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Some Aspects of the Present Status of Food Irradiation

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Not long after Roentgen discovered X-rays in 1895, their capacity to destroy microorganisms was realized, and possibly their use to sterilize food was also considered. However, only recently have there been suitably large sources of radiation for food processing, and there is now a great upsurge of interest in the project. This article gives a brief summary of the problems and possibilities in applying ionizing radiations to the food industry.

NATURE AND PRODUCTION OF IONIZING RADIATIONS

Ionizing radiations, as their name suggests, differ from other radiations, such as infrared and visible light, by their ability to ionize atoms or molecules, giving rise to positive and negative ions. Some well-known ionizing radiations are listed in the table opposite. However, many of these are not suitable for food irradiation, and those that have received most attention for this purpose are X-rays, gamma rays, cathode rays, and beta rays.

The energy unit for all these radiations is the electron-volt, which is equivalent to the kinetic energy acquired by an electron in falling through a potential difference of 1 volt. Radiations of use for food preservation often have energies in excess of 1 million electron-volts, and for convenience the energy of these radiations is often expressed in million electron volts (MeV).

Cathode rays and gamma rays will probably be the most widely used should food processing by ionizing radiations become commercially established. Typical machines for generating cathode rays are resonant transformers, linear accelerators, van de Graaf accelerators, and insulated core transformers. A linear accelerator, forming part of a plant for sterilization of sutures by irradiation, is illustrated in Figure 1. A closer view of a unit through which an electron beam emerges can be seen in Figure 2.

Cobalt-60 and spent fuel rods from atomic reactors are common sources of gamma radiation. An irradiation plant which operates on gamma rays from cobalt-60 is shown diagrammatically in Figure 3. Packages are transported by a conveyor system from the storage racks, make several passes by the radiation source, and are returned to the output storage rack. When it is desired to enter the radiation cell, the cobalt-60 can be lowered into a safe position in a well of water.

Caesium-137 may be an important future source of gamma rays. It is produced as a by-product of the fission reaction in atomic energy plants and, with large-scale operations, extraction from the fuel elements could prove to be economic. Its use may be preferred to the fuel elements themselves, the activity from which varies widely and decays rapidly.

Three commonly used units, all about the same value, used to express radiation dose are the roentgen, the rep, and the rad. The rad, defined as the absorption of 100 ergs of energy per gram of irradiated material, is widely used in food irradiation studies. In the table on p. 45 the approximate radiation sensitivity of various organisms is expressed in terms of the rad. One million rads would cause a temperature rise of only about 2°C in a foodstuff, hence the term cold sterilization is often applied to the radiation processing.

GENERAL EFFECTS OF RADIATIONS

Ionizing radiations of the types being considered are absorbed by all atoms or molecules; there is no selective absorption, as when less energetic radiations such as visible or ultraviolet light pass through atoms or molecules. The absorption of ionizing radiation usually leads to the formation of active intermediates which react to form new products. In systems as complex as foods there are immense possibilities for a wide variety of complex reactions. It is virtually

Some Well-Known Ionizing Radiations

From "Scientific and Technological Problems Involved in Using Ionizing Radiation for the Preservation of Food" by R. S. Hannan

Radiation	Description	Main Source
Electromagnetic waves		
X-rays	Wavelength approx. 10Å to 10^{-1}Å	Electrical generators
Gamma rays		Radioactive elements
Particulate radiations		
Cathode rays	Fast electrons	Electrical generators
Beta rays	Fast electrons	Radioactive elements
Fast protons	Mass 1, + charge	Electrical generators and nuclear reactions
Fast neutrons	Mass 1, no charge	
Fast deuterons	Mass 2, + charge	Electrical generators
Alpha rays	Mass 4, two + charges (helium nucleus)	Radioactive elements
Nuclear fission fragments	Heavy atomic particles	Nuclear reactions

impossible to predict the effect of radiation on such heterogeneous systems.

Concern is sometimes expressed that irradiation may give rise to induced radioactivity in a food. In fact, radiation of very high energy can cause nuclear changes and thus induced radioactivity. The energy of the radiation has to exceed a threshold value which is characteristic of the element being irradiated. Up to about 9 MeV, which is considerably greater than the energy usually used for food irradiation, there should be no danger from induced radioactivities in foods.

APPLICATION TO FOODSTUFFS

Three main types of treatment may be distinguished, corresponding to three dose levels, although there is considerable overlap:

- Sterilization treatments: dose range 1–5 million rads.
- Pasteurization treatments: dose range 50,000 to 1 million rads.
- Insect disinfestation and antisprouting treatments: dose range 5000 to 100,000 rads.

Sterilization Treatments

The destruction of microorganisms by radiation generally follows a logarithmic relationship, so theoretically there is no radiation dose that guarantees absolute sterility. This situation is similar to that encountered in heat processing, and so far it has been assumed that the microbiological requirements for commercial sterility will be similar for both heat and irradiation processing. The spores of the dangerous food-poisoning organism *Clostridium botulinum* are among the most radiation-resistant of the pathogenic organisms encountered in foods, and where this organism can occur, the sterilization dose appears to be near 5 million rads. However, practical experience with irradiated foods is not yet wide enough to give confidence in this figure. The radiation resistance of microorganisms varies with the type of food and the conditions before, during, and after irradiation; therefore the effect of changes in all or any of these variables needs thorough investigation. However, early hopes that radiation would eliminate all spoilage organisms without adverse effects on the food have not been achieved. Simultaneously with microbial destruction, there occurs damage to the food which is roughly proportional to the dose. Foods vary considerably in their susceptibility to radiation damage; for example pork withstands radiation much better than beef. Little is known about the reasons for this variation.

