RADIATION PRESERVATION AND ITS POSSIBLE EFFECTS ON FOOD DISTRIBUTION

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by

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AN ABSTRACT

Submitted to the College of Business and Public Service
of Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF ARTS

Department of Marketing and Transportation Administration

Curriculum in Food Distribution

Approved E. A. Brand

ABSTRACT

The preservation of food has been one of man's problems since antiquity. Only a small portion of his edibles are consumed at the time of harvest, therefore the remainder must be preserved or allowed to spoil. Various modes of preservation have evolved, none of which is capable of keeping commodities in a fresh condition without the use of heavy, bulky, and expensive equipment.

Radiation preservation, though still in the research stage, shows promise of meeting more food preservation requirements than any other method known. In its highest stage of perfection, radiation would permit the preservation of perishable foods indefinitely, theoretically forever, without any supplementary preservative, such as refrigeration.

Preservation techniques are needed which will lead to reductions in food spoilage and facilitate wider distribution of perishables, goals which today are economically and physically impractical to attain.

This study is principally an investigation of the effectiveness of radiation preservation and its possible impact on food distribution.

Periodicals and reprints of reports emanating from Dr. L. E. Brownell, head of the University of Michigan Research Laboratory constitute the major sources of data for this report. Interviews with two Michigan State professors, Dr. D. R. Isleib and Dr. Albert M. Pearson, provided pertinent information on research projects in which they had participated. The Quartermaster Corps, under whose sponsorship most of the radiation research projects are being conducted, advised the writer of their inability to provide direct information due to the classified nature of the data. The few available books that deal with food radiation were also utilized.

Even though radiation might eventually fall short of its high potential, partial perfection, or the successful "pasteurization" of foods might be sufficient to bring about substantial changes in food processing, handling, and merchandising which would allow various benefits to accrue to both civilians and the military.

Serious, though presumably surmountable, shortcomings in the food radiation process have been encountered. Flavor, odor, color, and texture are often adversely affected, but experiments continue in an effort to gain knowledge of the optimum radiation dosages and the best physical conditions under which the food should be radiated. Although studies on costs and packaging have been inconclusive, plastic materials offer the most desirable packaging properties of all those tested to date.

Sterile foods would be a boon to military men at the front by providing more variety and better quality than the usual canned rations. Sterile foods would permit the sale of perishables from unrefrigerated supermarket shelves, and either pasteurized or sterilized commodities could lead to more centralized processing of meats and produce.

MAYNARD B. SHAWVER ABSTRACT

Radiation should make foods more wholesome; trichinae, tapeworms, and other dangerous microorganisms can be rendered harmless by adequate dosages of radiation energy. The reduction of spoilage, the need for fewer fixtures, and the economy of mass processing could possibly lead to lower food prices despite the large investment required to construct a radiation facility and install the energy source.

There is a strong probability that foods treated with low dosages of radiation will be marketed within a few years, perhaps two or three, with certain meat products leading the way. Sterile radiated foods are not likely to be available for many years.

The Curriculum in Food Distribution at Michigan
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CHAPTER I

INTRODUCTION

Man is a biological entity subsisting upon other biological matter, either animal, vegetable, or both. Whether he chooses animal or vegetable products for his diet he is faced with the task of maintaining their edibility until consumption is desired, since all biological matter is perishable. If the Creator had designed humans to acquire their nourishment from stones and soil, there would be no problems of food preservation, merely one of supply.

Man's health depends upon a balanced diet and many of his most nourishing foods, such as milk, are the most susceptible to spoilage. Man also eats for pleasure and fresh foods are usually superior in both flavor and nourishment to preserved commodities. Thus, food preservation enables man (1) to stay alive between harvests, and (2) to enjoy the pleasures of good eating.

Preservation of food dates back to antiquity but not until the late nineteenth century did the largest single means of preservation, thermal sterilization, come into being. The subsequent utilization of refrigeration, dehydration, and antibiotics has further facilitated the storage of edibles, but there is still need for a process that will keep food fresh over an extended period without the use of cumbersome facilities.

Following Roentgen's discovery of X-ray in 1895 scientists realized that this energy source could, if applied for a sufficient time, bring about death to living cells. This fact was exploited by medical scientists, but not until the 1940's were experiments conducted in the use of radioactive rays as food preservatives. With the dawn of the Atomic Age and subsequent supplies of wastes from atomic reactors, radiation preservation of food was begun in earnest.

Objectives of the Study

Extensive efforts are being made by scientists to determine the value of atomic energy as a food preservative. In this study the writer will review the highlights of the accomplishments to date and discuss their possible effects on the retail food industry.

Chapter II will briefly relate the history of food preservation techniques. Chapter III will deal with the nature of the radiation process, including sources and applications of energy and their effects on foods in general. The merits and deficiencies of radiation when applied to specific food items will be the topic of Chapter IV, and Chapter V will deal with the packaging of radiated foods. The ways in which food radiation can benefit various groups will be discussed in Chapter VI. The summary and conclusion will form the contents of Chapter VII.

Limitations of the Study

The food radiation process is a technological function and much of the literature dealing with the topic was written by and for scientific personnel.

This report will be written from the layman's viewpoint and will be concerned primarily with end results rather than processing technicalities. Results of tests on each food item will not be discussed instead the writer will endeavor to report only the most significant findings.

Experiments in food radiation have been underway for a relatively short period. The information made available to the writer covers certain topics in only a sketchy fashion and because of the classified nature of new findings, information on the most recent tests is not released to the public. An article dealing with food radiation and appearing in a current periodical is invariably a report on tests made several months previously. For these reasons this study will lack comprehensiveness in certain areas.

Methodology

The writer's most prolific sources of information were current periodicals and reprints of progress reports issued by Dr. L. E. Brownell of the University of Michigan, with whom the writer corresponded directly. Personal interviews were arranged with two Michigan State University professors, Dr. D. R. Islieb and Dr. Albert M. Pearson, who have taken part in laboratory experiments with radiated potatoes and meat, respectively.

The writer attempted to secure information directly from the Quartermaster Corps but was advised of the classified status of recently-acquired data and referred to various periodicals which keep abreast of new developments in food radiation.

Hardly any books have been written on radiation of food and only a few more contain as much as one chapter which deals with the topic. A few such books were found and utilized but compared to sources already discussed, they were of relatively little value.

The Need For Study

Most of the writings pertaining to food radiation have dealt with the reactions of various commodities to the radiation source. There is need for more consideration of the effects that this new process may have on food distribution procedures.

Any new development which can possibly lead to unlimited shelf life of perishable merchandise at room temperature merits the attention of food retailers, wholesalers, processors, and producers.

CHAPTER II

A BRIEF HISTORY OF THE DEVELOPMENT OF FOOD PRESERVATION

The most important cause of food spoilage is attack by micro-organisms. These bacteria are present almost everywhere--on objects, in the air, and in the food humans eat. The purpose of food preservation is to kill off completely the organisms which exist in the food, or to inhibit their growth for a period of time in order to prevent spoilage before the food can be devoured. Chemical reactions (e. g. rancidity in fats), the absorbtion of undesirable odors, and damage by animal and insect pests are other contributors to spoilage.

