been arrived at. Solution of this problem is difficult since in addition to non-tendering, other considerations such as brightness, affinity and fastness have to be taken into account.

In the face of several problems regarding the existing dyes which are still unsolved one may doubt the wisdom of the search for new dyes. However, some of the shortcomings of the group of vat dyes indicated in this article will justify continued researches in the way of making new and better dyes to suit different requirements. Fresh impetus has been given to research in chemistry of dyes by the availability of the newly discovered raw materials from coal-tar and petroleum industry such as the polycyclic compounds—pyrene, fluoranthrene, chrysene, etc. and thiophene (synthesised from butadiene). The use of these products may lead to the discovery of cheaper and useful vat dyes. In fact, there has been considerable activity in search for new vat and other dyes mostly confined to the industrial laboratories but the results of such investigations are given little publicity. However, research on technical aspects in the field of dyestuffs should go hand in hand with research on fundamental theoretical problems. For this reason, research in chemistry of dyes should be given its due importance in the university research laboratories also.

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Radiation—Processing of Foods

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IT is well-known that conventional means of heat processing irreversibly alter the flavour, colour and texture of many foods. Much research has been conducted in recent years to ascertain whether it is possible to minimise such adverse effects of heat processing. There is promise in the methods that involve utilisation of several of the radiations of the electromagnetic spectrum. Progress in this field has been substantial during the last decade partly because of the development of new equipment by physicists and electrical engineers.

What all this may mean to food industries today, cannot yet be stated fully. Canned foods may be expected to be remarkably improved, since overcooking that results from the heat processing needed to destroy spoilage organisms will be obviated. They probably would be cooked to a degree determined by palatability considerations. Other food items having relatively short periods of acceptable quality may have them extended. In addition, vast uncharted fields for the application of these radiations are daily being opened by developments in widely varying types of food processing.

Types of Radiations and Their Uses :—

All electromagnetic radiations consist of electric and magnetic vibrations of high frequency. Depending on differences

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in the frequency of the waves or in the energy of the wave packets, their location in the electromagnetic spectrum will vary. The main radiations are discussed here: —

1. *Sonic and ultrasonic vibrations :—*

Sonic energy is energy in waveform comprising alternate, regularly spaced compressions and rarefractions at frequencies as high as 20 kilocycles per second. Above this frequency the energy becomes ultrasonic. These radiations occur in the low frequency range of the electromagnetic spectrum and are usually produced in the laboratory by a radio oscillator or a transducer, consisting of a device for converting electrical or mechanical energy to sonic energy. The waves are carried from the transducer to their point of application in a coupling medium such as oil or water.

In the laboratories, ultrasonics are doing seemingly impossible jobs; for example: —

(i) homogenizing and emulsifying (Milk, babyfoods, chocolates, etc.).

(ii) precipitating solids from liquids (as in clarifying fruit and vegetable juices).

(iii) gaging liquid levels in sealed containers (of beverages, soups, etc.).

(iv) catalysing chemical reactions (such as fermentation), ageing of wines, etc.).

(v) cleansing metal parts (as in degreasing of food processing equipments).

The bactericidal effect of ultrasonic waves is known and several theories have been put forward regarding this action of these waves. According to one view, micro-organisms are disrupted by intense sonic vibrations. Another school holds that bactericidal effect of high frequency sonic waves is not specific and is confined to the heating effect resulting in the denaturation of the protein components of the cell. However, cell death is more rapid in a field of high frequency waves than in the thermal control. This is considered to be due to the activation of proteolytic enzymes. Large-scale use of sonic or ultrasonic vibrations for sterilization of packaged foods is contra-indicated because of technical limitations, including barrier effects of packaging materials.