There are two obvious approaches to the reduction of radiation damage:

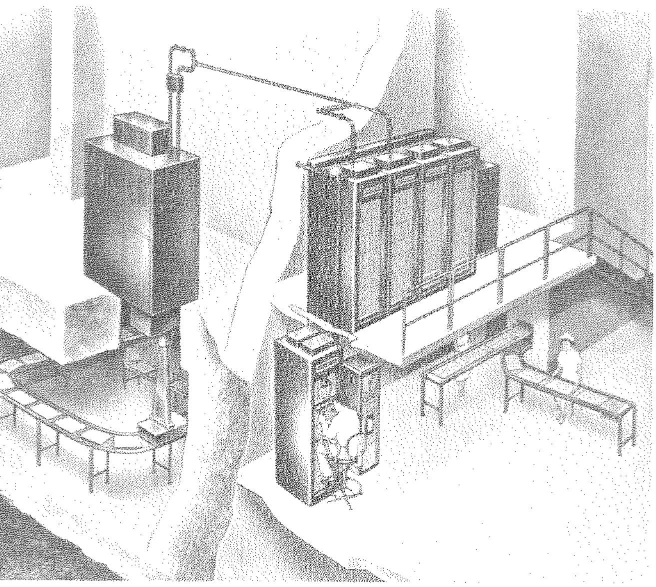


Fig. 1.—Model of 7MeV linear accelerator at Ethicon Inc., Somerville, U.S.A., for sterilization of sutures.

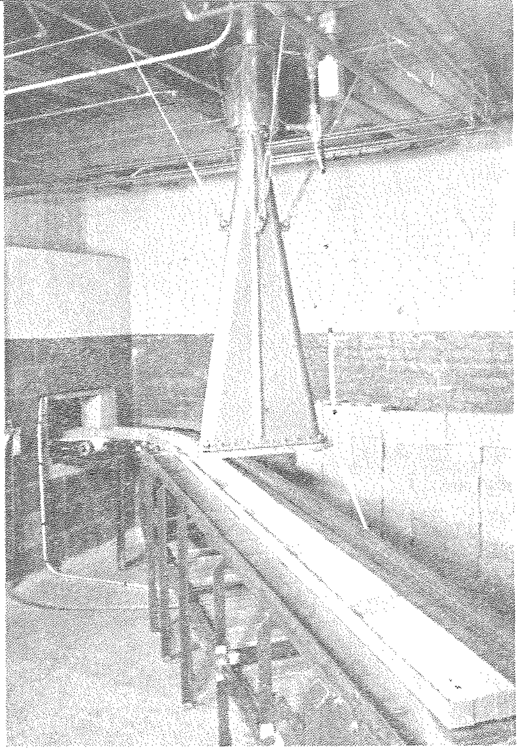


Fig. 2.—Conveyor belt passing under electron beam. (Figures courtesy High Voltage Engineering Corp.)

- Increase the sensitivity of microorganisms so that a smaller radiation dose will suffice.
- Protect the constituents of the foods.

Little success has been achieved with the first method. For the method to be successful, it is essential that the sensitivity of the food constituents be not increased proportionally. Conversely, the second method must not lead to a similar protection of the microorganisms.

Protection of Food Constituents.—The following three ways of protecting the constituents of foods have received much attention:

- Remove oxygen. This generally decreases the yield of a radiation reaction and also reduces the variety of products formed. The development of oxidative rancidity in fats is accelerated by radiation, so that it is necessary to exclude oxygen when fat is present in quantity.
- Freeze the product during irradiation. This probably reduces the damage by reducing the mobility of the free radicals formed during irradiation.
- Add a "free radical acceptor" such as vitamin C. These substances combine with and render inactive many of the active chemical species formed during irradiation.

The possible development of masking agents should also be mentioned. These substances combine with radiation-susceptible groups in a food, protecting them against irradiation.

All fresh foods contain enzymes which cause quality deterioration during storage. Therefore it is necessary to inactivate these enzymes, particularly when prolonged storage is contemplated. To do this with radiation alone would result in gross damage to the food. To date, a short heat treatment appears to be the only practicable way of controlling enzyme activity, but unfortunately it results in a partly cooked product.

The nutritive value of radiation-sterilized products is comparable to that of heat-sterilized products. Extensive studies on wholesomeness carried out in recent years have not revealed the presence of injurious compounds such as toxins or carcinogens.

Pasteurization Treatments

The guiding principle here is to find the maximum dose of radiation that a product can be given without observable or at least objectionable effects. The product is then examined to see if microbiological improvement has resulted. This treatment has been

Approximate Doses of Ionizing Radiations Needed for Effective Inactivation of Various Microorganisms

Organism	Upper Limit of Dose Range (rads)
Man and higher animals	1000
Sprouting tissues of plants	10,000
Insects and their eggs etc.	50,000
Vegetative bacteria	500,000
Yeasts and moulds	1,000,000
Bacterial spores	2,000,000
Viruses	5,000,000
Enzymes	10,000,000

combined with refrigeration, antibiotics, etc. to give further microbiological control. The apparent shelf life of fresh beef, irradiated to 50,000 rads and subsequently kept in chilled storage, has been increased by a factor of three to five. In this case it is to be noted that refrigeration, besides retarding bacterial growth during storage, is necessary to prevent the growth of food-poisoning organisms not destroyed by radiation. The reason for the term "apparent" shelf life is that it has been observed recently that at least some radiation-pasteurized foods decrease in acceptability before being considered spoiled microbiologically.

Irradiation of Meat and Meat Products.—Figure 4 shows the result of an experiment conducted at the Low Temperature Research Station to investigate this effect. Whole chickens were irradiated to 800,000 rads, then stored at 1°C until removed for flavour assessment. Members of the taste panel had been educated to detect irradiation flavour. Acceptability decreased during storage and after about 10 days the frozen controls were preferred to the irradiated samples. The radiation pasteurization of other meat products, notably sausages and fish, has received much attention.