The Earliest Methods of Food Preservation

The earliest known methods of successful preservation of food were drying and pickling, the former being a form of dehydration and the latter a chemical process.[1] Ancient though they be, these processes are still in widespread use today. The curing of meat, another chemical treatment, has been practiced for many years. Pickling and curing give foods distinctive flavors which, in many cases, are considered preferable to the product in a fresh condition. Man has long known how to effect fermentation of fruit juices and more recently has learned how to make preserves and jams. All of

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[1] "Food Science," Research, Vol. VI (September, 1953), p. 293.

these processes change the character of the food in such a way that the flavor and texture are still enjoyable, but microorganisms do not prosper.

Sterilization and Refrigeration

Modern methods of food preservation attempt to retain the qualities of the fresh product insofar as possible. The earliest success was achieved by Nicholas Appert during the Napoleonic Wars as he sought a means of providing fresh meat for French troops.[2] Appert is given credit for discovering the art of canning as practiced today, even though the bacteriological studies of Louis Pasteur which came later contributed extensive knowledge to canning principles. The canned goods found on supermarket shelves today rely on the principles set forth by Appert.

In the heat sterilization process the food is placed in cans which are then sealed and subjected to heat. Next, the contents of the cans are partially or totally cooked to kill the undesirable bacteria. No additional organisms can attack the food through the sealed can. The product can then be stored on shelves at room temperature for indefinite periods without the risk of spoilage.

Man's earliest attempts at the refrigeration of food consisted of collecting blocks of ice from frozen lakes, rivers, ponds, creeks, etc., and storing them in an ice-house. The ice-house was often built

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[2] Ibid., p. 294.

underground for protection from direct rays of the summer sun. The cache of ice aided in keeping temperatures cool within the enclosure and provided a place where the family could store fresh food to protect it from spoilage.

Refrigeration neither sterilizes nor pasteurizes, but simply provides an atmosphere in which bacteria grow at a relatively slow rate. Significant use of refrigeration as a food preservative was not achieved commercially until a mechanical refrigerator was invented late in the nineteenth century, but not until about 1930 did the refrigerator make a sizeable impact on food retailing practices.[3]

The earliest commercial application of refrigeration was for chilling perishables. Food stores were able to stock larger varieties and quantities of meats, milk, and butter. As time went by, grocers gradually increased the size of their refrigeration facilities. More and more consumers bought refrigerators for their homes, and were willing to buy more perishables than they had in the past. Grocery stores responded to the demand.

During the years which followed World War II frozen food suddenly became popular. The flavor, convenience, and nutrition of vegetables, juices, fruits, and prepared foods in a frozen state caught the consumers' fancy and forced retail food stores to install additional expensive refrigeration equipment and expand their lines of

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[3]L. E. Clifcorn, "Radiation Treatment of Foods," Food Technology, Vol. X (Supplement to May, 1956 issue), p. 36.

frozen merchandise. Families purchased home food freezers which enabled them to make quantity purchases of fresh edibles at reduced prices. Manufacturers increased the size of refrigerators and added larger freezer compartments.

Frozen foods can be kept for longer periods than food which is merely chilled, but since temperatures should remain at zero degrees or lower in order to preserve quality for maximum shelf life, transportation and storage facilities are expensive.

Dehydration

Dehydrated foods are frequently regarded as a relatively recent development in preservation but this technique was used to a fair extent during the Civil War in an attempt to reduce scurvy among the troops.[4] In the Boer War, dried soups and vegetables were fed to the British Army.[5] United States troops of World War II were given dried eggs, dried milk, and dehydrated potatoes on a large scale, although these items were not accepted with great popularity.[6]

Dehydrated soups are now gaining general acceptance on the civilian food market. Dehydrated potatoes are becoming more popular and are being used by many institutions as a means of eliminating the peeling task, minimizing problems of handling, and preventing losses due to spoilage. Dried milk is available in most supermarkets but has not challenged the popularity of the fresh product.

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[4] "Food Science," op. cit., p. 294.

[5] Ibid. [6] Ibid.

The main criticism of certain dehydrated foods is their unpleasant flavor. This is especially true in the case of dried eggs and milk which servicemen found to be unpalatable, but which are gradually being improved.

A major advantage of dehydrated food, aside from the extended shelf life as compared to the fresh product, is the reduction of bulk. With all water removed the commodities become compact and more easily handled. Dehydration is the only preservation medium which substantially reduces the particular item's volume; for this reason, dehydration must be regarded as a strong possibility for having more widespread applications in the future.

Antibiotics

The term "antibiotics" conveys a medical connotation to most persons and this is understandable since the application of antibiotics to date has been largely in the field of medicine. Following the successful use of penicillin as an infection fighter during World War II, scientists started considering this and other drugs as possible means of preserving foods. Research men began experimenting in the early 1950's and soon learned that certain antibiotics could be used to extend the shelf life of specific products, but that no one antibody would acceptably preserve all food items. The scientists foresaw antibiotics to be a supplement to refrigeration but not as its replacement.

The Food and Drug Administration, a Federal Government entity, must approve all food additives before they can be applied to commodities which will be distributed through interstate commerce. Any chemical preservative, coloring, or flavoring agent must undergo tests designed to determine whether the additive is safe for human consumption. The Food and Drug Administration regards antibiotics as being basically harmful, since approximately ten per cent of the population is allergic, in varying degrees, to these drugs. In 1955, the Food and Drug Administration approved the marketing of aureomycin-treated poultry after tests had proved that all of the antibody is destroyed in the normal cooking process.[7] Antibiotics have not been approved for preservation of other edibles since it has not been established that all of the preservative disappears in the course of normal preparation procedures. The problem is not whether shelf life can be extended, but whether a method can be found which will remove all traces of the drug before the food is consumed.

Radiation

The principles of the radiation preservation process are based on the early discoveries of W. K. Von Roentgen, the discoverer of X-rays, and H. Becquerel, an explorer in the field of radioactivity. Curie experimented with radioactivity as an inhibitor to the growth of cancerous cells.[8] The primary concern of these scientists was the use

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[7]"Antibiotics in Food Preservation," American Journal of Public Health, Vol. XLVI (October, 1956), p. 1306.

[8]The Interdepartmental Radiation Preservation of Food Program, United States Department of Commerce (Washington: Office of Technical Services, February 15, 1957), p. 4.

of radiation to correct pathological conditions in animals, and later in plants.

The first experiments in food radiation took place in the early 1940's. By 1948 there were three laboratories conducting research on cold sterilization; by 1950 the number had increased to ten, and in 1955 there were twenty-five.[9]

In the late 1940's the Department of Defense recognized the potential adaptability of this new process to the problems of feeding soldiers in the field with fresh, wholesome food. The Army recommended a five year radiation preservation of food program, and in 1953 the Army General Staff approved the Army plans and funds were alloted for the first year. During the same year, an advisory committee, composed of outstanding leaders in universities, industrial foundations, and government was organized by the National Academy of Sciences to provide scientific advice in the program.[10] In 1955, at the suggestion of the Secretary of the Army, the Interdepartmental Committee was formed. Initial membership included representatives from the Departments of State, Defense, Agriculture, Commerce, the Atomic Energy Commission, and the Department of Health, Education and Welfare. Later, the Department of Interior was invited to participate.

It was agreed that the primary objectives of the Committee on Radiation Preservation of Food were to achieve a high level

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[9]Clifcorn, op. cit., p. 32.

