Mr. Beard

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Dr. M. M. Wilson was, until recently, Assistant Director of the Public Health Laboratory of the University of Melbourne. A graduate with honours in Natural Sciences from Cambridge University, Dr. Wilson qualified also in medicine in London, and holds the Diploma of Tropical Medicine and Hygiene. Dr. Wilson was particularly fitted to speak on the above subject at the Food Science Conference, held at North Ryde, N.S.W., in September 1961, having served as a member of the U.K. Emergency Public Health Laboratory Service and on the staff of the Pathology Department, Cambridge University, prior to his Melbourne appointment. This paper was a contribution to a Panel Discussion on Public Health Aspects of Handling Food.

Public Health Aspects of the Handling and the Processing of Foods

By Michael M. Wilson

FOR the present purpose we may divide the public into those who are concerned in producing, processing, and conveying food and those who consume it: there are hazards to both groups which public health authorities strive constantly to eliminate.

In the first group we find the infectious diseases of animals communicable to man, the so-called zoonoses, to which those who handle animals and their products may be occupationally exposed. The source of human infection is an infected animal, so the problem of prevention of human disease is primarily a veterinary one, and in this field veterinarians and public health authorities often work together: notable examples are brucellosis, leptospirosis, Q fever, and anthrax.

The second group, which involves the consumer, can be broadly covered by the term "food poisoning", and here again we must limit the field, excluding such examples as ergotism, lathyrism, and the chemical substances like cadmium and zinc.

Bacterial Food Poisoning

Bacterial food poisoning implies food-borne damage to health either by live pathogenic organisms or through toxic products of their growth in food. A line of demarcation between them is not always clear-cut, though in most cases classification is not usually difficult. In every case there must be a susceptible person, an inoculum of an appropriate microorganism in the food and, in most cases, conditions of time and temperature suitable for its survival and multiplication. Most foodstuffs desirable to man are also appreciated by bacteria, and incidentally anaerobic conditions obtain usually beneath the surface.

Organisms

The organisms to be considered in the infective group include the salmonellas, shigellas, certain coliforms, certain types of *Clostridium welchii*, brucellas, *Streptococcus* Group A, *Corynebacterium diphtheriae*, *Mycobacterium tuberculosis*, and some viruses such as those of hepatitis and the poliomyelitis group. The enterotoxigenic strains of *Staphylococcus* and *Clostridium botulinum* are examples of the toxin-producing group.

Salmonellas

The most common bacterial genus is probably *Salmonella* whose member species are distributed widely through the animal kingdom from reptiles and birds throughout

the mammals. Apparently healthy carriers in animals and man are not uncommon if the organisms are in their usual place of abode, the intestinal tract. They are excreted in the faeces and outside the body they can survive for some time and may, under appropriate conditions, multiply in many foods. The dose required to produce symptoms seems to vary considerably, being governed by the behaviour of the particular strain involved and by the susceptibility of the host, but it is probably fair to say that in general at least some thousands are needed to produce symptoms in man, except in the case of *Salmonella typhi* and *paratyphi.* It is very probable that the threshold dose required to produce symptoms in a given host may vary widely from one strain of *Salmonella* to another.

Greater Danger

The problems of bacterial food poisoning have increased progressively with the advance of civilization and the emancipation of women. In the old days when mother fed the family at home any trouble was confined to the household, but nowadays with so much of the domestic supply prepackaged and so much more feeding on the mass scale from a common kitchen, a single lapse in hygiene somewhere along the line can have much wider implications. Then again, the consumer is more often a paying customer and is entitled to the protection of the law if he or she becomes ill as a result of eating unwholesome food. It is indeed notable that incidents of food poisoning reported to health authorities over the last decade or two in America and England have shown no sign of decline in numbers despite growing awareness of the problems—in fact rather the reverse.

Cause Unknown

There are still many incidents of food poisoning where the cause is never discovered. Salmonellosis is, however, the commonest form and *Salmonella typhimurium* accounts for more than 50% of *Salmonella* incidence the world over.

The natural habitat of *Salmonella* is the intestinal tract of animals, both wild and domestic, including *Homo sapiens*, and infection may or may not produce obvious sickness. Rats and mice are commonly found to be carriers and meat animals, especially pigs and birds (including ducks and fowls) are often involved.

Susceptible Products

Of food products liable to be infected, meats—especially pig meats—egg products, artificial creams and icecream, shellfish, and desiccated coconut come high on the list. Just why desiccated coconut should be implicated is not really clear, but from my own experience I am convinced that it results from bad hygiene in the factories where the raw coconuts are split, peeled, shredded, and dried. The large population of small wild rodents which are attracted to the vicinity probably also plays an important part in the cycle of infection.

Dissemination of Infected Material

The processing of a large amount of produce by passing it along the same production line is very favourable for the dissemination of a small dose of organisms throughout a large batch of a product. This is well exemplified in egg products, where many thousands of individual eggs contribute to a batch of egg pulp, when a single infected egg may contaminate large numbers of sound ones. The same principle has been shown to obtain amongst pigs, for these animals appear to exchange their intestinal flora when they meet together at close quarters shortly before slaughter. Further dissemination is liable to take place as the carcasses pass through the abattoir by contact with cloths, knives, hands, and washing water. Sampling of the mesenteric glands of pigs at slaughter has shown that the *Salmonella* carrier rate in these organs varies from 2–12% in healthy animals. Possibly this results from the feeding habits of the pig and perhaps Moses had more than an inkling of this situation when he drafted his dietary laws in the Book of Leviticus. In recent years it has been found that animal feeding stuffs containing such things as bone meal, fishmeat, and offal sometimes harbour *Salmonella* species; even pastures can become infected and spread disease among cattle.

The next point to be considered in *Salmonella* food poisoning is the need for

multiplication of a small inoculum; this requires a period of some hours at least, at a temperature between 10 and 40°C. Growth of *Salmonella* in food may occur without obvious signs of putrefaction.

Avoid Multiplication

Because the ideal of eliminating *Salmonella* completely from raw materials is probably beyond attainment the aim should be to destroy the organisms before multiplication can take place; for instance, by pasteurization of egg pulp. The organisms, being vegetative, are destroyed fairly readily by heat, and the time and temperature of the ordinary process of pasteurization is quite adequate providing heat penetrates satisfactorily. That such penetration is not always effected easily, however, was shown in the large outbreak of *Salmonella bovismorbificans* poisoning from meat pies which was reported in England in 1955. Although the pie crusts were well baked in an oven at 170°C for 40 min the organisms survived inside the pies and subsequently multiplied. The same problem arises with desiccated coconut where the desiccation involves hot air treatment round about 90°C for some 40 min, yet the organisms in the mass of shreds can escape destruction. It has been shown experimentally that toasting ½-in. layers of coconut in an oven at 400°F cannot be guaranteed to kill *Salmonella* species in less than 12 min.

In addition to being introduced in the raw material or in processed food, *Salmonella* species can of course get in somewhere along the line of production from unhygienic handling and contamination by dust, flies, rodent excreta, dirty utensils, etc. There are many other organisms also which may be introduced in this way and give rise to a "poisonous" product. In this regard shigellas, streptococci, tubercle and diphtheria bacilli, and others, come to mind.

Heat-Resistant Spores

Another organism which not uncommonly gives rise to food poisoning, apparently by the action of the organism itself growing in the victim's bowel, is a special type of *Clostridium welchii*. This organism produces highly heat-resistant spores which are able to survive normal cooking, and are not destroyed by boiling for over an hour. The source of infection is uncertain but spores have been isolated from faeces of 2% of healthy people, from sewage, from flies, and from the faeces of various animals. They have also been found on and in raw meat such as beef, veal, and pork, probably as abattoir contaminants. The usual sequence of events is that meat, with or without gravy, is left after cooking to stand above refrigeration temperature for some hours and acts as an ideal anaerobic medium in which multiplication occurs, so that a high bacterial population is generated. When such meat is eaten there results a fairly typical clinical picture, characterized by an incubation period of 8–20 hours, followed by an attack of colicky abdominal pain, shivering, and watery diarrhoea. Vomiting is usually conspicuous by its absence. Recovery soon follows but examination of faeces for some days after the attack reveals a heavy growth of heat-resistant *Clostridium welchii* with typical growth features. Production of an enterotoxin has not been demonstrated.

Human Pathogens

If unpasteurized milk is to be regarded as a processed food it can, of course, act as a vehicle for two most important human pathogens—*Mycobacterium tuberculosis* and *Brucella* spp. and, to a lesser degree, *Rickettsia* of Q fever. Staphylococci of bovine mastitis may also cause trouble in milk if they multiply between the cow and the customer.