Irradiation of Fruit.—Microbial attack on fruit is mainly by moulds and yeasts, and radiation doses of from 100,000 to 500,000 rads show promise for controlling these agents. An application of the technique to control mould growth in strawberries is illustrated in Figure 5. There is no obvious growth of mould in the sample which has been subjected to 400,000 rads, although the fruit after 6 days' storage at 20°C is declining in quality through the continuation of the ripening process. Generally 100,000 rads does not give a very useful control of mould, while 500,000 rads, although generally effective, usually results in some deterioration of the fruit, particularly on storage.

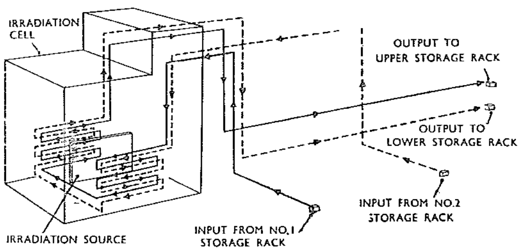
It also appears that some control over certain physiological disorders may be obtained by irradiation. For example, it has been recently reported that a dose of 85,000 rads results in a considerable decrease in the incidence of core flush (a browning of the core) in stored apples, without significant changes in texture, flavour, breakdown, or fungal wastage.

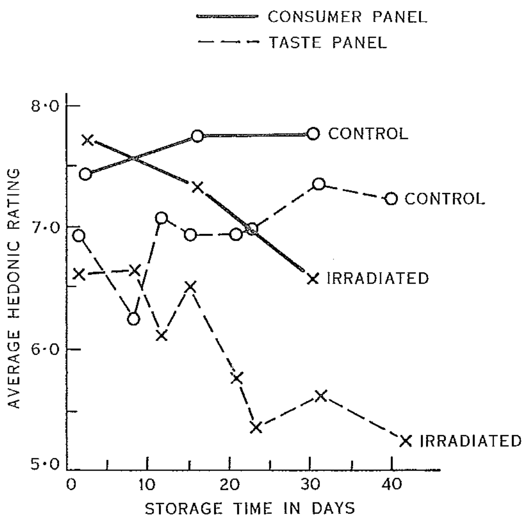
Right:

Fig. 4.—Effect of storage at 1°C on flavour of chickens irradiated to 800,000 rads. (Courtesy Dr. B. Coleby, Low Temperature Research Station, Cambridge.)

Below:

Fig. 3.—Diagram of a spent fuel-rod irradiation unit. (Courtesy Atomic Energy Authority, Harwell, U.K.)





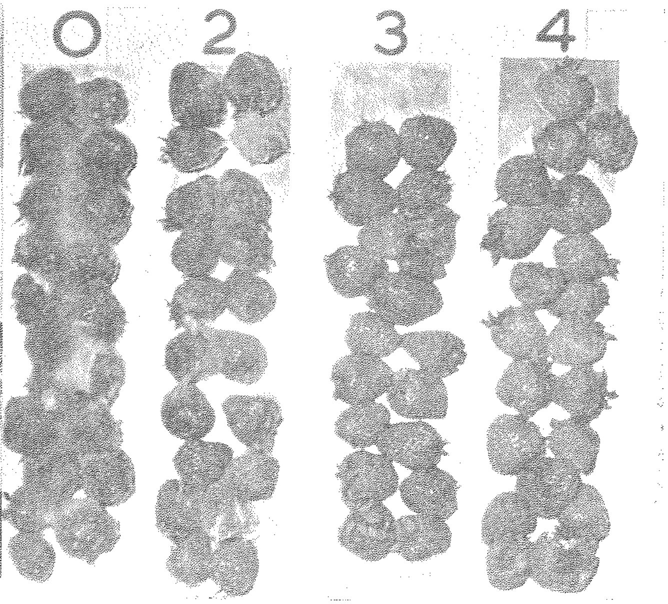


Fig. 5.—Effect of various doses of radiation on mould control on strawberries. 0: Control, 2: 200,000 rads; 3: 300,000 rads; 4: 400,000 rads. (Courtesy Dr. I. Clark, A.E.R.E., Harwell.)

Irradiation of Food-Poisoning Organisms.—An application considered to show much promise in the United Kingdom is the elimination of the *Salmonella* group of food-poisoning organisms from imported frozen whole-egg pulp. A dose of 500,000 rads appears to be adequate for this purpose, and has little or no detectable effect on the baking qualities of the product. An added advantage in this case is that the egg pulp can be treated while still frozen in its original container, whereas treatments such as heat pasteurization require the pulp to be thawed and removed from its container.

There is much scope for exploratory as well as fundamental work in the field of radiation pasteurization: (1) to find new applications, and (2) to determine the limitations of the treatments, particularly as regards deterioration on storage. The possible development of radiation-resistant strains of micro-organisms must also be considered.

INSECT DISINFESTATION AND ANTI-SPROUTING TREATMENTS

Doses of 100,000 rads or greater kill most insects relatively quickly. They also induce radiation lethargy, so reducing damage caused by the insects feeding after irradiation. Doses of 5000 rads may not appreciably shorten the life of insects, but will generally render them sterile, and therefore result in their ultimate elimination. On the other hand no damage to the commonly infested foodstuffs, for example grains and cereals, has been observed, with dosages up to 100,000 rads.

In the C.S.I.R.O. Division of Food Preservation, the feasibility of using radiation to destroy Queensland fruit-fly eggs in oranges is being investigated. Investigations are only in their initial stages, but it appears that there is a margin between the dose required to prevent eggs or larvae developing into flies and that which causes observable damage to the fruit.

Radiation is generally effective in preventing sprouting of stored vegetables such as carrots, onions, and potatoes. The optimum dose depends on many factors including variety, time of harvesting, and period elapsing between harvesting and irradiation. For potatoes the optimum dose is about 10,000 rads. The storage life of irradiated potatoes is not indefinite; complete breakdown has been reported after 15 months.