[10]The Interdepartmental Radiation Preservation of Food Program, op. cit., p. 5.

of participation by government agencies and industry and to effect a transition of program responsibility from the military department to other government agencies and industry as rapidly as possible. It was also agreed that the Committee was to act as a coordinating body, with the direction for the interdepartmental program resting in the individual member agencies.[11]

In the meanwhile, the Atomic Energy Commission had initiated a program to evaluate the possibilities of utilizing radiation for food preservation. Contracts had been awarded to four universities who were to use Cobalt-60 as a radiation source. In 1953, the U. S. Army Quartermaster Corps was authorized to embark upon the five year program which took over most of the Atomic Energy Commission contracts. Most of today's research projects on food radiation are under the auspices of the Quartermaster Corps, which in turn operates under the authority of the Interdepartmental Committee.

While some of the work has been done directly in the laboratories of the Government agencies involved, an extensive research and development program has also been developed to include more than seventy contractors, some of which represent industrial cooperative agreements which involve no exchange of funds. One of the outstanding advantages of this contractual program is the concurrent dissemination of new findings throughout the country.

Summary

Down through the years man has sought to discover the best possible methods of protecting the freshness of his food. By preserving

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[11] Ibid., p. 7.

the nutritional qualities, his health benefits; by maintaining good texture and flavor, his enjoyment of eating is enhanced.

The first effective preservatives of which there is knowledge were drying and pickling. The most recent efforts are through the application of atomic energy, although radiation is still in the experimental stages.

The keen interest of the Federal Government in the success of the radiation preservation program led to the formation of the Interdepartmental Committee, whose function is the coordination of the many experimental projects which are being conducted by both civilian and government laboratories across the country.

Food radiation is still in the research stage, but the results obtained thus far indicate the possible benefits to be enjoyed in the future.

CHAPTER III

THE NATURE OF THE RADIATION PROCESS AND ITS EFFECT ON FOOD

One of the peacetime uses of atomic energy which shows promise of elevating man's living standards is the preservation of food by radiation. This process has passed through a preliminary stage of research with the resulting indications that food preservation by atomic energy can actually be accomplished, but not without various undesirable side affects.

A general evaluation of the radiation preservation process should take into consideration such practical factors as the quality of the food prepared by the process, the equipment required to perform the necessary tasks, the costs relative to other preservation techniques, and the palatability of the end product.

This chapter will deal mainly with the general characteristics of the food radiation process relative to these factors.

Sources of Energy

Basically, there are two methods of sterilizing food by ionizing radiations. Mechanical devices have been developed which produce beta rays (high speed electrons). These machines can be turned on and off, a definite advantage, but the rays emitted have limited penetrating

power. A machine capable of generating five-million volts will sterilize a piece of meat about one inch thick.[1]

Gamma rays are emitted from gross fission products such as the wastes of atomic reactors. X-rays are essentially the same as gamma rays except that they are produced by a machine. (X-rays are often referred to as gamma rays in connection with food preservation processes). X-rays are relatively low in cost as compared to rays of gross fission products, and a machine might be designed which would work automatically and therefore require no trained operator.[2]

When gross fission products become plentiful this process could compete with other methods presently requiring less capital investment. However, large quantities may not be available for several years. Gamma rays are capable of penetrating food materials to an approximate depth of six to eight inches while producing a fairly uniform distribution of dosage. Another type of machine-produced energy, cathode rays, are reported to have higher efficiency than X-rays, but this process is more expensive.[3]

One definite advantage of machine-produced energy over atomic fission products is the reduced danger to persons concerned with

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[1]Radiation Sterilization, Research and Development Command (Chicago: Quartermaster Food and Container Institute for the Armed Forces, January, 1957), p. 31.

[2]Radcliffe F. Robinson, "Some Fundamentals of Radiation Sterilization," Food Technology, Vol. VIII (April, 1954), p. 191.

[3]Ibid.

operating the equipment. Machines can be turned off and rendered harmless when not in use, but radioactive atomic wastes must be well protected at all times to prevent harm to human life and health. Other disadvantages of the gamma ray process are low efficiency, the complexity of the operation in general, and the number of technically trained personnel required.[4]

Gamma sources from spent fuel rods and radioisotopes such as Cobalt-60 are currently being used in experimental work. The Atomic Energy Commission's Materials Testing Reactor at Arco, Idaho, is supplying spent fuel rods for research projects across the country. The rods are shipped in cylindrical lead caskets and must be replaced every three to six months to maintain an adequate dosage. Cobalt-60 has been produced by reactors at the Brookhaven National Laboratory in New York, the Oak Ridge National Laboratory in Tennessee, and the Chalk River facility in Canada.[5]

Man-made electron generators are available in varying sizes suitable for use in radiating food. Several types of electron accelerators are now commercially produced, one of which is being used in the pharmaceutical field. The U. S. Army has contracted for a

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[4]Wayne C. Trapp, "Radiation Sterilization of Food," (unpublished Seminar report, Michigan State University, East Lansing, Michigan, Spring, 1957), p. 6.

[5]W. D. Jackson, Status Report to Management on Radiation Preservation of Food, Office of Technical Services, United States Department of Commerce (Washington: Office of the Quartermaster General, July 1, 1957), p. 3.

machine capable of producing twenty-five million volts which will be able to penetrate approximately six-inches of food such as meat, with a capacity for sterilizing 1,000 tons of food per month.[6]

Dosages

All sources of energy which are used for food radiation are measured in terms of rep (Roentgen equivalent physical). One rep is equal to ninety-three ergs of absorbed energy per gram of material radiated.[7] An erg is an infinitesimal unit of energy, the amount required to perform 1/13,560,000th foot-pounds of work.[8]

Nuclear radiation can destroy all animal life, provided a sufficiently high dosage is used. The energy level required varies widely among different organisms with man being the most susceptible of the species and bacteria the most resistant. Even within the same species the dosage required to kill may vary with different conditions of radiation. About 400 to 1,000 rep is all that is necessary to kill a human, but some bacteria can withstand dosages of about five-million rep.[9]

As a general rule, the higher animals are more sensitive to radiation than lower animals. Man is more sensitive than mice and mice

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[6] Ibid., p. 4. [7] Radcliffe, loc. cit.

[8] Webster's New International Dictionary, Second Edition (Springfield, Mass.: G. C. Merriam Co., 1956), p. 867.

[9] "What to Expect in Irradiated Foods," Packaging Parade, Vol. XXVI (May, 1958), p. 147.

are more sensitive than the fruit fly.[10] Table I shows responses to given doses of gamma rays or X-rays by various animals.

TABLE I

RESPONSES TO GIVEN DOSES OF GAMMA RAYS OR X-RAYS FOR VARIOUS ANIMALS[1]

Organism	Dosage in Rep	Effect
Rat	5	Decreased uptake of iron by red blood corpuscles
Mouse	30	Doubled spontaneous mutation rate
Rat	50-100	Embryos affected
Man	200	Reduction all blood elements
Dog	300-430	LD·50 (Lethal Dose for 50 per cent of the organisms that are radiated
Man	400	Estimated LD 50
Rat	590	LD 50
Mouse	650	LD 50
Chicken	1,000	LD 50

[1] William E. Dick, Atomic Energy In Agriculture (New York: Philosophical Library, 1957), p. 131.

Tests have been conducted on various foods by exposure to pasteurization and sterilization dosages of radiation. The pasteurization process kills most, but not all bacteria and thereby retards spoilage. Doses of 200,000 rep are sufficient for pasteurizing most foods.[11] Pasteurized commodities are usually stored under refrigeration;

[10] William E. Dick, Atomic Energy In Agriculture (New York: Philosophical Library, 1957), p. 131.