Like any other food, milk, whether previously pasteurized or not, can be contaminated with a wide variety of pathogenic organisms and can serve as a medium for multiplication.

Toxic Group

In the toxic group, strains of *Staphylococcus pyogenes* are responsible for the bulk of cases. The essential requirements to produce disease are infection of the food with the appropriate organism, and an opportunity for its multiplication in terms of time and temperature; in this case the enterotoxin is a by-product of bacterial growth. This particular toxin is sufficiently heat-stable to survive, even though subsequent heating may be sufficient to destroy

the organisms themselves. This means it is not always possible to isolate a heavy growth of viable staphylococci from a poisonous product. In practice, however, one can usually do so and the organism may also be found in large numbers in the faeces of the victim after the attack. Clinically, this type of poisoning is characterized by a short incubation period of 1–4 hours with sudden onset of vomiting followed by pain and diarrhoea. The picture may be most alarming and the patient may collapse, but recovery is usually quite rapid.

Salt-Tolerant

Staphylococci are able to grow in concentrations of sodium chloride exceeding 10%, so that salt meats are not uncommonly involved. A few years ago during a heatwave in Melbourne there was an outbreak which was traced to corned beef. The corned beef was salted and sold by a large manufacturing firm to delicatessens which retailed it, mostly in sandwiches. The normal factory procedure was to boil large joints of salted beef, cool them quickly, and store in a refrigerator for a few days before distribution. The heatwave produced unusually large demands for this particular product and it was found that the incriminated batch had been distributed immediately after cooking without the usual period of refrigerator storage. It was presumably contaminated after cooking and was warm enough for significant multiplication to occur while it was being distributed.

Staphylococcus pyogenes is widely distributed through the population amongst nasal and skin carriers, and is particularly liable to be spread from infected cuts and other lesions on the fingers or, indirectly, from infections such as boils on other parts of the person, by way of hand contact.

Botulism

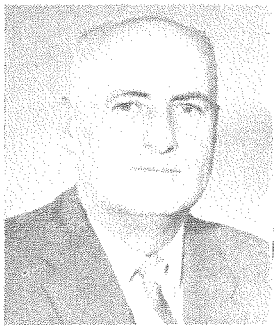
The other important toxin-producing organism is *Clostridium botulinum*. Though botulism is fortunately a rare disease it is so dramatic and so lethal in its effect that it has to be kept constantly in mind. From the point of view of the food technologists it is important for two reasons: firstly, the spores are among the most resistant of all bacterial forms to destruction by heat, and second, conditions within food packs are ideal for multiplication and elaboration of toxin; it grows best at an alkaline pH. It is perhaps remarkable that although the spores are widely distributed in soil, botulism is an extremely rare disease and, of the recorded incidents, a large proportion have been attributed to food processing by amateurs, a fact for which the professionals can claim credit. Happily most, though not all, strains are markedly proteolytic so that toxin production is usually accompanied by obvious spoilage. However, death has resulted from merely tasting preserved food to see if it was all right. Human botulism is rare in Australia, but Gray (1948)* reported two outbreaks among Forces personnel; in all 31 people were affected of whom eight died. These incidents were attributed to commercially canned beetroot.

Summary

Food-borne disease due to microbes can result from infection by organisms which have (*a*) been present in the raw material and have not been destroyed in the processing; (*b*) from organisms which have been introduced during processing; or (*c*) from toxic substances produced as a by-product of bacterial multiplication within the food.

In prevention, (i) raw materials must obviously be as sound as possible; (ii) hygienic measures must be taken to prevent contamination during processing; (iii) when possible a terminal sterilization is desirable; if it is not (iv) the opportunity for bacterial multiplication in any product which is not subjected to a reliable sterilization process must be kept at a minimum by refrigeration up till the time of consumption; (v) even sterilized foods may be subsequently contaminated so protection from this hazard is necessary; satisfactory containers which will withstand the rigours of transport are essential for sterilized products.

* Gray, D. F. (1948).—Human botulism in Australia. *Med. J. Aust.* **2**: 37.



This article is based on a talk given at North Ryde, N.S.W., by a visiting Canadian scientist, Mr. F. E. Atkinson, to members of the C.S.I.R.O. Division of Food Preservation. Mr. F. E. Atkinson, a Fellow of the Agricultural Institute of Canada, has been in charge of the Fruit and Vegetable Processing Laboratory, at the Summerland Research Station, B.C., Canada, since it was established in 1929.

The Summerland Fruit and Vegetable Processing Laboratory

By F. E. Atkinson

DURING its 33 years of existence, research workers at the Fruit and Vegetable Processing Laboratory of the Canada Department of Agriculture, which forms part of the Research Station at Summerland, British Columbia, have studied a wide variety of products. Their main findings have been adopted by the fruit and vegetable processing industries in Canada and other countries.

FRUIT AND VEGETABLE PROCESSING

The laboratory for the processing of fruit and vegetables was added to the original Horticultural Building, at Summerland, following five years of preliminary work on the subject at Grimsby, Ontario, and Penticton, B.C. The Experimental Farms Service of the Department of Agriculture contributed the buildings and most of the equipment; it furnished food technologists, a home economist, and the necessary support technicians. The Science Service, which is another division of the Department, provided chemists and bacteriologists to carry out fundamental science studies. These Services have now been combined in the Research Branch.

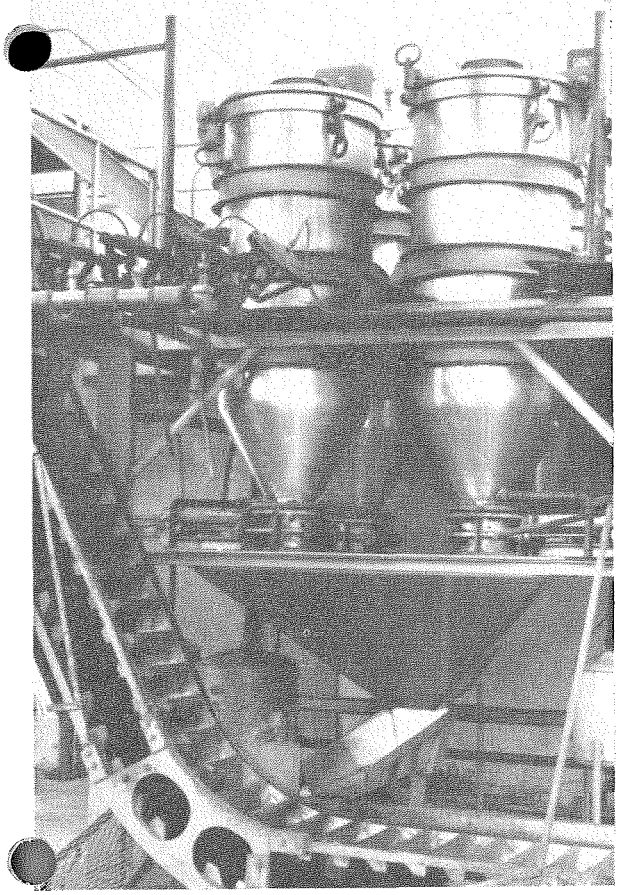
To help the small operator the Laboratory undertook, in its early days, the problem of devising equipment for small canneries. In the pre-war depression years it prepared and distributed plans and working process outlines which resulted in 19 small canneries being built, some of which have since developed into large factories.

During the Second World War technical supervision was provided for the vegetable dehydration plants which were established in Winnipeg and west to Vancouver. Other work has concerned the preparation and blanching of vegetables for freezing, improving the quality of dehydrated apples, the manufacture of various juices and blends, and the vinting of wine from new grape varieties and from tree fruits. A canned clarified apple juice was developed in the late thirties and during the war a technique was developed for adding Vitamin C to the apple juice. The present pack in British Columbia of clarified juice, and of a later product, a vitaminized opalescent apple juice, has now reached a million cases (or 3½ million gallons) per annum.

RECENT RESEARCH ACTIVITIES

Vacuum Treatment of Fruit and Vegetable Tissue

Unless the high percentage of gases present in the tissue of some fruits such as apples is reduced, processed fruits soften seriously during heat treatment, and an unsatisfactory product results. Research into the problem has led to the designing of a commercial vacuum unit. This consists of two stainless steel cylinders with 10-in. gate valves, operated by compressed air, at the top and bottom. By the alternate loading and emptying of the cylinders continuous batch processing has proved possible. A pilot plant demonstrating



Stainless steel vacuum chambers for processing apple.

continuous vacuum treatment has also been devised. This consists of a vacuum chamber mounted on the top of two hydrostatic legs about 33 ft high. Cubed apple, fed into the unit by a Moyno pump, is carried in water up one leg, vacuum treated on a wire conveyor belt, and discharged down the other leg through a dewatering screen and a hot water blancher. The resultant product appears identical with that prepared in the batch type plant. The use of a chamber with revolving compartments is also being studied.