In spite of the fact that radiation can be used for insect disinfestation and to control sprouting, and although it causes little damage to the product, two main factors have delayed its adoption for these purposes in industry: (1) the industrial reorganization which would be required for its introduction, and (2) the cost of the process.

CONCLUSION

Our knowledge of the effects of radiation on foodstuffs is still very meagre, and much remains to be done before the influence of irradiation techniques on the food industry can be confidently assessed. The first application is most likely to be in insect disinfestation in which the low dosage requirements make health hazards unlikely, and lessen the problem of controlling undesirable changes in the treated foods. As confidence in the irradiation process grows, its applications may extend to the pasteurizing dose range.

Sensory Tests for Colour, Flavour, and Texture

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THE arrangement of this series of articles on the examination of canned foods has been based on a specimen report form which was set out in Part I (Kefford 1953). The section of that report headed "Chemical Examination" has now been covered, and the next section headed "Quality Examination" relates to the assessment of the colour and appearance, flavour and aroma, and texture or consistency of canned foods. These are properties of foods that are less amenable to quantitative objective measurement than those that have been previously discussed. It is true that objective methods are available for the measurement of colour, texture, and consistency and these will be described in later parts of this series; but sensory tests are still widely used to evaluate these properties and they are the only methods available for the assessment of flavour. Generally speaking, when canned foods are subjected to sensory tests, the three attributes colour, flavour, and texture are assessed simultaneously.

Since World War II, sensory testing of foods has been widely investigated and many food research establishments and food manufacturers throughout the world have set up tasting laboratories. This is a field where food technology enters the domain of applied psychology. Food technologists, however, are seldom trained in the fundamentals of the science of psychometrics and therefore they must generally be contented to apply an empirical methodology. Some general references which may be useful are: Hicks (1948), Boggs and Hanson (1950), Foster (1954), Little (1958), Peryam (1958), Pilgrim and Peryam (1958), Kenna (1959), and Ferris (1960).

In the examination of canned foods, sensory tests may be required for a number of purposes, for example:

- In quality control, to check the conformity of production samples with quality standards.
- In "trouble-shooting", when problems of tainting or discoloration or texture defects are encountered.
- In research and development on new products and containers, to determine acceptability and keeping qualities.

The sensory tests required in these various applications may be classified in two general types: analytical tests and consumer reaction tests.

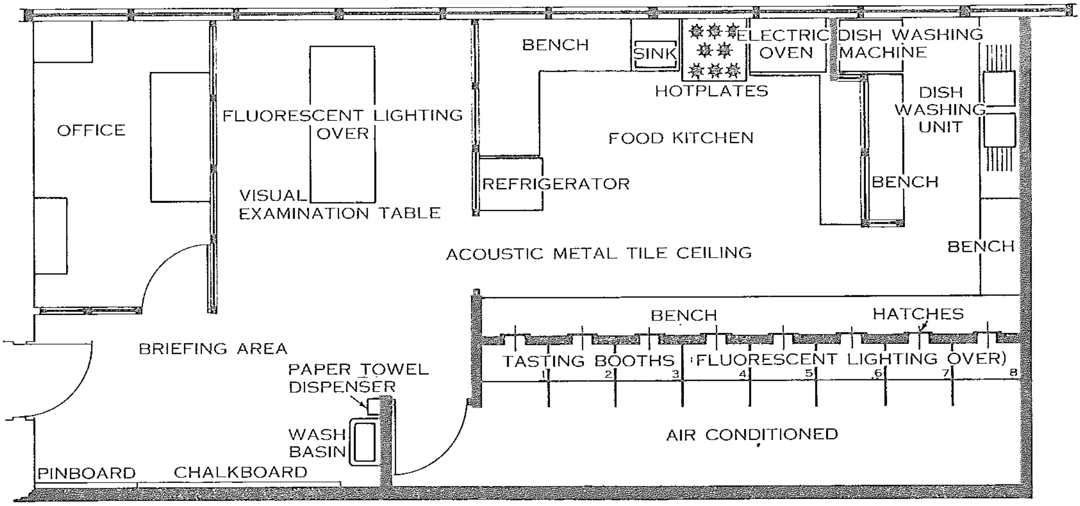
ANALYTICAL TESTS

Analytical tests are sensory tests in which the human palate is used as an instrument to assess the properties of foods. In some branches of the food industry it is traditional to rely on individual observers for sensory testing, e.g. tea tasters, wine tasters, and cheese and butter graders. Such observers, however, even after long training and experience are not free from the possibility of bias. Recent practice therefore favours the use of panels of observers for sensory testing.

For analytical tests a small panel of 6 to 12 members is usually adequate. The members of the panel, called judges, should exhibit intelligence, concentration, and good motivation towards sensory testing. Therefore analytical panels are usually best selected from technical staff. It is desirable for the judges to be sensitive, i.e. to be able to discriminate between fine differences in specific attributes of foods, and to be con-

* Based on lectures given to a Winter School on "The Taste Evaluation of Foods", University of New South Wales, May 1960.

Earlier articles in this series appeared in *C.S.I.R.O. Food Preservation Quarterly*, Vol. 13 (1953), pp. 3–8, 21–31; Vol. 14 (1954), pp. 8–18, 26–31, 46–52, 74–6; Vol. 15 (1955), pp. 28–32, 52–7, 72–7; Vol. 16 (1956), pp. 7–10; Vol. 17 (1957), pp. 11–14, 30–5, 42–7; Vol. 18 (1958), pp. 15–19, 25–9; and Vol. 19 (1959), pp. 22–7, 55–8.