[11] Robert Ryer, "Influence of Radiation Preservation of Foods on Military Feeding," Food Technology, Vol. X (November, 1956), p. 517.

lower temperatures are not as conducive to the prosperity of bacteria which remain in the pasteurized product.

Dosages of about 2,500,000 rep usually cause sterilization, or the destruction of all bacteria.[12] Once the food has been sterilized all that is necessary to insure freshness for an unlimited period, theoretically forever, is an air-tight container. There are no organisms within the sterilized product to induce spoilage, and the package prevents other bacteria from entering, therefore continued freshness is assured without refrigeration or other means of preservation. Obviously, the effectiveness of the process depends upon the destruction of all bacteria by radiation after the food has been packaged in a container which will remain air tight until consumption is desired. Packaging will be discussed more thoroughly later.

Quality Changes Induced by Radiation

Whether a new food product or process proves to be economically worthwhile depends partly upon the reactions of the consumer. The particular kinds of food which an individual relishes is determined by his ethnic background, geographical location, economic status, sex, and his enviroment with regard to the proximity of transportation and processing facilities. Poor cooking methods, unfamilarity with the commodity, and personal prejudice are other factors which bear upon individual preferences.

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[12] *Ibid.*

Consumers have learned to like the flavor of foods in their fresh state and also in preserved conditions, even though the various preservation processes frequently alter the flavor of the item substantially. Consumers may eventually accept the new flavors of radiated foods if scientists are unable to find methods of precluding those quality changes. Many of the radiated flavors, however, are described as repulsive, so some improvement appears necessary. Experiments conducted thus far have indicated that many radiated samples possessed flavors quite different from those usually associated with the particular items.

The Nature of Taste and Flavor

The terms "flavor" and "taste" are frequently used interchangeably although their denotations differ. The act of tasting is the judgment of flavor; the latter is a blend of sensations which includes taste, smell, and touch.

Some flavors depend more on the tongue for perception, some are more easily distinguished by the nasal passages, while others produce a more general sense of feeling. In the tongue group are salt and sugar; fruits, coffee, and butter are sensitized through odor; the sense of feeling is evidenced by the burning sensation caused by pepper and horseradish, and the coolness of peppermint.[13]

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[13] L. E. Brownell and others, Utilization of the Gross Fission Products (Ann Arbor: Engineering Research Institute, April, 1954), p. 57.

Perceptual evaluations of food are learned through experience and training. Most individuals probably are not aware of this learning and acquiring of preferences, therefore they are unlikely to analyze their reactions to specific flavors. Few persons can explain why a flavor is pleasant or unpleasant; an individual might dislike a certain food item because it conveys an unconscious association of an unpleasant experience. Perhaps the texture, or the "feel" of the food to the mouth is disagreeable.

Sterilization of food by radiation is often referred to as "cold" sterilization. This is a comparison to the heat sterilization process which is used in the canning of foods. After the product has been placed in a can and hermetically sealed, the container is subjected to heat in order to kill the microorganisms in the food. During the thermal treatment, the contents of the can are either wholly or partially cooked, depending on the nature of the food in the can and the length of time allowed for sterilization.

Food can be sterilized by radiation while raising the temperature of the product only about four or five degrees. If desirable, the item may be held in a frozen state during the entire process. Frozen or not, radiation sterilization is effected without cooking the product.

Some Variations in the Effects of Radiation on Different Commodities

Flavor. Research personnel are continually experimenting with radiation processes in an effort to discover the key to sterilization without flavor change. Some of the methods which have been tested are radiation in the frozen state, in a vacuum, under inert gas, in the presence of various chemicals, with the elimination of oxygen which was dissolved in the foodstuffs prior to radiation, and combinations of these techniques.[14] Results in some instances have been promising although no general conclusions have been made.

The same degree of off-flavor is not consistently produced in the same foods under uniform conditions of radiation.

Certain foods are able to withstand many more rep than others without impairment of flavor. For example, milk develops an off-flavor at 100,000 rep, but dried prunes are not affected by 3,000,000 rep. At pasteurization levels of 200,000 rep bananas, crab meat, oranges, strawberries, butter, and cheese are adversely affected; luncheon meat, pork, ham, carrots, cole slaw, spinach, and mackrel remain most acceptable following the same dosage.[15]

If no process is discovered whereby flavor remains unharmed, the acceptance of radiated foods by consumers could be long in coming, thus the importance of knowing why persons dislike certain edibles. If the cause is known, a cure might be effected, otherwise the chances are poor.

A connection between radioactive fallout and food preserved by the radiation process might be sufficient reason for a substantial

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[14] L. E. Clifcorn, "Radiation Treatment of Foods," Food Technology, Vol. X (Supplement to May, 1956 issue), p. 40.

[15] Ryer, loc. cit.

number of individuals not only to dislike radiated food but to fear bodily harm. Actually, foods do not become radioactive as a result of beta or gamma radiations at energy levels required for sterilization.

Odor, consistency, and color. Changes in odor, consistency or texture, and color have been encountered in the radiation of certain foods. For example, dark sweet cherries become much softer in texture at high levels of treatment, and the natural red color is bleached in proportion to the dosage level.[16]

Changes in odor are particularly noticeable in protein foods such as meat, as are changes in color. In one series of tests cuts from different animal types were selected for quality and variety, in fresh, cured, and frozen conditions. The meat was placed in hermetically sealed cans prior to radiation. The source of energy was controlled to produce levels of 1,450,000 rep and 2,000,000 rep at the center of the can. All samples were refrigerated during radiation with water ice and dry ice to keep temperatures at 1 degree C for unfrozen samples and 29 degrees C for frozen portions. Results revealed that the red pigments of all canned raw meats showed radiation damage but recovered during storage so that all samples except beef liver showed good pigmentation. All raw beef and beef products were given lower grades than comparable pork and pork products.[17]

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[16] Ibid., p. 56.

[17] W. M. Urbain and H. J. Czarnecki, "Characteristics of Electron Irradiated Meats Stored at Refrigerator Temperatures," Food Technology, Vol. X (November, 1956), p. 601.

The pre-cooked and raw meats in general had very good texture, but beef liver showed considerable shrinkage. After extensive storage small crystalline clusters appeared in the raw beef.[18]

Experiments have shown that radiated meats tend to recover color and flavor when held under anaerobic conditions (lack of oxygen). The improvement takes place within a period of from ten to thirty days. In the tests described above, further aging did not improve the quality.[19]

Enzymes. The term "enzyme" is derived from a Greek word which means "to leaven." In the field of food technology enzymes refer to the complex organic compounds which catalyze chemical transformations of foods and result in odor, flavor, appearance, and texture changes.[20]

For many years scientists have known that some living cells turn sugar into alcohol, the chemical process through which wine is made. When a scientist discovered that a chemical removed from yeast cells performed the same way in a test tube he concluded that all living things make chemicals which produce changes, like the fermentation of wine. The chemicals are the enzymes, and although they are not alive, enzymes are made by all living cells and are found wherever there is life. Enzymes act as catalysts by speeding up any chemical reaction taking place in any cell, but the enzymes themselves are not changed in the process.[21]

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[18] Ibid., p. 602. [19] Ibid. [20] Robinson, op. cit., p. 192.