Canned Fruit Pie Fillings

Ready-to-use fruit pie fillings, consisting of up to 80% fruit with added thickening agents, are not a new product, but their quality in the past has often limited consumer acceptance. Fillings developed by the laboratory, made from apricot, peach, prune, and apple, met with public acclaim when placed on the market. Apple, peach, and apricot pie fillings were found to retain their quality for 5–6 years when stored at 0° and 40°F. Although some of the fillings from the darker pigmented fruits—blueberry, blackcurrant–apple, and strawberry (colour added)—did not suffer much deterioration on storage, those made from sour cherry, raspberry, and prune lost colour and flavour and proved generally unsatisfactory.

Fruit Syrups and Sauces

Two types of blackcurrant juice prepared from frozen fruit were sweetened to 42% soluble solids for dilution with an equal part of water. For one type of juice the coarser fruit particles were removed by passing over a shaker fitted with a 40–60 mesh screen. For the second type, enzyme clarification and filtering gave a very satisfactory product. Blackcurrant juice was used also in a blend with juice from low acid varieties of apples, such as Rome Beauty and Delicious. Unfortunately this juice, which is of attractive colour and has a predominantly blackcurrant flavour, deteriorated rapidly in storage. The problems involved are being studied. The other blended juices holding promise for commercial manufacture are an opalescent apple–lime, and peach–grapefruit.

Recipes have been provided for fruit sauces, of similar texture to apple sauce, made from cherries, peaches, and pears. A blend considered to have a satisfactory flavour consists of equal parts of apricot, apple, peach, and pear.

Dietetic-Pack Fruits

Cherries, apricots, peaches, pears, and prunes were packed with cyclamate and saccharine as sweeteners. Low methoxyl pectin and carboxymethylcellulose were added to improve syrup viscosity. The former was found the more satisfactory. The cellulose gum tended to cause too much thickness and a white leathery skin on peach halves.

Cider

The laboratory developed and patented a process for the manufacture of cider from dessert apples which allows a uniform product to be made throughout the processing season. No less than 2500 tons of apples were used in the first large-scale commercial test. The commercial process is essentially the same as that developed in the laboratory,

except that a 2% sulphur dioxide solution is metered into the pump delivering the milled apples to the press, so as to prevent oxidation. The juice is fermented at 77°F until the percentage of total soluble solids, by refractometer, is reduced to 8·2. The resultant product is chilled to 29°F, filtered through diatomaceous earth, carbonated at 35 p.s.i., bottled, and pasteurized at 146–150°F.

In a study of the various flavours in cider made from McIntosh apples, methods of extracting flavour components from apple juice and cider have been developed. Sixteen components separated from juice and fifteen from cider are being purified for identification by infrared spectroscopy.

Frozen Foods

The suitability for freezing, of fruits and vegetables grown normally in British Columbia has been investigated. The correct times for blanching have been determined and a study was made of their retention of nutritive value.

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LABORATORY EXAMINATION OF CANNED FOODS—XIX

Objective Measurement of Colour

By J. F. Kefford

Division of Food Preservation, C.S.I.R.O., North Ryde, N.S.W.

BECAUSE colour is the first quality attribute a consumer perceives when a can of food is opened it is often regarded as an index of the general quality of the pack and so may influence the consumer's judgment of other attributes such as flavour.

The colour that the consumer sees depends upon a chain of both physical and physiological events. Light reflected or transmitted by the food is received by the retina of the eye and sensations are conveyed to the brain which give rise to the concept of colour.

Visual assessment of colour by the use of panels of observers has been discussed already in this series (Kefford and Christie 1960). The difficulties associated with sensory testing have encouraged the development of objective methods for the measurement of colour based on photoelectric instruments which reproduce in part the functions of the retina (Kramer and Twigg 1962; Mackinney and Little 1962).

Measurement of colour implies expressing the concept in terms of numerical dimensions. Two approaches are possible: a complete quantitative specification may be sought, or it may suffice to use a numerical index which defines a colour adequately for specific purposes and permits comparisons. It was recognized early that complete specification of colour, as seen by human observers, requires three dimensions, roughly analogous to the specification of geometrical

shape in terms of length, breadth, and height. The three dimensions of colour are:

(1) *Hue*, which means the kind of colour, whether it is a red or a blue, etc.
(2) *Saturation*, which means the depth of colour or the extent to which the pure hue is diluted with white, and
(3) *Lightness*, which may be understood as the extent to which the hue is diluted with black.

It is necessary to relate these dimensions of colour to properties of the light which stimulates the retina. The amounts of light in different parts of the visible spectrum reflected or transmitted by a coloured body can be measured by a spectrophotometer. A spectral curve showing intensity versus wavelength will give a complete specification of the colour in physical terms.

Although this spectral curve may show that the colour is made up of radiations of many different wavelengths, the human eye cannot distinguish between all these radiations. It is a known fact that any colour can be matched exactly by a suitable mixture of only three colours selected from the red, blue, and green parts of the spectrum. The three selected colours are called *primaries*, and the relative amounts of them required to match a given colour are called its *tristimulus values*. Colours which have different spectral curves may appear identical to the human eye and they are then called *metameric* colours.

THE C.I.E. SYSTEM

An internationally accepted system of colour standardization, based on tristimulus values, has been established by the Commission Internationale de l'Eclairage (C.I.E.). For a full explanation of this system the reader is referred to a textbook on colour measurement (e.g. Wright 1958). The simplified account which follows may help food technologists to interpret the literature on colour measurement, which is heavily loaded with jargon and with concepts defined by convention.

The C.I.E. system brings together the physical and psychological aspects of colour by defining a standard observer, standard illuminants, and three theoretical primary colours or reference stimuli. The illuminant most frequently used is Illuminant C (colour temperature 6740° Kelvin) which approximates to average cloudy daylight in colour and spectral distribution,

The three primaries, designated by convention (X), (Y), and (Z), were chosen so that a mixture of equal amounts of each matches a standard white. Further it was considered to be desirable to ensure that all real colours could be specified entirely in terms of positive quantities and this required that the three reference stimuli should be imaginary rather than real colours. As an additional mathematical device, which is at first confusing but which greatly simplifies calculations, two of the reference stimuli, (X) and (Z), were made to have zero luminous efficiency, which means that all of the light energy represented by a colour is regarded as coming from stimulus Y. This means that the amount of Y is then a direct measure of the lightness dimension of the colour.

Under the C.I.E. system an equation can be written for any real colour (C) as seen by the standard observer in average daylight, thus:

$$C(\mathrm{C}) = X(\mathrm{X}) + Y(\mathrm{Y}) + Z(\mathrm{Z}),$$

where an amount C of the colour (C) is matched by a mixture of the amounts X, Y, and Z of the three standard primaries (X), (Y), and (Z). X, Y, and Z are the *tristimulus values* of the colour (C).

It is convenient to be able to specify a colour independently of the total amount of light energy involved. To do this, C is made equal to a unit amount of colour, called the *trichromatic unit*, and the equation is written:

$$1\mathrm{C} = x(\mathrm{X}) + y(\mathrm{Y}) + z(\mathrm{Z}),$$

where $x = X/(X+Y+Z)$, $y = Y/(X+Y+Z)$, and $z = Z/(X+Y+Z)$.

x, y, and z are called *trichromatic coefficients* and they represent the amounts of the primaries (X), (Y), and (Z) required to match one trichromatic unit of the colour (C). Only two of these coefficients, usually x and y, need be specified since the third is then given by:

$$z = 1 - x - y.$$

When the C.I.E. values x and y for all real colours are plotted on rectangular coordinates, all the points fall within the limits of a plane figure, shaped like the sole of a shoe, which is called a *chromaticity diagram* (see Fig. 1). The point S representing the standard white of illuminant C falls close to the centre of gravity of this diagram.

It has already been mentioned that Y, the amount of the primary stimulus (Y), is a measure of the lightness dimension of a colour. If Y values are now plotted perpendicularly to the chromaticity plane, an irregular *colour solid* or *colour space* is created within which any real colour can be fixed as a unique point with the C.I.E. coordinates x, y, and Y.