2. *Radio Waves :—*

The next large group of frequencies covers the range of radio frequencies. There are two distinct forms one could think of: the induction heat that can be developed in electric conductors and the dielecric heat, where the product to be heated is a non-conductor. The food plants are therefore concerned with the dielectric heat and practically all foodstuffs can be through-heated by this means. Here the product is carried on a belt between a pair of metal plates that are charged with high frequency voltage. It is largely frictional heat that is produced and arises from the fact that each molecule of the foodstuff is being repeatedly stressed or distorted by the high voltage field. The direction of the electrical stress reverses with the energy alterations of the high frequency voltage. Since we are moving by this distortion a tiny mass of material through a short distance, the repeated distortion of the particles constitutes work and this work appears as heat. The amount of heat created by each voltage reversal is small, but in dielectric heating these reversals are occurring at a high rate of 27,000,000 times per second. It is this fact that accounts for the rapid temperature rise throughout the mass of the foodstuff.

The important thing about dielectric heat as compared to conventional heat is its ability to convert each interior particle of the foodstuff into a tiny heating element which experiences heating within itself and also can transmit this heat to adjacent particles or surfaces. The efficiency of the generator is also high, because substantially all of the generator output appears as heat in the foodstuff and very little is lost as stray oven heat.

Electronic heating has been successfully employed to food products for their dehydration, cooking, melting, roasting, deinfestion, baking, defrosting and mold inhibition.

(i) *Dehydration* :—By using radio frequency, it is possible to dehydrate food materials uniformly without obtaining case-hardening which usually results when conventional means are used. Dehydration of compressed cabbage blocks and potato blocks and milk and milk products *in vacuo* with high frequency has yielded excellent results with less time required for dehydration. In addition, considerable reduction in enzyme activity prevents discoloration or other undesirable changes of enzymatic origin which occur during the processing.

(ii) *Blanching* :—Several vegetables have been blanched successfully by means of radio frequency energy on a laboratory scale. Favourable results with a minimum loss of soluble nutrients were obtained. Large-scale continuous equipment for the process is still in the developmental stage.

(iii) *Sterilisation* :—Mode of sterilisation by radio frequency energy is still open to discussion. Whether the lethal effect on micro-organisms and insects is a specific effect *per se* or is an effect caused by heat generated is unknown; extended research is necessary in this field.

Experiments were carried out on the effect of dielectric heat on meat to be frozen with the object of destroying the virus that causes hoof and mouth disease. It is reported that this virus could be destroyed by dielectric heat without adverse effects on the texture and flavour of meat.

Table wines were successfully pasteurised by radio frequency energy in less than 4 seconds. the shortness of the time required was attributed to the instant penetration of heat into the cells of micro-organisms and to the possible breakdown of the cells by molecular dipole rotation. Improvement in flavour and colour were also mentioned. The application may be extended to fruit juices.

It has been reported that radio waves can be utilised to kill insects, larvæ and pupæ of insects feeding on stored products. The irradiated grains sprout more readily and grow faster than untreated grain.

(iv) *Defrosting* :—The defrosting of frozen foods has been considerably accelerated and can be done in a few minutes. From the health stand-point electronic defrosting is therefore a means of securing an exceptionally low bacterial count, due to short exposure to atmosphere.

(v) *Miscellaneous uses* :—The effect of high frequency low powered generator on various fruit and vegetable crops for very short time was studied. It is found that such crops keep better than controlled crops, lose less nutritive value and Vitamin C. The irradiation also accelerates naturing of fruits.

3. *Infra-red radiation* :—

This portion of the spectrum lies between the radio waves and visible region. Speed of infra-red heating is considerable owing to the fact that the temperature differential between the source and material to be heated is great (*e.g.* the usual difference is about 2300°C.)

Infra-red lamps use tungsten wire filaments, their primary function being to produce heat with light as by-product. This is done by reducing the filament temperature from a Mazda lamp operating temperature of 2698.9°C. to a drying temperature of 2298.9°C.

Infra-red radiation is chiefly used for dehydration purposes, though other minor uses are known. Banks of infra-red lamps controlled accurately with ease by rheostats were used on a pilot plant basis for drying numerous food products at relatively low temperatures with excellent results.

An infra-red toasting unit has been employed to treat wheat germs in a flour milling system. Using this unit was said to make possible the inactivation of fat-splitting enzymes and to change the germs to a friable condition without substantially altering the vitamins or mineral components. By this means, a sterile product of improved palatability and keeping quality can be obtained.

Infra-red radiation has been developed as a practical method for protecting fruit and vegetable crops from frost damage.