[21] Dorothy Callahan and Alma Smith Payne, The Great Nutrition Puzzle (New York: Charles Scribner's Sons, 1956), p. 89.

A high degree of food stability in storage is necessary, therefore the enzyme actions are an important phase of radiation research. Like microorganisms, all enzymes do not react in the same manner when radiation is introduced. Few, if any, are inactivated by a dosage of 3,000,000 rep and some can withstand 10,000,000 rep.[22]

Tests thus far indicate that products in which enzymes are not inactivated show signs of enzymatic degradation. The principal problem is whether these degradative changes go on at such a rapid rate that undesirable attributes are developed before a reasonable anticipated storage period is fulfilled. If enzyme inactivation is necessary, techniques for doing so are well known and are not difficult to apply.[23] Efforts are now being made to combine barely enough heat to inactivate the enzymes, with just the amount of radiation needed to kill the bacteria.[24]

Tests have been conducted on raw meat under the procedure described above and the results have shown no occurance of bitterness or undue texture breakdown during subsequent periods of unrefrigerated storage.[25]

In taste panel tests any off-flavor might be immediately attributed to the radiation energy source, whereas the true cause could

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[22]Ryer, op. cit., p. 518. [23]Ibid.

[24]George E. Donald, "Food Irradiation Makes Strides," Food Engineering, Vol. XXIX (December, 1957), p. 58.

[25]Ibid.

be due to enzymes, hence the necessity of defining the effects of both radiation and enzymatic actions.

Food value. The importance of vitamins in the diet of animals was discovered through the works of Lunin in the latter part of the nineteenth century, and Hopkins early in the twentieth century.[26] Deprivation of vitamins leads to various physical reactions ranging up to death. When the important functions of vitamins were first discovered they were referred to as "accesory factors of the diet." Later the word "vitamine" was suggested, meaning "life" (vita), and nitrogen containing compound" (amine). When scientists subsequently discovered that accesory factors differed widely in chemical composition, the "e" was dropped to change the word to "vitamin" and thus avoid any chemical significance.[27]

Vitamins are subject to destruction by heat. This has led to the encouragement of eating certain foods in the raw state rather than cooked.

Tests on the nutritional value of radiated foods indicate that vitamins which are destroyed by heat are also subject to destruction through gamma and beta rays. The amount of vitamin loss seems to depend upon the nature of the product, and since radiation represents "cold" sterilization the loss might be of relatively low magnitude.[28]

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[26]Callahan and Payne, op. cit., p. 122. [27]Ibid., p. 123.

[28]Brownell, Utilization of the Gross Fission Products (April, 1954), p. 54.

Table II shows a comparison of two sterilization processes and their effect on certain vitamins.

TABLE II

RETENTION OF VITAMINS IN MEAT[1]

Treatment	Niacin	Riboflavin	Thiamine	Vitamin E
3,000,000 rep	84	72	12	60
(No. 2 1/2 can heated (146 minutes at 235 (degrees F.	80	76	52	--

[1]Robert Ryer, "Influence of Radiation Preservation of Foods on Military Feeding," Food Technology, Vol. X (November, 1956), p. 517.

In a study of milk, beef, beans, and peas which were radiated at sterilization doses, there was no more effect on the nutritive value of proteins than occured during heat sterilization.[29]

More will be said later about the nutritive qualities of radiated foods when the results of feeding tests are discussed.

Taste panels. The subjection of radiated food to human taste testing entails the selection of a requisite number of persons who can meet certain qualifications; the food is not simply tasted and scored by the research men.

As pointed out in the discussion of the flavor concept, preference for any one food depends upon the individual members of a

[29]Clifcorn, op. cit., p. 40.

particular civilization. No matter how accurately an experiment measures the flavor of a particular food, the best that can be expected of the result is that the true flavor, as conceived by the population represented by the panels, has been determined. This necessitates the exercise of care in selecting a taste panel if the results are to be significant. An attempt should be made to choose individuals whose tastes are representative of the population in general.

Choosing the panel. In selecting taste panel members for a project which was conducted at the University of Michigan, the following factors were considered:

1. The candidate should represent the population under study.
2. The candidate must be able to repeat his judgments.
3. The person must have flavor perception which is reasonably acute.
4. The candidate must be sufficiently motivated.[30]

For preference testing, item three is not too important as long as item one is satisfied. Failure to satisfy the fourth requirement will seriously impair any experiment in which the person participates.[31]

Taste tests are not always conducted for the same purpose. A panel might fall into any one of the following categories:

1. Panel for detection of differences. Such a panel usually consists of from three to ten members.

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[30]Brownell, Utilization of the Gross Fission Products (April, 1954), p. 80.

[31]Ibid., p. 81.

Intensive training of the participants is usually undertaken before tests are commenced.

2. Panel for quality control. Quality control test panels are usually panels of long standing and of more experience than the first type. These panels are utilized for the maintenance of fixed standards.

3. Panel for consumer preferences. Panels of this type are usually large and untrained. Generally, no standards are provided and decisions are based on preferences alone. The panel must be representative of the population of interest.

4. Panel for quality evaluation. Tasting is usually done by a small number of official graders when an attempt is made to conform to a uniform scaling system over long periods of time. Interest is in an absolute taste score and not in comparative scores for several products.[32]

The testing conditions. Tests should be conducted in an environment which is as free from interruption and distraction as possible. Cooking odors, tardiness, and excess noise should be guarded against. Panel members should not sample any one food at the same time in the presence of another panel member for fear that a facial expression will prejudice the judgments. Usually, at any given moment each participant is testing a different food. Equal amounts are used for each sample, usually bite-size portions.[33]

The food samples should be served within a temperature range of about thirty-five to forty-five degrees C (about seventy-seven to ninety-five degrees F) since this is the optimum temperature range for taste perception. Panel members usually do not swallow the samples

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[32]Ibid. [33]Ibid., p. 82.

but eject them into a suitable container; this method has been proven most satisfactory.[34]

Types of tests. Various types of tests are used in taste panel experiments. Paired and triangle tests indicate whether there is any difference between samples, or in specific characteristics such as tenderness or flavor. In a paired test the participants may be asked which of two samples is more tender, or which has the better flavor. In the triangle test, three samples are used, two of which are duplicates. Panelists are asked to identify the identical samples.[35]

The dilution test is used to determine the smallest amount of an unknown that can be detected when mixed with a standard material.[36]

The tests which are used most frequently are scoring, or rating tests. Panel members are asked to assign a score within a given range to the samples. The range is usually from one to five, seven, or ten, although there is considerable variation as to the exact scale ranges employed.[37]

On certain occasions taste tests have been conducted on foods which had their general appearance altered as a result of radiation. In one such instance artificial vegetable coloring was added until the radiated and control samples looked identical. If there is any probability that a particular sample has been scored for flavor when

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[34]Ibid. [35]Ibid., p. 83.

[36]Ibid. [37]Ibid.

appearance actually was a significant factor the results are discounted. Although a blindfold test would seem appropriate in such instances the writer has not read of any tests conducted in that manner.

The eventual success or failure of the radiation sterilization process depends in part upon the flavor of the treated product. Even if the food should prove to be satisfactory in texture, color, wholesomeness, etc., without a flavor which most people can enjoy the process will not be satisfactory. That the scientists are well aware of this fact is borne out by the care with which taste tests are conducted.