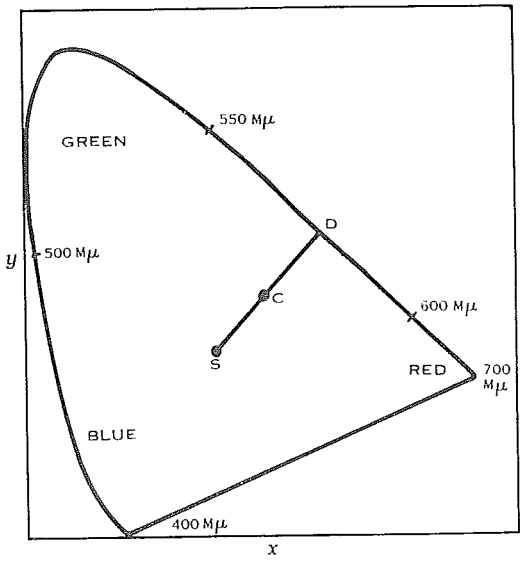

Fig. 1.—C.I.E. chromaticity diagram.

To determine the visual dimensions of a particular colour *C*, a line is drawn from the white point S to the point C and produced to the edge of the figure which is the locus of the wavelengths of the spectral colours. Reds are located at the right of the chromaticity diagram, greens at the top, and blues at the bottom left. The *hue* of the colour (C) is given in terms of the *dominant wavelength* at the point D. The *saturation* dimension is measured in this system in terms of *purity* which is the distance, SC, between the colour point and the white point. The *lightness* of *C* is given by its *Y* coordinate, perpendicular to the chromaticity plane.

The C.I.E. system has major disadvantages. For instance, equal differences in perceptibility between colours are represented by lines of unequal length in different parts of the colour space. Further, it is very difficult to form a mental picture of a colour from its C.I.E. coordinates.

Other colour spaces based on different coordinates are also used for the specification of colours, e.g. the Munsell and the Hunter colour spaces. In these systems the white point is located on the central axis of the colour solid and colours are more readily visualized from their coordinates.

Values in any one of the colour spaces mentioned can be converted into values in the other spaces (cf. Esau 1958).

COLOUR MATCHING

A move towards objective measurement of colour is represented by matching procedures, in which the human observer is still used but the colour of the food is matched against standard colours. Two points should be emphasized here:

- Observers for colour testing should be tested for normal colour vision.
- Illumination is of fundamental importance in colour matching.

Metameric colours may match under one, and not under another, illumination. The colours of foods are likely to be metameric with, for instance, standard colours printed on paper (Hand *et al.* 1953). Standard illuminants such as illuminant C can be reproduced approximately by suitable combinations of lamps and filters (Wegener, Thompson, and Fenn 1957; Wright 1958).

Three methods of colour matching which have been used with foods are colour dictionaries, disk colorimetry, and the Lovibond Tintometer.

Colour Dictionaries

Colour dictionaries or atlases are series of charts of graded standard colours which are identified by standard names or by a coding system. The dictionary of Maerz and Paul (1950) is the one most commonly used for foods and it presents the greatest number of standard colours available: 7056 colours on 56 charts. There are seven main groups of hues presented in order of the spectrum. In each group there are eight plates, the first printed on white and the successive ones on deepening shades of grey until the colours approach black. The Maerz and Paul colours have been defined in C.I.E. terms and may also be converted to Munsell values (Esau 1958).

The colour dictionary is used in conjunction with a mask of neutral grey having two openings each the size of an individual colour patch. One opening is placed over the sample and the other is placed over different patches on the chart until a match is achieved.

Colour dictionaries have some notable disadvantages: it is difficult to match colours when the natures of the surfaces are different, e.g. when attempting to match the colour of a glossy wet surface against a matt printed chart. Further, there is a small but definite jump between neighbouring patches on the chart which makes exact matching difficult. Finally, the printed paper standards are not permanent and may deteriorate through exposure. Alternatively, colours may be reproduced on secondary standards, e.g. painted test panels, rings, disks, or plastic models (Southerland 1961).

Disk Colorimetry

Disk colorimetry (Nickerson 1946) is an additive system based on the use of coloured disks having radial slits so that several may be slipped together with portion of each showing. The disks are spun on a central spindle at a speed (about 2700 r.p.m.) great enough to cause the colours to merge into one shade without flicker. A food sample is mounted adjacent to the spinning disk, under controlled illumination, and both are viewed simultaneously through openings in a neutral grey mask (Gould 1953; Yeatman, Sidwell, and Norris 1960). If the sample is not homogeneous in colour it may also be spun. In a more elaborate form of disk colorimeter both disk and sample are viewed through scanning prisms rotated at high speed which perform the function of colour merging. There is also an optical system which brings the sample and the disk together in the field of view. Dupaigne (1953) has described still another form of disk colorimeter.

In conjunction with disk colorimetry a system of colour classification known as the Munsell system is most frequently used. In the Munsell colour space (see Fig. 2) colours are specified according to the three dimensions: *hue*, *value* (lightness), and *chroma* (saturation). There are ten *hues* coded as follows: R, red; YR, yellow-red; Y, yellow; GY, green-yellow; G, green; BG, blue-green; B, blue; PB, purple-blue; P, purple; and RP, red-purple. Each hue is subdivided into ten shades. The scale of *values* ranges from 0 at black to 10 at white. *Chroma* is expressed on an arbitrary scale of intensity of saturation ranging from 0 to as far as 18 for some hues. On each scale the divisions represent approximately equal visual steps.

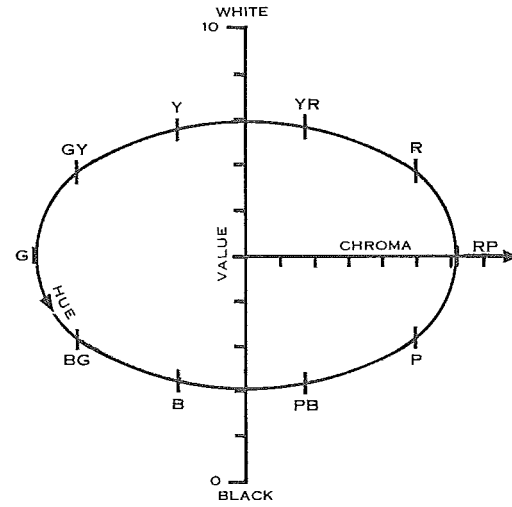

Fig. 2.—Munsell colour dimensions.

When the colour of a sample is matched by Munsell disks, it is specified in terms of the areas of the disks exposed as percentages of the total area. The disks are printed with either a glossy or a matt finish to facilitate matching with samples of varied surface characteristics. Matching with Munsell disks is, however, a tedious procedure and differences between individual observers may be significant (Robinson *et al.* 1952).

An example of the application of disk colorimetry with the Munsell system to canned foods is provided by the American and South African standards for canned tomato juice (United States Department of Agriculture 1958; South African Bureau of Standards 1956). The American Standard for Grade A juice requires a colour containing "as much red as, or more red than, that produced by spinning the specified Munsell colour discs in the following combinations: 65% of the area of disc 1, 21% of the area of disc 2, 14% of the area of disc 3 or of disc 4, or 7% of the area of disc 3 and 7% of the area of disc 4, whichever most nearly matches the reflectance of the product". Disk 1 is a red disk (5R 2·6/13 glossy finish) which has the hue 5

red with a value of 2·6 and a chroma of 13. Disk 2 is a yellow-red disk (2·5YR 5/12 glossy finish) which has the hue 2·5 yellow-red with a value of 5 and a chroma of 12. Disk 3 is a black disk (N1 glossy finish) and disk 4 is a grey disk (N4 matt finish). The comparison is made "under a diffused light source of approximately 250 foot-candle intensity and having a spectral quality approximating that of daylight under a moderately overcast sky and a colour temperature of 7,500° Kelvin ±200°. With the light source directly over the disc and product, observation is made at an angle of 45° from a distance of about 24 in. from the product."

Plastic disks are now available* representing the minimum red colours for U.S. Grade A and Grade C tomato products.

Tintometers

The Lovibond Tintometer is a subtractive colorimeter provided with sets of red, yellow, and blue glass slides to be used as permanent standards. The slides form an evenly graded series from very light tints (0) to deep colours (20) numbered according to their depth of colour. The colour intensities in each series of slides are additive so that the slide of value 10 is equivalent to two or more slides having a total value of 10. The three series are so related that when three slides of equal value are combined and viewed against white, they appear grey or neutral in colour. The instrument makes provision for illuminating the sample with a standard source of white light and viewing it in one half of a field of view, while in the other half of the field an illuminated white surface is seen through the glass slides as selected by the observer. When the colour of the sample is matched it is specified by the values of the red, yellow, and blue slides required in the comparison field, thus: 3·2R+2·5Y+4·1B.

A modified instrument, the Lovibond Schofield Tintometer, is provided with a shading vane which imparts a measurable amount of greyness to either the standard or the sample field. In this instrument no more than two colours, together with the shading device, are used in matching. Some experience indicates that this matching is easier than with three colours in the original Lovibond instrument. Moreover, measurements with the modified instrument can be converted to C.I.E. units.