Plan of taste test room at the new laboratories of the Division at North Ryde, near Sydney. Approximate dimensions, 38 *by* 18 *feet.*

sistent, i.e. to give reasonably reproducible judgments when testing the same samples at different times. Judges for analytical panels should therefore be selected on the basis of sensitivity and consistency.

There are different schools of thought on methods of panel selection. Some believe in tests for sensitivity to the primary taste factors: sweetness, sourness, bitterness, and saltiness; while others consider that selection need be based only on tests with samples similar to those to be examined. Girardot, Peryam, and Shapiro (1952) have described a scheme for panel selection involving both kinds of test.

In this Division, tests for sensitivity to primary taste factors have rarely been used. When a panel of 12 judges is to be selected, about 18 persons are invited to take part in preliminary replicated trials on the test products. A statistical analysis is then made for discrimination and consistency and a graphical comparison of each judge's scores with the panel means. The poorer performers are then eliminated but borderline performers are left in for further experience. The sensitivity and particularly the consistency of judges can be improved by training, i.e. by conducting frequent training tests and discussing with the panel the results of such tests (cf. Bennett, Spahr, and Dodds 1956).

The procedure followed in selecting a panel for the testing of bitterness in canned orange juice has been outlined by Coote (1956).

It is important to mention that panels for colour testing must be tested for normal colour vision.

CONSUMER REACTION TESTS

Consumer reaction tests are designed to reveal whether specific foods are liked or disliked by consumers. Thus, in contrast to analytical tests, they are intended to define the attributes of consumers rather than foods.

The organization of panels truly representative of the consuming public and large enough to give reliable results may be beyond the resources of individual food manufacturers. If they wish to explore consumer reactions they are usually obliged to use panels that can be conveniently assembled from their own staffs. For consumer reaction tests, the panel should be as large as possible, preferably more than 30 judges, but the judges should be unselected, and they are commonly recruited from non-technical as well as technical staff. Special training and experience are not necessary and may in fact be disadvantageous.

It is important to recognize the limitations of such panels since they are small and rather special samples of the consuming public, but they can provide worthwhile guidance in the development of new products and processes. Some workers (Miller, Nair, and Harriman 1955) have found satisfactory agreement between large household panels and laboratory panels, while others have not (Pangborn *et al.* (1959).

STANDARD ENVIRONMENT

It is an accepted principle of psychometric testing that the panel of judges must work in a standard environment if reliable results are to be obtained. The standard environment desirable for sensory testing of foods may best be illustrated by describing the facilities provided in this Division (Christie 1957) which are generally referred to as the Tasting Laboratory. A plan of the Division's Tasting Laboratory at North Ryde is shown opposite. The primary purpose of the Tasting Laboratory is to permit tests to be conducted under controlled conditions where irrelevant variables which might distract judges are minimized. In addition, the provision of special facilities has been found to have an important influence on motivation, by impressing judges with the need to take sensory testing seriously.

The Tasting Laboratory is divided into three sections: a kitchen with preparation, cooking, and dishwashing facilities; an office and briefing room; and a series of tasting booths. The six booths with chairs are separated by screens to provide privacy for each judge and to ensure as far as possible independent judgments. The walls are pale neutral grey. A glass of water, a paper cup for rejected material, and a pencil for recording are provided in each booth. Samples are passed through a hatch in front of the judge. Illumination is provided by fluorescent lights overhead and these lights may be fitted with perspex filters of red, amber, or green when it is desired to mask the colours of samples. Air-conditioning of the tasting booths is desirable to eliminate kitchen and other external odours and to maintain uniform conditions of temperature and humidity.

Colour judgments are generally made separately from flavour and texture judgments and for this purpose samples are set out on white saucers on a white table in the briefing room under three colour-matching fluorescent lights together with one tungsten light.

The Tasting Laboratory is supervised by an officer who is a qualified dietitian and who has responsibility for all the sensory testing conducted in the Division.

PLANNING OF TESTS

The principal object in planning sensory tests is to secure independent judgments, i.e. to ensure that judgments are determined only by real properties of the samples and are not influenced by extraneous factors. The guidance of a statistician experienced in sensory testing problems should be sought in planning any programme of sensory tests.

There are a number of influences which may prejudice the independence of judgments in sensory tests:

Other Judges.—It is well known that judges may influence each other by gestures, facial expressions, and comments, leading to "round-table bias". The provision of tasting booths ensures that each judge works out of sight of other judges and discussion is forbidden during tests.

Order Effects.—A panel's judgment of a particular sample may be influenced by other samples tasted at the same session and by the order in which the samples are tasted. "First-sample bias" leading to a high rating of the first sample tasted is commonly observed and may be minimized by presenting "warm-up" or dummy samples. Then there may be "carry-over" effects of early samples on the palate which influence the ratings of subsequent samples and restrict the number of samples that can be appraised at the one time. Various techniques of palate clearing are used to minimize these effects. Further, it is often observed that adaptation occurs so that the rating of a particular sample is influenced by the general level of quality in the series under test. In order to ensure that these influences contribute only random errors, the number of samples in each test of a series should be constant, and the samples should be presented to judges in different orders, preferably so that each sample appears in each position an equal number of times. There are a number of balanced statistical designs, such as Latin squares, which meet these requirements. When a balanced design is not practicable, the samples should be presented to judges in random orders.

Other Properties of the Sample.—Judgments of flavour may be influenced by the appearance or colour of the sample. Differences in appearance may sometimes be eliminated by homogenizing the samples. Differences in colour may be masked by coloured lights or coloured containers.

Prior Knowledge.—Sensory judgments should not be influenced by prior knowledge about the samples, and the identity of the samples should be hidden by the use of codes.

In general, persons concerned with preparing the samples or vitally interested in the results should not be used as judges, but in small laboratory groups it is often difficult to make up a panel without them. In instructing judges a balance must be observed between giving enough information to maintain their interest and giving so much information as to influence their judgments. Except during training periods, discussion between judges about their results should be forbidden until a series of tests is concluded.