4. *Ultra-violet radiation :—*

The ultra-violet region of the spectrum extends beyond the visible portion up to the very soft X-rays. They are produced by high voltage low pressure lamps. The recent development of fluorescent lamps is indicative of the new methods used for producing such radiations.

Ultra-violet radiation has found wide use in food industry due to its germicidal action. The wave-length for maximum germicidal action was found to be in the vicinity of 2660°A. In application of ultra-violet radiation to food preservation and processing, ozone has a bactericidal effect and commercial lamps producing a maximum amount of irradiation also produce some ozone by reacting with the oxygen of the air, thus increasing the bactericidal effect of the radiation.

The use of ultra-violet light at various points in dairies and food plants has been found to have an effective check on the bacterial quality of the product. Equipment for pasteurising milk by exposing it to ultra-violet lamps in thin films on the surface of revolving cylinders has been described. Such equipment may also have application in pasteurisation of fruit juices.

In the icecream industry, ultra-violet light has been used when the mix is cooled on a surface type cooler. Under such conditions bacterial count may be reduced by more than 60%. It is also used to reduce the bacterial count on the surface of meat prior to its freezing.

In addition to these, ultra-violet light has been successfully used in poultry industry to speed up growth in chicks, and reduce mortality in brooder houses, in agriculture and in breweries by maintaining an effective check on airborne infections.

The "Tenderay" process of ageing meat is another application of ultra-violet radiation. By this process, meat is aged more rapidly than by conventional means. The speed of bacterial decomposition is reduced so that a longer storage time is obtainable.

Yet another important use of ultra-violet light is for the activation of pro-vitamins D. The most common procedure is to irradiate milk in a thin film. This procedure is one requiring careful control because excessive irradiation may produce off flavours.

In poultry husbandry, the growth of

young birds is accelerated by activation of provitamins D by exposure to ultra-violet light.

Ultra-violet light has also been used for the detection of infected or washed eggs. The advantage of the method is that it permits very rapid checking of a large number of eggs.

5. *X-Rays :—*

X-rays also known as "gamma rays" are among the oldest known of the artificially produced radiations. They are produced when electrons or cathode rays from an X-ray tube impinge on a suitable metallic target. But the method is highly inefficient since only a small portion of the energy input appears as X-ray radiation, the rest being dissipated as heat. The X-rays so produced are called soft, hard, or supervoltage X-rays depending upon the accelerations of the electrons which go to produce them and their ability to penetrate into matter.

The future of the process of X-ray sterilisation of food is promising in spite of hurdles yet to be overcome. The penetration of X-ray radiation without production of heat and with its potential for complete sterilisation gives it a great advantage over other types of radiations.

The mechanism of X-ray destruction of bacteria is explained by two theories —"the target" theory and the "indirect hit" theory. According to the target theory a photon directly hitting a bacterium may cause disruption of the nuclear function and death. A hit in the area less vital than the nucleus may cause injury instead of death. This may result in interference in normal cell function. For example, reproductive capacity may be destroyed.

Besides actually hitting the bacterium there is a possibility of a photon passing close to it, disturbing atoms and molecules and knocking off molecular targets. These latter particles thus acquire some of the energy of the electron and they may be, in some cases, highly reactive free radicals which may diffuse and thereby extend effect of the electron well beyond its traversed path. This is called the "indirect hit" theory.

It has been found that ground meat could be sterilised by irradiation with super voltage X-rays as X-rays produced at high voltage are able to sterilise food materials without raising the temperature to an appreciable extent. This may appear to be an efficient method of cold sterilisation, but the time required and low efficiency from a power stand-point appear to make such a method one of questionable application for the food industry, where high speed operations and economy are essential.

X-rays are employed in the fluoroscopic evaluation of fruits. For example, when a substance to be examined is placed between an X-ray source and a fluorescent screen, the variations in the density of the substance are outlined on the screen by variations in the degree of fluorescence. The advantages are, speedy examination and low equipment cost compared with the value of the fruit examined. As a means of determining metallic contaminants in foods, flouroscopy has proved useful in equipment whereby foods and food products in packages may be conducted past a flouroscopic screen and viewed by an operator. One disadvantage in this use, however, is the eye strain which has been reported to occur with some operators.