For examination in the Tintometer, clear liquid samples are contained in standard glass cells and examined by transmitted light while solid samples or opaque liquids are contained in porcelain cups and examined by reflected light. Samples that are not homogeneous may be examined in a spinning cup. With the Lovibond instruments greater difficulty is experienced in matching dark-coloured, than light-coloured, samples. This difficulty is due in part to inherent properties of the human retina.

* From Munsell Color Co. Inc., 2441 N. Calvert St., Baltimore 18, Md., U.S.A.

OBJECTIVE METHODS

Methods of colour measurement and standardization based on visual comparisons are subject to shortcomings of human observers, such as the variability in the reactions of different observers, and in those of the one observer, at different times and under different viewing conditions, and the unreliability of colour memory. There have been many attempts therefore to use colour measurement methods which eliminate the human retina in favour of the photoelectric cell. Livingston (1959) describes a wide range of available instruments. No one instrument has yet been devised by which it is possible to measure all the characteristics of coloured bodies discernible to the human eye.

Spectrophotometry

As already mentioned, a spectrophotometric curve relating wavelength and intensity through the visible part of the spectrum gives a complete physical specification of colour, and it is possible to calculate the C.I.E. values x, y, and Y from the spectral curve by methods based on selected ordinates (Wright 1958).

A number of spectrophotometers suitable for colour measurements on foods are available. Some with optical systems including a prism or grating and a slit are able to select wavelengths in narrow bands (1–10 mμ), while others which depend on filters select broader bands (about 30 mμ). Selected

bands in succession are transmitted or reflected by the sample and the intensity of the resultant light is measured by means of photoelectric cells and appropriate amplifying and metering circuits. Results are generally expressed in terms of percentage transmittance (T) or reflectance (R):

$$T(\text{or } R) = 100I/I_0,$$

where I and I_0 are respectively the intensities of the light transmitted (or reflected) by the sample and a standard. Alternatively, results may be expressed in terms of absorbance (optical density) (A):

$$A = \log_{10}(I_0/I).$$

The standard in transmittance measurements is usually the sample cell filled with pure solvent, while in reflectance measurements a standard white surface of magnesium oxide, magnesium carbonate, or Vitrolite is used.

Manual plotting of spectral curves is a tedious procedure unsuited for routine colour measurement. Instruments are available which automatically record the spectral curve and compute the C.I.E. values, but they are expensive and require skilled operation (Pomerantz, Goldblith, and Proctor 1955; Wright 1958; Livingston 1959).

In most applications of colour measurements to canned foods a complete specification of colour is not required. While it is wise in the first place to plot a spectral curve for the product concerned, an examination of this curve may reveal that measurements at one or a few specific wavelengths will provide an adequate index of colour, where the measure of adequacy is a close relation with sensory evaluation of colour.

Transmittance Methods.—Some foods are transparent or can be made so by filtration or centrifuging. In such products the colour may be assessed in terms of transmitted light. The amount of the colour depends upon the length of the light path, which must therefore be specified in reporting transmittance measurements. In the examination of canned foods transmittance measurements have been applied chiefly to prepared extracts of the natural pigments.

Kramer and Smith (1946) showed that transmittance measurements on the extracted red carotenoid pigments of tomatoes, on the green chlorophyll pigments of beans, on the yellow carotenoid pigments of carrots and corn, and on the red pigments of beetroot, were useful indices of colour in these canned vegetables. Similar procedures applied to canned apricots and peaches (Kramer and Smith 1947) indicated that the transmittance at 665 mμ of an ether extract was inversely proportional to the amount of green pigment and was not affected by the yellow pigments in the fruit. This method with slight modifications has been adopted by the National Canners' Association as a test for maturity in canned apricots and peaches (Townsend *et al.* 1954). With asparagus also, Kramer *et al.* (1949) found a good correlation between sensory evaluations of colour and the transmittance of accetone extracts at 665 mμ.

As an index of the loss of green colour in canned green peas, Gold and Weckel (1959) proposed the determination on acetone extracts of the ratio of the absorbance at 536 mμ to that at 558 mμ. In similar studies on canned and frozen green beans, Shewfelt and Dennison (1959) used the ratio of the absorbance at 665 mμ to that at 556 mμ as an index of chlorophyll *a* retention. These ratios are readily determined with inexpensive spectrophotometers and are suitable for routine quality control.

Estimation of lycopene in tomato products by measuring the transmittance of benzene extracts at 485 mμ or of petroleum ether extracts at 503 mμ has been proposed as a colour index (Kramer, Guyer, and Smith 1948; McCollum 1953) and as a method for detecting adulteration (Kramer 1952; Beerh and Sidappa 1959). However, Robinson *et al.* (1952) have pointed out that lycopene content is not a good index of colour in tomato products, since the visual colour is influenced by the amount and size distribution of the insoluble solids, which carry the pigment.

A different kind of colour measurement on tomato products, the transmittance of the serum fraction at 420 mμ, was used by Hernandez and Feaster (1960) as an index of heat damage during processing.

In the author's laboratory the colour of canned beetroot (acidified pack, pH 4·3) has been assessed, in varietal trials and in tests of the performance of lacquered cans, by measuring the transmittance of aqueous extracts at about 510 mμ (cf. Kramer and Smith 1946). Contents of the entire can are comminuted in a blender and a portion is filtered through a Whatman No. 1 filter paper. An aliquot (usually 5 ml) of the filtrate is made up to 100 ml, and the percentage transmittance is measured against distilled water in a Beckman spectrophotometer using 1 cm cells.

Extensive studies on beetroot colour, using both transmittance and tristimulus measurements, are reported by Lusas, Rice, and Weckel (1960).

To determine the amount of red anthocyanin pigment in strawberry products, Sondheimer and Kertesz (1948) made use of the fact that the difference between the optical density at 500 mμ of an extract at pH 3·4 and that of an extract at pH 2·0 is proportional to the concentration of pigment.

Absorbance measurements at 520 mμ were used by Ponting, Sanshuck, and Brekke (1960) as indices of red colour in grape and berry juices and concentrates.

Meschter (1954) has described a procedure in which transmittance measurements on the product itself, strawberry conserve, are used to calculate a colour index which is correlated with visual appearance. A sample of the whole preserve, containing as few seeds and fibres as possible, is examined in a 1-mm cell. The transmittance at 500 mμ is a measure of the residual red anthocyanin pigment, the transmittance at 420 mμ is a measure of pigment produced by browning reactions, and the transmittance at 650 mμ is a measure of residual turbidity. From formulae and charts, relating these measurements, it is claimed to be possible to set quantitative limits for satisfactory colour in strawberry preserves.

Reflectance Methods.—Although Meschter was able to assess the colour of strawberry preserve by means of transmitted light, most foods are too opaque for this to be possible and their colours can only be measured in terms of reflected light. It is generally considered desirable to avoid the effects of surface sheen or gloss by measuring only diffuse reflectance, e.g. by illuminating the sample from a direction normal to its surface and viewing at 45°, or vice versa. Reflectance attachments designed to measure diffuse reflectance are available for spectrophotometers.

The general procedure for reflectance measurements is to place the sample in a suitable glass or rigid plastic cell filled to the brim and covered with a clear glass slide so as to exclude air bubbles. The cell should be deep enough to ensure that increasing the depth does not change the amount of light reflected. Many foods are not completely opaque but translucent so that some light penetrates to an appreciable depth before reflection. The amount of internally reflected light picked up by an instrument will depend on the diameter of the field of view.

Worthington, Cain, and Wiegand (1949) have described a procedure for making reflectance measurements using the can itself as a sample holder. For grapefruit juice, the least opaque product examined, it was necessary for the can to be at least 3 in. in diameter and 3 in. deep so as to avoid the effects of reflection from the body and the end.

On the other hand, reflectance measurements may be made using shallow cells on a standard white background. In this case the light measured is a mixture of that reflected from the product and light reflected from the background and transmitted through the product. The depth of the cell and the nature of the background must be specified when reporting measurements in this way.

Special problems are presented by foods that are not homogeneous but consist of discrete units or of mixtures of translucent and opaque materials. As already mentioned, spinning of the sample is one method of merging colour differences in the field of view. Devices for spinning samples for instrumental colour assessment are described by Bockian and Hirzel (1958) and Lukens and Creese (1958).