Fatigue.—The number of samples tasted at a single session should be restricted to avoid fatigue—both fatigue of the palate and mental fatigue associated with the process of making judgments.

TEST PROCEDURES

At the beginning of a series of sensory tests instructions are given to judges verbally, or they are written on the blackboard, or printed on the score sheet. When a test is in progress, judges file into the Tasting Laboratory, collect a score sheet and take their places in the booths. The hatch is opened to indicate that a judge is ready for a sample and when the judge is finished the used dishes are passed out through the hatch.

Sample Presentation

Containers and utensils must be clean and free from taste or odour. In this Division 3-oz pyrex dishes have proved to be suitable for all solid foods, either hot or cold, and for soups, and 5-oz plain glass tumblers for beverages. Orange-coloured glass tumblers are used to mask colour differences when tasting orange juice. Silver or stainless steel spoons are used, or plastic spoons if a metallic taint is being investigated. Small plastic trays are used to hold the sample dishes for each judge in each test.

Sample Temperature

Generally speaking, samples for sensory testing should be served hot or cold according to the normal pattern of consumption of the foods concerned. It is difficult, however, to ensure that heated or chilled samples are served at the same temperature and in this Division most items are tested at room temperature. The effect of sample temperature in the tasting of canned peas was investigated by testing sets of identical samples served hot on one occasion and at room temperature on another. The ratings on both occasions were the same and therefore, although the judges preferred the hot samples, canned peas in subsequent tests have been served at room temperature. Tompkins and Pratt (1959) investigated the effect of tasting orange juice chilled and at room temperature and found differences in absolute scores but no differences in relative scores.

Since canned foods are already adequately cooked the problem of standard cooking procedures, encountered with many other foods, arises only when they are to be tested in prepared dishes.

Sample Size

The samples submitted to the judges should be sufficient to permit them to taste with confidence. In this Division typical samples are 1 dessert-spoon of solids and 1½ oz of liquids. Judges are usually told that they may have more of a sample but this is seldom requested. The samples in any one session should be uniform in size to avoid bias. Judges generally swallow samples tasted but they are free to reject any sample found to be unpalatable. Unless differences in appearance between samples are likely to cause bias, judges prefer foods in their natural form rather than as a homogenized purée. Large units such as peach and pear halves should be cut into bite-size pieces.

The number of samples tested at one session is usually three to eight, depending on the intensity of flavour in the food and the judge's capacity and interest. In practice, most sessions include four samples. Consumer reaction tests should preferably be restricted to two samples. In colour tests depending on visual judgments alone many more samples can be satisfactorily examined at one session.

The statistical design of a sensory test should lay down the manner in which the canned foods under test are to be sampled, including the number of cans to be opened and the way in which the judges' samples are to be taken from the can.

Coding

The need to disguise the identity of samples by the use of codes has already been mentioned. Codes consisting of random letters marked on the sample containers with grease pencil have been generally used in this Division. The use of letters in alphabetical order, e.g. A, B, C, should be avoided since this has been found to cause bias. One procedure is to take a code word or sentence and use the letters in order, eliminating duplicates. Other methods of coding are by the use of distinguishing marks of different colour or different geometrical shape.

Palate Clearing

To minimize palate fatigue and "carry-over" effects judges should be provided with means for clearing the palate between samples. A glass of water is always placed in each tasting booth for this purpose and is adequate for most tasting tests. Cubes of dry bread are effective for palate clearing with many foods of more lingering flavour, while pieces of apple are useful when tasting fats or fatty foods. If a judge uses a palate-clearing procedure he should use it before every sample tasted.

Times for Testing

It is generally accepted that judges perform best when sensory tests are conducted not too soon after meals. In this Division the most convenient times have been found to be 10.15 and 11.45 a.m., and 3 p.m. Tasters are requested not to smoke during the period 30 min before a test.

RECORDING OF JUDGMENTS

The results of sensory tests are obtained from judges in the form of written records on score sheets. The score sheet must be carefully designed to secure the precise information that is required from the test. It must be readily understood by the judges; it should encourage clear-cut decisions; and it should permit the results of the whole panel to be tabulated readily.

A good score sheet for a particular sensory test is seldom designed at the first attempt, but evolves during training periods and actual use.

A number of established psychometric methods have been used as bases for score sheets in the sensory testing of foods, notably ranking and rating scales.

Ranking

The simplest system, perhaps, is ranking, in which judges place samples in order, from greatest to least, with respect to some specific dimension. Thus ranking involves relative judgments between samples rather than absolute judgments against real or implied standards. Statistical procedures are available for the treatment of ranked judgments in tests conforming to certain classes of design.

TABLE 1: Score Sheet for Paired Comparison Test

Booth No.................................Date.........................Time...............

Name..

Product...

In each pair of samples mark 1 for your first preference and 2 for your second preference. If possible state the reason for your preference. Taste samples in the order shown.

	Sample Code	Rank	Remarks	Is Sample Acceptable ? (Yes or No)
Pair				
Pair				

When only two samples are ranked the test is known as a paired comparison and a score sheet of this type is shown in Table 1. In addition to ranking the samples in order of preference the judge is asked to give reasons and also to state whether the samples are acceptable or not. Such a test for preference and acceptability would be a consumer reaction test but the paired comparison procedure is also applicable to analytical tests for specific attributes, such as colour, bitterness, and tenderness. The paired comparison test is useful for assessing differences in preference which may exist between samples which receive the same scores on a rating scale (see below).