Radiation Costs

Any statement concerning costs of radiation preservation is simply an estimate. The only work done to date has been conducted in laboratories and the expenses encountered may bear little resemblance to those of a commercial operation using mass production techniques. Scientists have not yet discovered which sources of energy are most suitable for given foods and since costs vary considerably, both with the source and the facility required, the task of making accurate cost estimates is further complicated. The savings which might be effected from reduced food spoilage and lower expenditures for refrigeration equipment are also important.

Savings through reduced spoilage. The Army feels that the radiation of food may lead to significant savings by reducing the

burden imposed upon its logistics system. Costs might be reduced in four ways:

1. Food handling expenses could be reduced.
2. Less refrigeration equipment would be required.
3. There would be a decrease in the amount of maintenance support needed.
4. Food losses would be minimized.[38]

The Army has estimated that the cost of overseas shipments of refrigerated food alone amounts to $40.00 per man-year. During World War II, the United States had 5,000,000 men overseas, therefore the potential saving can be estimated at $200,000,000 per year.[39]

Shipping perishables under refrigeration is not enough; additional equipment is needed at the receiving port, for transportation along the lines, and at the point of consumption.

> It takes one walk-in and two reach-in refrigerators for each mess feeding 450 men, a total weight of 8500 pounds equivalent to $2500.00, or nineteen pounds per person. For a field army of 400,000 men this is 3,800 tons, for 1,000,000 men $5,000,000.[40]

Savings in the food itself could be effected in two ways. First, spoilage enroute should be reduced. (One post-World War II shipment of fresh vegetables to the Far East totaling 500,000 pounds was fifty per cent spoiled upon arrival at the destination).[41] Second, if the food arrived in a fresher condition the soldiers should consume more and throw less into the garbage cans.

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[38] Ryer, *op. cit.*, p. 519. [39] *Ibid.*

[40] *Ibid.* [41] *Ibid.*

The military is not the only group which could benefit from radiated foods. Handling and equipment costs, and losses due to spoilage are of major concern to food producers, retailers, and consumers. Estimates of the amount of food which is thrown away in the United States vary but most are in the fifteen to twenty-five per cent range. This includes food which is simply wasted, as well as losses through spoilage.

Processing costs. Research men at the University of Michigan conducted tests using three different radiation facilities and computed costs as accurately as possible. In the first experiment, cesium-137 was used as the energy source with a minimum dosage of 25,000 rep. The facility is capable of breaking the trichinosis cycle of hog carcasses and can process 2,000 hogs per day. The estimated costs of treatment, including amortization of the investment over a five year period, is one-fourth cent per pound of pork.[42]

The second facility uses the same energy source but is designed to double or triple the shelf life of meat by pasteurization. Doses of 80,000 rep have been found to be sufficient for this task. The facility can process thirteen tons of meat per hour at an estimated cost of one-fourteenth cent per pound.[43] This device is about five

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[42] L. E. Brownell and J. V. Nehemias, "Techniques Used in Studies With High Intensity Gamma Radiation," The Scientific Monthly, Vol. XXXII (February, 1956), p. 93.

[43] Ibid.

times more efficient than the first facility, hence the lower processing cost.

A facility designed to radiate potatoes uses spent fuel rods as the energy source and is capable of delivering 10,000 rep to about 250 bushels per hour. Cost estimates are about six cents a bushel.[44]

In another test, 25,000 rep was used to treat grain, flour, and cereal products for control of insect infestation. Reports indicate that flour can be radiated in 100-pound bags at an estimated cost of two-cents per 100 pounds. Taste panels have found that bread, biscuits, and cakes made with treated flour at doses of 50,000 rep had no undesirable qualities.[45]

Table III shows estimated radiation costs for selected tasks, taking into account both gamma and beta ray sources.

These figures represent the range of costs encountered at several research stations employing various energy sources.

The estimated per-pound costs consider the initial outlay for construction of the radiation facility and the energy source, cesium-137. Estimated costs of a unit such as that used for radiating hogs, and capable of administering a dose of 30,000 rep are $82,500. The energy source installed and its shipping container cost approximately $508,000,

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[44] Ibid., p. 94.

[45] "What's New in Food Radiation?," Food Engineering, Vol. XXVII (December, 1955), p. 167.

making the total cost of the facility $590,500. The suggestion is made that the source should be amortized over a fifty-year period.[46]

TABLE III

COST AS CALCULATED FROM AVERAGE RADIATION SERVICE CHARGES[1]

Purpose	Cost
Sprout Inhibition	14¢ to $5.00 per ton
Grain Disinfestation	10¢ to $1.00 per ton
Meat Sterilization	.03¢ to .07¢ per pound

[1]Robert Ryer, "Influence of Radiation Preservation of Foods on Military Feeding," Food Technology, Vol. X (November, 1956), p. 518.

Plants equipped to radiate food will require several trained persons for supervisory jobs. Facilities will have to be adequately equipped to safeguard the health of those involved in the work. Fixtures required for the radiation process and the energy source are quite expensive, although the latter is expected to decrease in price as atomic wastes become more plentiful. In view of the high fixed costs involved, full economy of operation will necessitate working on a large scale so that each facility can be pushed to capacity output.

Manufacturers will probably choose to build only a pilot plant when first adopting the radiation process. Expansions could be made

[46]Brownell, Utilization of the Gross Fission Products (April, 1954), p. 164.

subsequently as experience and needs warranted. Radiation plants will tend to be inflexible, therefore persons charged with the responsibility of approving the necessary expenditures must be reasonably sure of what they are doing.

Since the radiation preservation of food is such a new concept and requires much more testing, the few cost estimates which have been voiced may be insignificant. The economic advantages over current preservation practices cannot be assessed at this time.

Feeding Tests

The most important factor in the consideration of radiated food is not whether the flavor, odor, texture, and appearance are satisfactory, but whether any toxic effects result. Bodily harm from dangerous chemical changes, or radioactivity of the food are two possible dangers which scientists recognize.

Feeding tests have been conducted on animals and humans, although studies with the latter group have generally been of short duration.

Feeding tests with rats. A study by University of Michigan scientists was conducted on 124 rats, sixty-two of each sex. The animals were subjected to both long and short term tests. Part of the long term group was fed a diet radiated with 4,000 rep doses; after a period of 224 days the animals which were given a control diet showed a slightly superior growth rate as compared to the animals which ate the radiated food. Thirty-one males of the control group had an average

weight of 560 grams while the average weight for the same number of males which were given radiated food was 530 grams. There was little difference in weight between females in the two groups, but variations due to pregnancies made this factor difficult to interpret.[47]

Studies of the rats involved in the short term tests showed that those fed a complete diet treated by 20,000 rep suffered vitamin deficiencies. The inclusion of a nonradiated vitamin supplement was shown to correct the symptoms.[48]

With regard to reproduction, the results of the experiments were inconclusive. One strain of rats which subsisted on a radiated diet failed to reproduce, but another strain eating the same food bore young, as did both control groups. In the long-term studies, two out of sixty-two animals which ate the radiated diet developed tumors, but more study is needed before any conclusions can be made.[49]

Some animals which were fed the completely radiated diet showed slower growth rates than control groups or groups which were allowed to choose between radiated and non-radiated food, but this was attributed to a smaller intake of the radiated diet. Apparently the animals found a reduction in the palatability of the treated foods.[50]

Feeding tests with humans. Human feeding tests have not been conducted on a large scale with the exception of an experiment at Fort

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[47] L. E. Brownell and others, Utilization of the Gross Fission Products (Ann Arbor: Engineering Research Institute, December, 1954) p. 190.