In the Division of Food Preservation, spectrophotometers with reflectance attach-

ments have been used for colour measurements on a number of canned foods. Taylor (1960) examined a series of 23 samples of canned tomato pulp representing different varieties of fruit and picking times. These samples were ranked visually by 12 randomly selected judges in an incomplete blocks design so that rank sums for all samples were calculated over the same number of replicates. The spectral reflectance of each sample was then measured with a Beckman Model DU Spectrophotometer (Beckman Instruments Inc., Fullerton, Calif., U.S.A.). The mounting of the reflectance attachment on this instrument was modified so that the sample was viewed from below through $\frac{1}{8}$ in. thick "Perspex" which formed the bottom of a cell 2 in. in diameter and $1\frac{1}{2}$ in. deep. A block of magnesium carbonate, also viewed through "Perspex", was used as a standard. Reflectance values measured at intervals of 10 mμ from 400 to 700 mμ were plotted and the C.I.E. tristimulus values X, Y, Z calculated from 30 selected ordinates.

An attempt was then made to find a useful single value index of tomato pulp colour. The ratio $(1{\cdot}02X-Y)/(Y-0{\cdot}847Z)$ was calculated since this ratio is related to the Hunter hue ratio a/b (see below). The tomato pulp samples were ranked according to the magnitude of this ratio and the ranking was compared with the visual ranking. The rank correlation coefficient ($-0{\cdot}726$) was very highly significant.

Further simplification was sought by using reflectance values at only three selected wavelengths, 440, 550, and 620 mμ, which correspond to the peaks in the spectral distribution curves of the C.I.E. reference stimuli (Z), (Y), and (X) respectively. When the reflectances (R) at these three wavelengths were combined in several arbitrary ways, the ratio $R_{620}/(R_{550}-R_{440})$ appeared to be the simplest formula which placed the samples approximately in order of visual ranking. Again the rank correlation coefficient ($-0{\cdot}615$) was very highly significant. This restricted study suggests therefore that either of the objective measures mentioned could be useful for comparing the colour of tomato pulps and for defining limits of satisfactory colour.

As an index of colour in strawberry jellies, Decareau, Livingston, and Fellers (1956) used the C.I.E. Y value calculated from spectral reflectance data. The jelly samples were examined in a white enamelled curvette 40 mm in diameter and 9 mm deep and the reflectance was measured with a Beckman Model DU spectrophotometer.

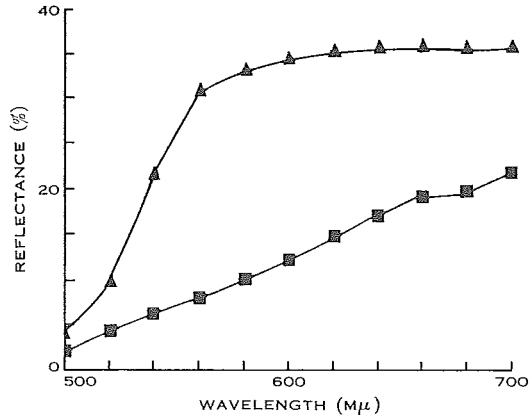

Fig. 3.—Reflectance of orange juice concentrates.

The Beckman Model B spectrophotometer with reflectance attachment has also been used in this Division for objective assessments of colour changes. For instance reflectance measurements at 530 mμ have provided a useful measure of pink discoloration in canned pears. On the other hand this instrument failed to measure satisfactorily a pink-brown discoloration in green bean purée that was readily detectable visually.

Gohain (1959) used the Beckman Model B instrument to obtain the reflectance curves shown in Figure 3 for a series of orange juice concentrates stored at different temperatures. The samples were contained in metal cups $\frac{3}{4}$ in. in diameter and $\frac{5}{16}$ in. deep, carefully covered with glass coverslips so as to eliminate air bubbles. The curve indicating high reflectance was given by samples with normal bright orange colours, while that indicating low reflectance was given by samples which were discoloured brown. In a case such as this, complete specification of the brown colour serves little purpose. It is obvious that a useful index of browning would be provided by a single reflectance measurement, at any one of a number, or over a range, of wavelengths, such as could be made with a

simple filter photometer. Thus Kefford, McKenzie, and Thompson (1959) were able to measure browning in canned orange juice by means of an EEL Reflectometer (Evans Electroselenium Ltd., Harlow, Essex, U.K.) using a minus blue filter. Samples of normal colour gave reflectance readings above 30% while those showing marked brown discoloration gave readings under 20%.

It may be pointed out here that any filter–photocell combination may be used to give an arbitrary index of colour but it may not be possible to relate the data to standard specifications.

Tricolorimeters

Photoelectric instruments, called tricolorimeters, have been designed in an attempt to measure directly the three C.I.E. tristimulus values required to specify a colour. Three filter–photocell combinations are used having spectral sensitivity curves similar to the spectral distribution curves of the C.I.E. reference stimuli (X), (Y), (Z). Evaluation of the colour of a sample involves three measurements, one for each filter–photocell combination. The photocurrents are amplified to give readings which are related to C.I.E. values.

Tricolorimeters are limited, however, by the fact that available filter–photocell combinations do not reproduce perfectly the desired tristimulus functions. They perform best when comparing colours that are close together in the colour space, and therefore they are usually standardized against a calibrated reference panel of porcelain enamel of a colour similar to the samples to be examined.

These instruments measure diffuse reflectance, and samples are presented in a manner similar to that described in the preceding section.

Hunter System.—One of the most successful tricolorimetric systems for measuring food colours was devised by R. S. Hunter using tristimulus amber, blue, and green filters together with carefully chosen photocells and three separate metering circuits. Several instruments are available incorporating the Hunter system and they are widely used in the U.S.A.

Measurements according to the Hunter system locate colours in a colour space

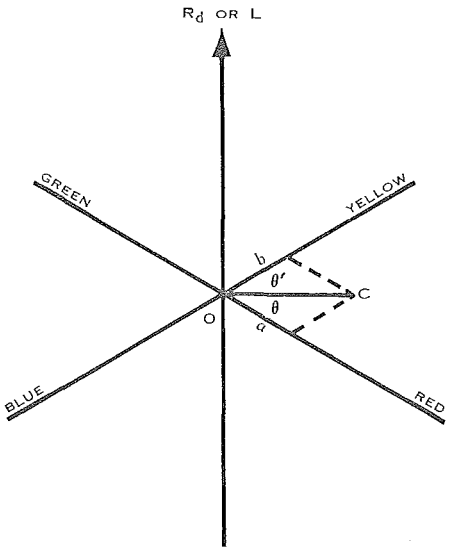

Fig. 4.—Hunter colour dimensions.

which is not identical with the C.I.E. colour space but is related to it (see Fig. 4). The chromaticity plane is defined by dimensions a and b. The white point is at the origin; positive a values indicate redness, and negative a values greenness, while positive b values indicate yellowness and negative b values blueness. For a particular colour C represented by point C in Figure 4, a measure of the hue or dominant wavelength is given by the ratio a/b or by one of the angles $\theta = \tan^{-1}(b/a)$ or $\theta' = \tan^{-1}(a/b)$. The saturation of colour C is given by the distance from the colour point C to the white point, which is $\sqrt{(a^2+b^2)}$.

The lightness dimension perpendicular to the chromaticity plane in the Hunter system is either diffuse reflectance (R_d) or, with a different circuit in the instrument, visual lightness (L) in perceptibility units. The relations between these quantities and C.I.E. Y values are given by:

$$R_d = 100\,Y,$$
$$L = 100\sqrt{Y} = 10\sqrt{R_d}.$$

The a and b values will be different according to the circuit used and they may be designated a_{R_d}, b_{R_d}, or a_L, b_L.

Hunter values may be used to calculate the total colour difference (ΔE) between a

sample and a standard in visual perceptibility units, the so-called National Bureau of Standards (NBS) units, thus:

$$\Delta E = \sqrt{[(\Delta L)^2+(\Delta a)^2+(\Delta b)^2]}.$$

Instruments based on the Hunter system have the disadvantage, associated with the use of barrier-layer photocells, that it is difficult to obtain accurate measurements of dark colours which give low intensities of reflected light. More sensitive measurements of such colours are possible in tricolorimeters which incorporate vacuum photocells (Livingston 1959).

Applications of Tricolorimeters

More attention has been given to objective colour measurement in tomato products than in any other canned food, particularly in the U.S.A. where the aim has been to develop instruments which would give colour values, preferably single values, closely correlated with visual colour scores awarded according to the U.S. Department of Agriculture Standards for Grades. The usefulness of the Hunter system for this purpose has been demonstrated by many workers (Kramer 1950; Younkin 1950; Buck and Sparks 1952; Friedman, Marsh, and Mackinney 1952; Robinson *et al.* 1952; Asselbergs, Wyszecki, and Mohr 1961; Kramer and Twigg 1962). Some believe that the L or R_d dimension can be neglected in the colours of tomato products and that useful single-value indices of colour are provided by certain measures of hue such as the ratio a/b or the expression $(3b-15)/a$. Others, however, maintain that it is necessary to use all three dimensions to specify tomato colours adequately. For instance, Yeatman, Sidwell, and Norris (1960) propose a Tomato Colour Index given by $(2000\cos\theta)/L$, where θ is $\tan^{-1}(b/a)$. A special tricolorimeter has been designed to measure this index.