Some examples of paired comparison tests of canned foods conducted in the Division of Food Preservation are: salmon, for tenderness; pineapple, for texture; baked beans, for colour, flavour, and texture; baby foods, for preference and acceptability; peas, for flavour and texture preference; and orange juice, for flavour preference with different levels of peel oil. Ranking tests with three or four samples have been carried out with tropical fruit salad, for acceptability; tomato soup, tomato sauce, tomato juice, and mushroom soup, for colour, flavour, and

TABLE 2: Rating Scales with General Adjectives

C.S.I.R.O. Scale

Excellent	10	
Good	9	
	8	
Satisfactory	7	
	6	
Not quite satisfactory	5	
	4	
Poor	3	
	2	
Completely unacceptable	1	
	0	

Quality Grading Scale (Pilgrim and Peryam 1958)

Excellent	9	
Very good	8	
Good	7	
Below Good above Fair	6	
Fair	4	
Below Fair above Poor	4	
Poor	3	
Very poor	2	
Extremely Poor	1	

acceptability; and apricots, for colour and flavour preference between different picking maturities.

It is difficult to rank more than three or four samples for flavour at the one session but many more samples can be ranked successfully for colour. In colour ranking the samples may be actually moved around by the judge until the order on the table represents the rank order. Ranking tests for colour have been made with tomato juices and fish pastes in the Division.

Rating Scales

The system most frequently used for recording sensory judgments is the rating or scoring scale, often a scale from 0 to 10 points. The rating scale may be used in consumer reaction tests but it is specially suitable for analytical tests where the panel is trained so that the points on the scale have a common meaning for all judges. To assist judges to maintain conformity, some or all of the points on the scale are usually defined in descriptive terms. These terms may be general adjectives representing successive levels of "goodness" or "badness" (Table 2), or the general adjectives may be supplemented by additional description appropriate to the attribute under test, as in Table 3. Table 3 also shows that more than one attribute of a set of samples may be assessed simultaneously by the use of rating scales. In some cases the rating scale can be defined in terms of a primary taste factor as in Table 4.

During training in the use of a rating scale judges should be encouraged to make suggestions for improvements in the descriptive terms used. Standard samples selected to represent certain points on the scale are valuable for training purposes but it is seldom feasible to include standard samples throughout a particular series of sensory tests. The panel therefore must be trained to retain a reliable mental concept of the meaning of the scale.

The rating scale method is described as a "single stimulus" psychometric technique because, in contrast to ranking, each sample is supposed to be rated on the scale without reference to any other sample tested at the same time. It is very doubtful whether this independence is realized in practice. There is a strong tendency for judges to rate samples

TABLE 3: Rating Scales for Sensory Tests on Canned Peas

		Flavour
Excellent	10 9	Full normal pea flavour
Good	8 7	Typical pea flavour
Satisfactory	6 5	Slight lack of flavour or slight off-flavour
Not quite satisfactory	4 3	Weak flavour or distinct off-flavour
Poor	2 1	Flavour flat or unpleasant
Inedible	0	Complete lack of flavour or objectionable
		Texture
Excellent	10 9	Highly acceptable uniform texture
Good	8 7	Very slightly hard or very slightly soft
Satisfactory	6 5	Slightly starchy or slightly soft
Not quite satisfactory	4 3	Starchy or soft or watery
Poor	2 1	Very hard or very soft or very watery
Completely unacceptable	0	Too hard and starchy or completely mashed

TABLE 4: Rating Scale for Bitterness in Orange Juice

Not bitter	0
Bitterness doubtful	1
Slightly bitter	2 3
Moderately bitter	4 5
Bitter	6 7
Strongly bitter	8 9
Extremely bitter	10

TABLE 5: Flavour Rating Scales with Central Zero

C.S.I.R.O. Scale	
Good flavour, entirely free from off-flavour	+2
Acceptable, probably free from off-flavour	+1
Questionable off-flavour	0
Slight off-flavour	−1
Definite off-flavour	−2
North-east Regional Scale (Wiley *et al.* 1957)	
Better than standard in flavour	+2
Equal to standard in flavour	+1
Below standard in flavour, no detectable off-flavour	0
Slightly off-flavour	−1
Definitely off-flavour, not acceptable	−2

relatively as well as absolutely in relation to the scale. A number of workers have established good correlations between ranking and rating scale assessments of the same samples (e.g. Tompkins and Pratt 1959). The rating scale however has the advantage that it measures degrees of difference between samples as well as the relative order.

The 0–10 rating scale has been used in this Division in sensory tests on a variety of canned foods for the assessment of a wide range of properties, such as colour, flavour, bitterness, lacquer taints, texture, consistency, and retention of shape.

Central Zero Scale

Another form of rating scale is a scale with zero as the central value and + and − values indicating qualities above or below a standard or normal level. A 5-point scale of this type (Table 5) has been used with success in this Division for investigating taints in canned foods, e.g. taints due to can lacquers, to excessive chlorination of cannery water, and to contamination with pesticides, weedicides, or lubricating oil. In such studies it is usually possible to provide standard samples of normal flavour.

Investigators of pesticide taints in U.S.A. have reported encouraging progress in the development of standardized tasting procedures. One group of cooperating laboratories used a central zero scale (Table 5) with selected panels of 10–12 judges making at least 40 judgments and reported excellent agreement between five panels in different areas (Wiley *et al.* 1957). Similar good agreement was secured between 11 panels using a 9-point rating scale (Mahoney, Stier, and Crosby 1957). In both these series of tests untreated control samples were used as reference standards and the dimension measured was the difference in flavour from

TABLE 6: Score Sheet based on the Hedonic Scale

Booth No.................... Date.................... Time....................

Name..

Product..

Please check the appropriate remark to show your opinion of each of these samples. Comments showing reasons for judgments are very helpful.

	Sample Codes in Order of Tasting		
9. Like extremely			
8. Like very much			
7. Like moderately			
6. Like slightly			
5. Neither like nor dislike			
4. Dislike slightly			
3. Dislike moderately			
2. Dislike very much			
1. Dislike extremely			

the standard. Hall, Tarver, and McDonald (1959) also used a rating scale to measure flavour differences from a standard for the purpose of evaluating materials for beer cans.