[48] Ibid. [49] Ibid., 191. [50] Ibid., 195.

Lee, Virginia which was scheduled to commence early in 1958. The results have not been made known to date.

Studies were made at Fitzsimons Army Hospital in Denver where conscientious objectors were subjected to diets in which thirty-five per cent of the calories came from radiated foods. Subsequent tests were with diets in which up to 100 per cent of the calories were radiated. The subjects showed no untoward effects from any of the experiments.

The approval by the Food and Drug Administration of the marketability of radiated food is not required at this time although several researchers think otherwise. The Food and Drug Administration, in answer to a direct inquiry by Supermarket News, stated that radiated products can be sold without prior approval by the Government. Food and Drug Administration officials are sponsoring a bill which would require their approval of the sale of radiated foods, but the law now stipulates that only additives need to be considered, and radiation is not regarded as an additive.[51]

> If radiated food was placed on the market without Food and Drug Administration consultation the Government agency could legally not do anything. It could only have the food seized and taken off the market if the agency could prove the food to be mislabeled or adulterated.[52]

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[51]"Irradiated Foods on Shelf Depends on Speed of Research Production," Supermarket News, Vol. VI (November 25, 1957), p. 30.

[52]Ibid.

The Food and Drug Administration has stated that the Army tests show no traces of radiation left in the food, but the resulting chemical changes, and radiation's effectiveness as preservative are not known.[53]

Summary

Scientists have determined the sources of energy which can be used for radiation preservation of food and have established the approximate dosage levels of pasteurization and sterilization. Optimum dosages for specific commodities, and the conditions under which individual items can be treated with the least possible alterations to odor, flavor, texture, appearance, and nutritional qualities have not been defined conclusively. Some approximations of plant and operating costs have been made, but a true cost picture cannot be drawn without considering the effects of mass processing at capacity levels. The possible savings which can be realized through reduced spoilage and fewer expensive fixtures must also be included in the overall cost picture. Feeding tests with humans have revealed no toxic qualities in completely radiated diets, but more samplings are needed.

[53] *Ibid.*

CHAPTER IV

THE RESULTS OF TESTS ON THE RADIATION OF SPECIFIC FOODS

The spoilage of various foods can take place through sprouting, infestation by vermin, chemical processes, or bacterial decomposition. For centuries, man has striven to overcome these forces through the use of preservatives, and atomic radiation represents his most recent attempt in that direction. Radiation may not prove to be the master of the task but today, based on the discoveries of research personnel in the United States and abroad, there is hope.

Meat

Scientists engaged in research on the preservation of food have found that certain meats respond favorably to radiation and show promise of becoming the first radiated commodities to be sold commercially.

There are certain meats that develop unfavorable characteristics when treated by radiation under the various laboratory techniques that scientists have learned to use, but in certain other respects radiation is expected to function better than any meat preservative presently in use.

For years, man has relied upon cooking and refrigeration to protect him from trichina larvae, the microorganisms that subsist in fresh pork and cause trichinosis in humans who devour pork which has not been properly preserved and prepared.

Cooking which raises the temperature of all parts of the meat to 137 degrees F will kill the larvae, but this precaution must be taken by the consumer and is not suited for public health control measures. If the pork is held at five degrees F for twenty days, or given a chilling of minus thirty-five degrees F for a few minutes, the larvae are destroyed, but these methods are expensive and result in changes in the meat texture. Research scientists have discovered that relatively low dosages of gamma or beta rays can kill trichinae without impairing the texture of the flesh, and possibly at a lower cost than through refrigeration.[1] This is but one advantage that may accrue to man from radiation preservation.

The results of experiments with various meat products are presented below.

Ground beef. In one series of tests, choice beef was ground, vacuum packed in cans, then given a radiation dosage of 1,000,000 rep. Immediately following treatment the meat had an attractive red color but there was a noticeable off-flavor and odor. These undesirable qualities were reduced somewhat by radiating the meat while frozen. Pasteurization of the meat following radiation by heating to 160 degrees F did not improve the flavor and odor. Neither the addition of

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[1] W. Ralph Singleton (ed.), Nuclear Radiation in Food and Agriculture (Princeton, N. J.: D. Van Nostrand Company, Inc., 1958), p. 347.

sodium ascorbate before radiation, nor the frying of the meat afterward altered the strange odor and flavor.[2]

After nine months storage at temperatures of seventy and ninety-eight degrees F, an off-flavor described by some as a "liver flavor" persisted. There was also some liquid formation. Both characteristics were reduced by heat pasteurization following radiation but this process impaired the color. Hard white particles which were numerous and hard to remove appeared on the surface, especially in the pasteurized samples. Those which contained sodium ascorbate developed no particles until after two years of storage at ninety-eight degrees F. The attractive red color faded somewhat after one year at either seventy or ninety-eight degrees F.[3]

In other tests with ground beef the samples were given doses of 50,000, 80,000, and 110,000 rep. Two portions were set aside as controls; one was stored in a frozen condition for use after spoilage of the other. The latter control was refrigerated at forty degrees, as were the radiated samples. The control samples used for taste panels after four days of refrigeration were spoiled and a preference was shown for the radiated samples. The frozen controls were used for taste panels after five days. At this time the radiated samples given 80,000 and 110,000 rep seemed to have a better flavor than the control, but no preference was shown for the radiated sample given 50,000 rep.

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[2]G. B. Pratt, and O. F. Ecklund, "Organoleptic Studies of Irradiated Foods," Food Technology, Vol. X (October, 1956), p. 497.

[3]Ibid.

After seven and eight days of storage the 50,000 rep sample was not liked as well as the control. The final taste test was made after eleven days of storage at which time the judges could make no preference because neither the controls nor radiated samples had a good flavor.[4]

The results of these tests indicate that ground beef radiated by gamma rays at 80,000 and 110,000 rep and stored at a temperature of forty degrees F can be kept for eight, and possibly ten days without noticeable flavor and odor changes.[5]

Beef tenderloin. Experiments with beef tenderloin have shown results similar to the ground beef tests except that there was no evidence of white particles, even after three years of storage at ninety-eight degrees F.[6]

Ground pork. Ground pork was canned in glass containers and treated with radiation dosages of 50,000, 70,000, and 100,000 rep and stored at forty degrees F. The control portion was held in a frozen state. The sample treated with 100,000 rep had a slight off-flavor described as rancid after nine days; the other two radiated samples had good flavor at that time. After twelve days of storage the sample given 100,000 rep was definitely rancid and the other two radiated

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[4]L. E. Brownell and others, Utilization of the Gross Fission Products (Ann Arbor: Engineering Research Institute, December, 1954), p. 57.

[5]Ibid. [6]Pratt, op. cit., p. 498.

portions had a bad odor which did not disappear on cooking. The odor was considered worse than the flavor. After thirteen days, the control samples were preferred to the radiated samples.[7]

Ground meat, whether pork or beef, is subject to spoilage more quickly than standard meat cuts, therefore the experiments on ground meats cited above can be considered as the most severe test possible. No tests were made with standard cuts of pork but research personnel expect that refrigerated shelf life would be as long or longer than that of ground meat.[8]

Canned pork. Stew size pieces of lean pork were canned raw and given radiation doses varying from 200,000 rep to 1,800,000 rep. Several cans of pork were set aside for controls. Taste panels found that definite changes in texture and flavor started to take place at dosages of 1,200,000 rep.[9] Only a few taste panel sittings were held on radiated canned pork, therefore the results of these tests were considered to be of limited value.