The Hunter system was applied to the measurement of colour in orange juice concentrates by Huggart and Wenzel (1955) who showed that the a value alone was a satisfactory index of colour quality. Similarly, Schmidt and Idler (1958) found the Hunter a value to be a suitable index of colour in canned salmon. With freestone peach purées, Wilson *et al.* (1957) found the closest relation with visual colour scores when a, b, and L values were used in a multiple relationship, but Leonard *et al.* (1961) used the a value alone as a measure of the colour of clingstone peaches. A close relation between the hue ratio a/b and the extent of conversion of chlorophyll to phaeophytin in canned green peas was established by Gold and Weckel (1959). Grunewald and Gutschmidt (1959) compared spectral and tricolorimetric methods for the measurement of colour in canned peas and used their findings to devise a colour chart.

Four tristimulus colorimeters were evaluated by Livingston, Tan, and Sabry (1959) for their ability to provide colour values related to visual scores and to pigment and browning measurements in strawberry preserves. The instrumental value giving the closest relations was the hue angle $\tan^{-1}(a/b)$ in the Hunter system. Worthington (1961) examined the correlations between panel assessments of the colour of canned plums and 18 objective colour indices derived from measurements on three colorimeters.

SUMMING UP

The ideal situation in the field of colour measurement is one in which quantitative specifications of colour can be written into quality standards in terms of universally applicable standard values. It follows that colour measurements made on different instruments, in different laboratories, by different observers, at different times must be convertible to the standard values for comparison between themselves and with the specification. This ideal situation has not yet been achieved.

A system of standard values, the C.I.E. system, exists but it is difficult to use directly to specify food colours. The Munsell and Hunter systems have some advantages in this respect.

Critical comparisons of the performances of colour measuring instruments have been made by Livingston, Gersten, and Shore (1958) who examined two spectrophotometers and two tricolorimeters, and by Little, Chichester, and Mackinney (1958) who studied five spectrophotometers and three tricolorimeters. Although there was substantial agreement between these instruments there were some significant discrepancies, even between those of the same design. Because of such discrepancies it

may be misleading to convert instrumental readings to standard values (e.g. C.I.E. values) and then to compare them with values measured on a different instrument. At the present stage of the subject it is preferable to report colour measurements as readings on a specific instrument under stated conditions of sample presentation.

Colour measuring instruments have better "colour memories" than human observers which means that a particular instrument can be used to compare values measured at one time with those measured at another.

Since, in cannery quality control, colour measurements will generally be made on one instrument, some of the difficulties mentioned will disappear. Single-value colour indices will be adequate measures of colour for many canned foods. Because of the psychophysical nature of colour, the criterion of performance of an instrument or a colour index must be a close relation with visual colour assessments made under statistically adequate conditions.

One aspect of this subject that has been inadequately explored is the permissible tolerance in colour values within quality grades for particular foods. It is reasonable to suggest that the level of accuracy required in colour measurements on foods is not as great as in some other fields. Wider tolerances are surely allowable when assessing the colours of foods for acceptability than, for instance, when matching the colour of a paint or a fabric.

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The Storage Life of Frozen Foods

By G. C. Walker

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THE past decade has witnessed the development of the "quick frozen food" industry in Australia. The industry is rapidly expanding, as shown by the increase in production of frozen vegetables from 14 million lb in 1957–58 to 23 million lb in 1959–60 and 47 million lb in 1961–62. This rapid expansion is an obvious sign that "quick frozen" products are highly acceptable to the consumer. However, as production continues to expand, increased competition demands products of higher and consistent quality. Only by selection of suitable raw materials, and care in their processing and subsequent handling can this quality be achieved.

Storage Life

Despite all precautions taken, frozen foods do not have an indefinite storage life and off-flavours will develop after various periods of time depending on the product and its storage temperature. In order to obtain more precise information on storage life, work is being carried out at various research centres in Australia and other parts of the world. The most complete set of data so far obtained are those from the Western Regional Laboratory of the United States Department of Agriculture, some of which are summarized in this article. Until results are obtained for Australian conditions these data provide a useful guide.

Rate of Spoilage

The rate of food spoilage was found to be temperature-dependent and doubled or even trebled with every 5°F rise in storage temperature. Thus a product with 12 months' storage life at 0°F would have an equivalent life of 6 months at 5°F, 3 months at 10°F, only 3 weeks at 20°F, or 5 days at 30°F. The life of products stored under conditions of fluctuating temperature, in the range −10°F to +25°F, was found to be the same as those maintained at a steady temperature corresponding to the true average value of the functions. Thus regular temperature fluctuations of −10°F to +10°F had the same effect on food flavour as storage at a constant temperature of 0°F.

The Storage Life of Frozen Foods*

Product	Maximum Storage Life at the Temperature Stated	∂_5†
Peaches—syrup packed, including ascorbic acid	1 year at 0°F	2–3
Strawberries—sugared, sliced berries packed in composite cartons	1 year at 0°F	2–3
Raspberries—individual fruit frozen	3 years at 0°F	2–3
Boysenberries—individually frozen and packed in composite cartons	1 year at 0°F	2
Sliced green beans	1 year at 0°F	2
Peas	10 months at 0°F	2
Spinach	7 months at 0°F	2–3
Frozen fried chicken	2 months at 0–10°F	2
Ready-to-cook cut up chicken	6 months at 0°F	1½
Turkey dinner and pies—sauce covered sample—turkey fat not used in sauce and gravy	6 months at 10°F	2–3

* Compiled from publications of the Western Regional Laboratory of the U.S. Department of Agriculture.

† Increase in rate of deterioration per 5°F rise in temperature.

These findings also apply to irregular temperature fluctuations, thus 1 week at 25°F followed by 6 months at 0°F had the same effect as 6 months at 0°F followed by 1 week at 25°F. Thus the effect of various temperatures during storage life is a strict addition of the effect of each individual temperature and the time for which it persists.

Equivalent Storage Time

The above findings also show that it is possible to calculate the equivalent storage time of a product at 0°F for any known conditions of handling and storage. To obtain this 0°F equivalence, in practice, very precise temperature records are required. However, simple instruments are now available which automatically record these fluctuations. The accompanying Table lists the maximum storage lives of several frozen products. While these values were obtained under American conditions they serve as a useful guide. If these 0°F equivalent storage times are exceeded consumer complaints are likely. Since the storage lives of vegetables listed in the Table do not exceed 12 months equivalence of 0°F, produce delivered to the retail cabinet is, for some parts of the year, close to the end of its storage life. Any elevated temperatures at this stage will almost certainly lead to off-flavoured products: it is therefore *imperative that temperatures of 0°F or lower be maintained.*

While fluctuating temperature, of itself, has no effect on off-flavour development it gives rise to undesirable physical reactions which detract from the appearance of the product. Of greatest importance in this regard is migration of moisture, which leads to frosting of the packages and desiccation of the product. In addition, sauces and gravies in frozen prepared foods break down at rates far in excess of those at the average steady temperature.

In summary, this work emphasizes the need to maintain correct temperatures at all stages of storage and distribution of "quick frozen foods", to ensure that attractive produce of good flavour is available to the consumer throughout the year.

Notes

Postgraduate Training for Research in Food Science

The Nuffield Foundation has announced its intention of awarding a number of scholarships to encourage science, medical, and veterinary graduates to acquire wider training in fundamental research in food science. It is stated, by way of explanation, that while the present position appears reasonably satisfactory as regards the training and supply of food scientists and technologists to carry out standard procedures, the numbers available for fundamental research in food science are entirely inadequate.

For the present the Nuffield Foundation is prepared to offer annually up to five research scholarships to science graduates and up to three for graduates in medicine. At a later date, the Foundation contemplates offering senior research fellowships to selected postdoctoral candidates. The present awards may be held for periods of up to four years. Successful candidates will be encouraged to study for appropriate advanced degrees, such as a Ph.D., in the fields of food science, toxicology, and pathology. The value of the awards will range from £650 to £1200 stg. per annum if taxable, or their equivalent tax free. Family allowances are available, and it is stated that applications for grants for additional expenses connected with a scholar's research programme will receive sympathetic consideration. A scholarship holder is not permitted to hold any other award concurrently, or to undertake any other work without the permission of the Foundation. The scholarships are open to men and women, preferably under the age of 35 years, who hold a science, medical, or veterinary degree of a U.K. or other Commonwealth university. Forms of application are obtainable from the Director, Nuffield Foundation, Nuffield Lodge, Regents Park, London, N.W.1.