In Britain the triangular test is favoured for testing for taints by crop protection chemicals (Adam 1955).

Hedonic Scale

A rating scale that has been used most successfully for consumer reaction tests is the hedonic scale (Table 6), a 9-point scale representing a psychological continuum from the pleasant to the unpleasant. The philosophy and practical applications of this scale have been discussed very fully by Peryam and Pilgrim (1957). In this Division the hedonic scale has given useful results even with inexperienced judges and has been used in many tests on canned foods, including green beans, for general acceptability in a maturity trial; berries, for colour and shape with different syrup strengths; pears, for preference with different sugar/acid ratios; orange juice concentrate, for colour and flavour; and baked beans, for colour, texture, flavour, bean/sauce ratio, and general acceptability.

In a comparative test using seven orange juice concentrates, Tompkins and Pratt (1958) showed satisfactory agreement between assessments by ranking, rating scale, and hedonic scale.

Questionnaires

Sometimes in consumer reaction tests, particularly of unfamiliar foods, the information required may be best obtained by asking the panel to complete a questionnaire which seeks mainly qualitative judgments. A questionnaire designed for a consumer reaction test on a canned rice pack is shown in Table 7. This questionnaire includes provision for ranking two samples for preference. The questions asked in tests of this kind will vary widely according to the nature of the product and the information desired.

Analysis of Results

It is essential that the results of sensory tests should be subjected to statistical analysis to determine whether differences found in qualities or preferences are likely to be real or whether they could have appeared by chance. Details of statistical procedures are, however, beyond the scope of this series, and the food technologist is advised to enlist the help of an experienced statistician to supervise both the planning and the analysis of sensory tests.

QUALITY CONTROL TESTS

Sensory tests in the routine quality control of canned foods from the production line are essentially special cases of analytical tests (Ferris 1960). The quality of production samples is assessed by a trained panel in relation to a standard of quality. In the first place the standard of quality must be established; it should be more than a concept in the mind of the head processor or the managing director. The fundamental way to determine standards of quality for a particular product is by consumer reaction tests to find out what the public desires and what tolerance in quality is acceptable. It is difficult and expensive to do this properly on a large scale,

TABLE 7: Rating Scales for Quality Control Tests

4	Superior commercial quality	or Fancy
3	Good commercial quality	or Choice
2	Fair commercial quality	or Standard
1	Substandard	

but useful information can be gleaned from consumer reaction tests with small panels. The panels, however, should be heterogeneous in preferences and untrained since expert panels have been shown to be unreliable in predicting consumer preferences (Pangborn *et al.* 1959).

Once established, the standard of quality must be defined. Memory standards are notoriously unreliable. The use of standard samples is sound in principle but difficult in practice because of quality deterioration with time. Comparison of production samples with the previous day's pack can be useful practice provided adequate safeguards are taken to avoid a gradual drift in quality away from the original standard. Many organizations maintain manuals of written standards in which they endeavour to define the quality factors colour, flavour, and texture as adequately as possible in descriptive terms. There are a number of published standards which may provide the basis for setting out manuals of quality for canned foods, e.g. Department of Primary Industry (1952), Commonwealth of Australia (1954), and the U.S. Standards for Grades of Canned Foods issued by the Agricultural Marketing Service of the United States Department of Agriculture.

The function of the expert panel in quality control testing is then to judge production samples for conformity to the defined quality standard. A simple rating scale of 4 points (Table 8) is usually adequate. To obtain reliable results in sensory tests for quality control it is desirable to provide the standard environment and to take the precautions in panel selection and training, and in the design and operation of the tests that have been outlined. Because of the restricted numbers in cannery laboratories, it may be necessary to use the same small panel over a period of years. It is then desirable to institute a regular system of checking panel performance by the use of special samples such as doctored samples and competitive products.

TABLE 8: Questionnaire for Consumer Reaction Test

Booth No.................... Date.......................... Time.....................

Name..

Product: Canned Savory Rice

Please indicate your opinion of each of these samples by checking the appropriate remarks and by making comments where possible. Also indicate your preference by marking 1 for first preference, and 2 for second preference.

	Sample Codes in Order of Tasting	
Colour Good Acceptable Not acceptable Other remark		
Texture Good Acceptable Not acceptable Other remark		
Flavour Good Acceptable Too highly seasoned Not seasoned enough Other remark		
Overall order of preference		
Is the sample acceptable? Yes or No		
Would you buy the sample at 2*s*. 2*d*. per 16 oz can? Yes or No		
How would you use the product: As a meat accompaniment? As a luncheon dish? As a party savory? Other suggestions		

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NEWS FROM THE DIVISION OF FOOD PRESERVATION AND TRANSPORT

PUBLICATIONS BY STAFF

Nature of the Olefines Produced by Apples. F. E. Huelin and B. H. Kennett. *Nature* **184**: 996 (1959).

From the results of experiments reported in this paper it seems reasonably established that normal olefines from propylene to hexene cannot be present in proportions which exceed one part of higher olefine to 1000 parts of ethylene. All unsaturated hydrocarbons cannot be excluded, as those with branched chains or more than one double bond may be more labile and hence not regenerated with the ethylene. Gas chromatography of a low-temperature condensate gave no evidence of saturated hydrocarbons.

A Mannitol Disulphonic Acid. D. L. Ingles. *Chem. & Ind.* **1959**: 1217.

Earlier workers suggested that sugar sulphonic acids were formed during the storage of foods treated with sulphur dioxide although such derivatives were not detected in model systems. This is the first description of a stable sugar sulphonic acid.

Copies of papers mentioned above may be obtained from the Librarian, Division of Food Preservation and Transport, Private Bag, P.O., Homebush, N.S.W. (Telephone: 76-8431, 76-0274).