannery waste. Near the end of the season waste was added every 12 hours.

The results indicated that perhaps the interval of addition may be shortened to 6 or 8 hours without losing the efficiency of thermophilic conditions generated in the compost mass. Higher rates of waste addition without objectionable odours were achieved by continuous aeration through a perforated copper pipe embedded below the wind-row.

Vegetable wastes alone have not been successfully composted, apparently because of a lack of sufficient carbohydrates to sustain microbial activity, but this deficiency can be corrected by mixing fruit wastes with the vegetable wastes.

* *CSIRO Fd. Preserv. Q.* **24**, 21.

NEWS FROM THE DIVISION OF FOOD PRESERVATION

UNIVERSITY APPOINTMENT

The newly appointed Head of the Department of Food Science in the University of Manitoba, Winnipeg, Canada, is Dr. R. A. Gallop, who chose food science as a career when in 1941 he joined the Division of Food Preservation as a junior laboratory assistant. Dr. Gallop obtained his initial qualifications at Sydney Technical College where he took the diploma in 1945. After gaining further experience in food chemistry and food technology in the Division's former laboratory at Homebush, N.S.W., and at Hobart, he was granted a research assistantship in the Department of Food Technology, Oregon State College, Corvallis, Oregon, U.S.A., in 1958. Here he took the M.Sc. degree and, later, obtained his Ph.D. He resigned from CSIRO in June 1962 to take up a post-doctoral fellowship for one year in the laboratories of the Fruit and Vegetable Canning and Quick Freezing Association, Chipping Campden, England. Dr. Gallop's next appointment was as head of the Food Group, New Brunswick Research and Productivity Council, Fredericton, N.B., Canada. He takes up his appointment in the University of Manitoba on May 1, 1966.

APPOINTMENTS TO STAFF

The Australian Meat Board has provided funds for investigations on the development of equipment for the mechanization of some slaughter-floor processes, and Mr. F. C. O. Sticher, who holds the degree of Bachelor of Engineering of the University of Sydney, has been appointed to CSIRO as an Experimental Officer to undertake these investigations. Initially, Mr. Sticher will be concerned with processes for the mechanical skinning of sheep. Mr. Sticher, who commenced duty on March 14, 1966, is working at the Metropolitan Meat Industry Board's abattoir at Homebush, N.S.W.

Dr. G. S. Sidhu, former Professor of Biochemistry in the Punjab Agricultural University, Ludhiana, India, has been appointed a Senior Research Scientist in the Division of Food Preservation. He will conduct biochemical studies on material from animal sources, particularly from fish and crustaceans.

Dr. Sidhu gained his bachelor's degree in agricultural science at the Punjab Agricultural University. In 1955 he obtained his Ph.D. in biochemistry at the University of Melbourne. He spent six months in the CSIRO Division of Food Preservation before rejoining the Punjab Agricultural University to conduct research in animal nutrition. Dr. Sidhu took up his appointment with the Division on March 4, 1966, at North Ryde.

Guest Workers

From time to time the Division of Food Preservation provides facilities for scientists from other institutions to work in its laboratories. The first visitor for 1966 was Professor E. Ross, who is Chairman of the Department of Food Science and Technology, University of Hawaii, Honolulu. Professor Ross spent five weeks of his sabbatical leave in Australia, and during January was for three weeks at the Division's headquarters at North Ryde.

Dr. E. Epstein, Professor of Plant Nutrition, University of California, Davis, is spending six months in the Division of Food Preservation as an Australian–American Educational Foundation Scholar. In January he joined Dr. J. Christian, head of the Microbiology Section at North Ryde, to make a study of salt-tolerant bacteria.

Dr. C. E. Allen is spending the year 1966 in the Division, and has joined the team investigating the chemical and biological effects of cyclopropenoid acids. These compounds are found in a number of vegetable oils and can produce serious effects in some animals when ingested. Dr. Allen comes from the University of Wisconsin, U.S.A., and holds a post-doctoral fellowship awarded by the U.S. National Science Foundation.

Dr. M. K. Shaw, who returned to Australia on January 8, 1966, from the University of California at Davis, where he spent two years on a CSIRO Overseas Studentship, is working in the Microbiology Section at North Ryde during 1966. Dr. Shaw will return to the Division's Meat Research Laboratory when its new laboratory opens early in 1967.

Asian Visitors

Mr. Chye Yam Theng, Chemist-in-Charge of the Department of Chemistry in Singapore, spent about three months in the Division from January 1966. The Department of Chemistry in Singapore is a laboratory which deals with toxicology, customs examinations, dangerous materials, and food and drugs. Mr. Theng is gaining experience at North Ryde in modern chemical techniques.

Two Indonesian post-graduate students, Mr. Hermana and Mr. Slamet, who spent 1964 and 1965 in Australia at the University of New South Wales, commenced work in the Division early in March 1966 to obtain up to six months' research experience in the post-harvest physiology of fruits and vegetables.

The Division also provided laboratory training for four Colombo Plan students during their vacation. These students had been engaged in post-graduate studies at the University of New South Wales, but spent December 1965 and January and February 1966 at North Ryde. They were Messrs. Ali Asghar, Hamid Ahmad, and A.Q.M.Q.R. Khandaker, all of Pakistan, and Mr. Muhammed Enoch of Indonesia.

RECENT PUBLICATIONS OF THE DIVISION

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