Science and Industry Day 1962

On November 26, 1962, the Division of Food Preservation held a Science and Industry Day for executives from organizations in the food industry that have given direct financial support to the work of the Division.

In welcoming the guests the Chief of the Division, Dr. J. R. Vickery, said that he greatly appreciated their interest in the Division and the practical expression they gave to it. One of the aims of the meeting was to acquaint industry with the contributions of the Laboratory to food science and technology. It was also highly important for the research scientist to learn the problems of the industrialist, and he hoped that the executives present would contribute freely to a discussion on the research needs of the Australian food industry.

Current Activities

The opening session of the conference was devoted to a series of short lectures on some current activities of the Division, and each was followed by questions and discussion. Speakers told of research on processed foods and vegetables, having for its aim the improvement of colour, flavour, and texture. One group is engaged in applying modern chemical techniques to the study of volatile flavours in pineapples and other fruits.

The Division has done a great deal of work on tinplate food containers: it has studied the properties of electrolytic tinplate and internal lacquers for cans, and the information obtained has been made known to the food industry. Sulphur staining and pitting corrosion of tinplate figure prominently in current investigations.

In the field of post-harvest technology of fruit and vegetables the laboratory is studying problems associated with the introduction of cartons and bulk bins, in which apples and pears are being exported from Australia to the United Kingdom. Research has greatly reduced the wastage of bananas, tomatoes, peas, and beans during unrefrigerated transport by rail, and mould attack on citrus fruit has been brought under control.

The microbiologists are studying the relations between organisms which cause food spoilage and food poisoning and their environment. The goal of the research is the prediction of the behaviour of an organism under specific physical and chemical conditions.

The Division is engaged on a number of physical, microbiological, and technological studies of the chief methods of preserving food, and it has a small group investigating the use of ionizing radiations for the preservation of food, and the disinfestation of fruit from Queensland fruit fly.

Research Needs of Industry

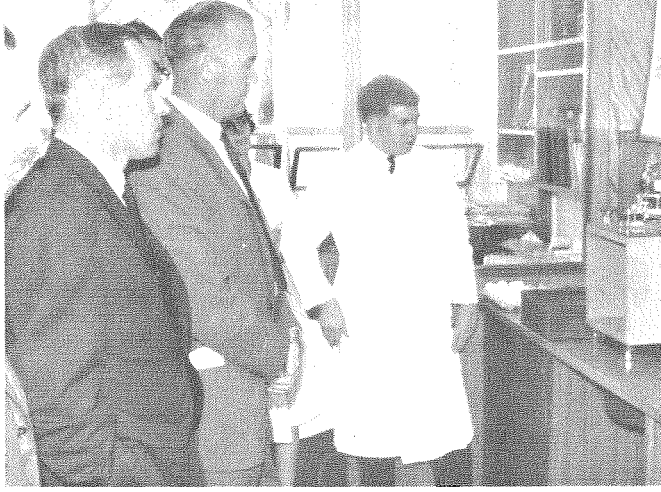
In opening a discussion on the research needs of the Australian food industry, Dr. Vickery pointed out that every year saw a greater application of science and technology. If the industry is to maintain its efficiency and its competitive position on world markets it must be prepared to make the fullest use of research findings.

In Australia about two-thirds of the expenditure on food research comes from Government sources and the greater part of this goes to C.S.I.R.O. However, expenditure on food research represents only 0·1% of the sales value of food, compared with a total expenditure on research in all fields amounting to 0·6% of the gross national product. The amount spent on food research by Australia is less than one-third of that in other advanced countries.

Dr. Vickery invited his hearers to give their views on the magnitude of the Australian effort in food research, and the respective roles of industry and Government in providing finance and carrying out the work. Comment would be welcomed on the research programmes of the Division and on the methods used to communicate research results to industry.

Provision of Finance

In the discussion on finance for research it was pointed out that research associations had not been invariably successful in Australia. A levy on an industry had proved a more reliable source of research



Members of the Animal Products Group demonstrate to visitors the use of a height measuring micrometer to obtain the quality of the thick white gel in eggs—an important factor in the assessment of quality.

funds in a number of cases, namely wool, wheat, dairy products, and beef. In Japan it was the practice to give taxation rebates of double the amount spent on research—over an extremely wide field. Some speakers considered this might be an effective way to promote the expansion of research by Australian industry.

Communication of Research Results

Many visitors stated that an annual science and industry day was of great value, but conferences at less frequent intervals were needed to make research results known in greater detail to selected sectors of the industry.

Representatives of several branches of the food industry stated that the research carried out in the Division met their needs very well. Some stated they would like to be informed of projected investigations, and suggested that research programmes be announced annually. Executives were, of course, greatly interested in the results of research, but they could afford time to read brief statements only. Dr. Vickery stated that accounts are published in the "Food Preservation Quarterly", and brief announcements are made in "Foodpres News", which is issued 5–6 times each year. He strongly emphasized that communication of research results was much more effective when industry had well qualified technical staff. Several speakers favoured the setting up of product advisory committees and Hobart, Brisbane, and Sydney were suggested as suitable centres. R.B.W.

NEWS FROM THE DIVISION OF FOOD PRESERVATION

CITRUS WASTAGE RESEARCH

Extensive alterations and additions are being made to the Citrus Wastage Research Laboratory at Gosford, N.S.W.

This Laboratory, operated jointly by C.S.I.R.O. and the New South Wales Department of Agriculture, was opened in October 1948 in the citrus packing house of the Gosford Bulk Loading Rural Co-operative Society Limited (now Sungold Co-operative). At that time it had some 1400 sq. ft. of floor space in the packing shed, but in 1949, a storage shed was erected on nearby land. Until 1955 the Laboratory staff devoted most of its attention to the control of wastage in oranges caused by green mould, and to studies designed to improve the keeping quality of citrus fruit, in which fields it has done notable work.

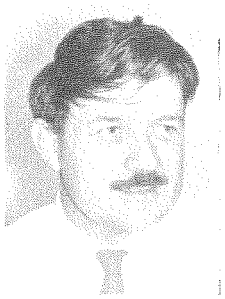
In 1955, following outbreaks of Queensland fruit fly in inland citrus districts, urgent investigations were commenced on the sterilization of oranges against Queensland fruit fly. Its staff successfully devised two methods—storage at 31°F for 14 days, and fumigation with ethylene dibromide. The new work entailed alterations to the former storage shed, the building of a unit for breeding fruit flies, and additions to the staff. Funds for these investigations were contributed by the Commonwealth Government, the States of New South Wales, Victoria, and South Australia, and the citrus industry.

Early in 1962 a decision was taken to extend the fruit fly sterilization investigations to citrus fruit other than oranges, and also to test the application of the process of sterilization by cold to fruit fly in pears. The Sungold Co-operative, which has adopted

a helpful attitude to the Laboratory since its inception, has been obliged to take over the original space made available but it has generously made land available for extensions to the nearby building, erected in 1949 as a storage shed. The latter has been converted into laboratories, offices, and stores, and the extensions to it will house equipment for experimental processing (washing, dipping, and waxing) of citrus fruit.

NEW LEADER FOR PHYSICS SECTION

Mr. J. Middlehurst, formerly a Senior Research Officer at the National Standards Laboratory, who has joined the Division of Food Preservation as leader of its Physics Section, has been a member of C.S.I.R.O. since 1950. He has done a great deal of research on the measurement of temperature, and the application of modern instrumentation to chemical detection and physical measurement. Mr. Middlehurst has had a wide experience also of the problems involved in the transfer of heat and moisture, which form an important part of the work of the Division of Food Preservation.



MR. L. J. LYNCH HONOURED

Mr. L. J. Lynch, Officer-in-Charge of the Canned Foods Section of the C.S.I.R.O. Division of Food Preservation, was guest of honour of the Hawkesbury Agricultural College Food Technology Association at a dinner at the N.S.W. Leagues Club on Wednesday, November 28, 1962. The occasion marked the tenth anniversary of the graduation of the first diplomates in Food Technology from the College.

Mr. H. R. Richardson, former Principal, and Mr. B. Doman, present Principal, of the College spoke of the part played by Mr. Lynch in encouraging the establishment of the Food Technology course, in drawing up the syllabus, and in planning the facilities, and his continued keen interest in the course as external examiner. Mr. Graham Thompson, a member of the first graduating class, paid tribute to Mr. Lynch's unfailing helpfulness to all Hawkesbury Food Technology diplomates throughout their careers, and then presented him with an electric razor and a handsome desk set, in tooled leather.

NEW PUBLICATIONS OF THE DIVISION

Copies of the following publications may be obtained from the Librarian, Division of Food Preservation, Box 43, P.O. Ryde, N.S.W. (Tel. 88-0233)

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