It has been demonstrated that when pear shoots are exposed to X-ray radiation before grafting to a mature tree, they bring forth exceptionally large, abnormally pointed fruits which ripen from three weeks to a month after other pears in the region. Recently it has been announced that a rapid ageing of cheese is possible with the use of X-rays.

6. *Cathode rays :—*

Artificially produced electrons or β-particles are called cathode rays. By irradiating with electrons directly without an intermediate target, one realises a greater portion of electron efficiency, since there is no heat dissipation as in X-rays. It has been stated that one can obtain the same biological effect with cathode rays in 1/500th of the time needed with X-rays, though their penetration into matter is much less than that of X-rays of equivalent potential.

Cathode ray machines produce beams of electrons that can be accelerated with + ve increasing voltage. It appears that three types of accelerators, the electrostatic or Van de Graaff generator, resonant transformer and capacitron have been developed to a point where they can be readily considered for irradiating foods.

Electrons so generated are capable of destroying bacteria in a relatively short period of time. The dosages necessary to sterilise different organisms varied widely. Regardless of this, it is possible to destroy micro-organisms of all kinds with great rapidity, even spore forming bacteria, in any medium and in containers of glass, fibre or metal with temperature rises of not over a few degrees F.

Milk could be pasteurised with super voltage cathode rays in a short period of time. Cottage cheeses when prepared from raw milk and from milk treated with cathode rays show no organoleptic difference.

Irradiation of canned chopped meat products by super voltage cathode rays results in a tendency towards discoloration of the meat. An off flavour also develops in some of the products. The extent of off flavour and discoloration appears to be related at least in part, to the presence of curing agents in the products.

7. *Fission products :—*

A brief mention of the utilisation of fission products in food processing may be made. Certain fission products resulting from the formation of plutonium in reactors emit gamma rays in the course of their radioactive decay. Several schemes have been proposed for securing this radiation, including both the gross fuel material itself or the separated and purified radioactive elements. Considerable work must yet be done before such fission products are made available even for experimental purposes. Experiments with gamma rays are being accomplished largely with artificially radioactive cobalt-60 obtained by exposing cobalt-59 to neutron flux in a reactor.

UTILITY AND ECONOMICS

The future of irradiation processing of foods depends upon the outcome of a number of researches yet to be carried out. First of all, problems in organoleptic changes in foods must be solved. Unless irradiated foods are produced with normal acceptability characteristics, it is unlikely that the process will be successful. Although typical changes characteristic of heat processing have been found to be absent in irradiated foods, other sometimes undesirable effects on taste, odour, colour and texture can nevertheless occur. Often these effects are strong enough to require protective processing techniques, prior to and during irradiation in order that a sterile product organoleptically acceptable may be obtained. Findings are, however, that foods irradiated at dose levels assuring commercial sterility can usually be protected against radiation-caused flavour changes by proper combination and selection of the above techniques.

Next comes the effect of radiation on nutritive value. It has been established that there is some loss in vitamins and essential amino acids, though it is not large enough to be taken into account. There are reports of limited nutritional studies with irradiated foods. Rats fed for two years on a diet of food treated by some of the radiations have grown well and have had a life span as long as those fed on a control diet.

Thus, it should appear that irradiation should cause, at the most, only minor effects in the general wholesomeness of foods. However, experiments now in progress in several laboratories should clearly answer all these aspects of this question in the near future.

Safety in handling equipment and fission products does not present serious problems. The basic principle is to absorb the radiation so that it does not reach the personnel. Protection is of course easier when generators are used. They can be turned off any time. Thus while the use of fission products will pose some problems these should not be insurmountable.

Costs of treatment will depend on many factors, some of which at least, will be determined by individual requirements of each particular operation. Such uses will be governed by relative costs and competitive processes. Continued development of work will undoubtedly produce better machines of radiation, but it is fair to say that at this time available sources are sufficiently developed to meet many requirements. Further work should improve performance and reliability and reduce costs and thus help towards their massive application in the food plants of the future.

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