Pork luncheon meat. A pork luncheon meat product was canned, sterilized by radiation, then pasteurized at 160 degrees F. In addition

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[7]Brownell, Utilization of the Gross Fission Products (December, 1954), p. 56.

[8]L. E. Brownell and others, Utilization of the Gross Fission Products (Ann Arbor: Engineering Research Institute, April, 1954), p. 100.

[9]Ibid., p. 96.

to an off-flavor and odor, the appearance was marred by separation of pinkish colored liquid fat from the loaf. A brown discoloration appeared on the surface of the loaf after one month at ninety-eight degrees F, and after two months at seventy degrees F. A heat-processed control sample was discolored to a lesser extent. After three years storage at ninety-eight degrees F all samples were unattractive in appearance and none were tasted.[10]

Canned ham. Canned cured ham was sterilized and found by a taste panel to have little off-flavor and odor. No further changes in these qualities occured in storage. The appearance of the meat was hardly affected by radiation but the color faded after extended storage, becoming very dark after three years of ninety-eight degrees F.[11]

Pork sausage links. Fresh pork sausage links were placed in evacuated saran bags and in non-evacuated cellophane bags. The radiation dosage used was 1,000,000 rep which was not sufficient to destroy all bacteria but served to kill all types which normally grow at temperatures lower than forty degrees F. After seventeen weeks of storage at temperatures between thirty-six and forty degrees F there was no deterioration due to bacteria, but there were traces of rancidity. The meat contained in the evacuated saran package showed less rancidity than did the cellophane-wrapped samples.[12]

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[10]Pratt, op. cit., p. 498. [11]Ibid.

[12]B. E. Proctor and others, "Extension of Food Storage Life by Irradiation," Food Technology, Vol. IX (november, 1955), p. 524.

Pork sausage patties. Sausage patties were packed in hermetically sealed cans, radiated at 1,000,000 rep, and stored at thirty-six to forty degrees F. After fourteen weeks the radiated sample had a better flavor than a frozen control sample.[13]

All beef frankfurters. Frankfurters were prepared by using amounts of sodium ascorbate ranging from none up to one-half of one per cent. Radiation dose levels varying from 250,000 to 1,000,000 rep were applied after the meat was packaged in cellophane bags. Results showed that one-quarter of one per cent of sodium ascorbate was required to prevent an off-flavor at dosage levels of 250,000 rep and 500,000 rep. When the dosage was raised to one-million rep, one-half of one per cent of ascorbate was needed. All samples were stored at thirty-six to forty degrees F. Those which were not radiated had spoiled after two months due to the growth of mold and bacteria, but after three months none of the radiated samples showed any such spoilage.[14]

Bacon. Cured bacon has been found to respond favorably to radiation although details on the experimental methods are sketchy. One publication reported that the shelf life of sliced bacon was increased three times under storage conditions at room temperature and in a frozen state.[15] The radiation dose and kind of packaging used were not made known.

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[13] Ibid.   [14] Ibid., pp. 525-6.

[15] "Radiation Sterilization in the USA," Food Technology in Australia, Vol. IX (June, 1957), p. 351.

Chicken. Cut-up frying chicken is a popular meat item but its storage life is considerably less than that of undrawn chicken. In order to determine the effects of radiation on chickens, legs and thighs were given radiation dosages of 80,000, 150,000, and 200,000 rep, then stored at a temperature of thirty-six to forty degrees F. No preference was shown through eight days of taste panel tests, but after this period the control portions developed a very disagreeable odor and flavor, even though they had been kept in a frozen state. Without good control chicken the judges were unable to come to any conclusions on the quality of the radiated samples after the eighth day.[16]

In other tests with chickens, four of six trials with samples radiated at 2,000,000 rep showed that the flavor was as good as the control portions. In six other trials with a radiation dosage of 2,500,000 rep, the radiated samples were significantly inferior to the controls.[17]

Chicken was given three different kinds of pre-radiation treatment in other tests. The parts were either frozen, vacuum packed, or treated with free radical acceptors. After energy dosages of 2,000,000

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[16]Brownell, Utilization of the Gross Fission Products (April, 1954), p. 102.

[17]B. E. Proctor and others, "Cathode Ray Irradiation of Chicken Meat for the Extension of Shelf Life," Food Research, Vol. XXI (January, 1956), p. 17.

or 2,500,000 rep, the radiated samples were not significantly different from the controls.[18]

Other samples were treated with 800,000 rep and stored at thirty-six to forty degrees F, or given 2,000,000 rep and stored at sixty-eight degrees F. After three and six weeks, the frozen controls received higher preference scores than the radiated samples.[19]

Long range tests. Tests were made at the Swift and Company laboratories to ascertain the keeping qualities of radiated meats stored for extended periods.

Cuts from various types of animals were placed in hermetically sealed cans and given dosages of 1,450,000 rep and 2,000,000 rep. Frozen meat samples were treated at minus twenty-nine degrees C; unfrozen samples were held at one degree C while radiated. Some of the meats were cooked to varying degrees before treatment. All samples were subsequently stored at seven degrees C. The results showed that cured bacon, raw and precooked pork sausage, precooked lamb, and chicken were in remarkably good condition after five years. The samples lacked the metallic taste which canned food often acquires after a long period, but this may have been due to the storage temperature. All raw beef samples had an extremely bitter flavor. In general, the food

[18] Ibid.

[19] Ibid., p. 18.

samples which had some heat processing prior to radiation yielded a more desirable product on long storage.[20]

General Conclusions Concerning Radiated Meat

A report by the United States Department of Commerce presents two lists of foods which have been given radiation tests. One list represents commodities which have been found to be relatively resistant to changes in flavor, odor, color, and texture when given a radiation treatment. The second list consists of foods which are relatively unresistant to changes in quality. The "less resistant" list does not include any meats but the "more resistant" group mentions several: beef liver, chicken, pork sausage, beef, ham, and lamb chops.[21]

Within recent months a project at Michigan State University was completed for the Quartermaster Corps in which pork, generally speaking, was found to be a better product following radiation than were chicken and beef.[22] Details were classified pending release by the Quartermaster Corps and were not available to the writer.

Although meats are considered to be relatively more adaptable to radiation preservation than are other foods, there is insufficient

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[20]J. F. Kirn, W. M. Urbain, and H. J. Czarnecki, "Characteristics of Electron Irradiated Meats Stored at Refrigerator Temperatures," Food Technology, Vol. X (November, 1956), pp. 602-03.

[21]W. D. Jackson, Status Report to Management on Radiation Preservation of Food, Office of Technical Services, United States Department of Commerce (Washington: Office of the Quartermaster General, July 1, 1957), p. 5.

[22]Personal interview with Dr. Albert M. Pearson, Michigan State University, College of Agriculture, East Lansing, Michigan.

information to permit the drawing of any hard and fast rules. To date, best results seem to have come from refrigeration storage following radiation. Pasteurization treatments of pre-packed meat at levels up to 600,000 rep have been found to produce no significant off-flavors and have extended refrigerator life five to twenty times.[23] Few products are able to withstand sterilization dosages while remaining unchanged in palatability.

Seafood

Many of the features of the radiation of meat will also be applicable to the treatment of fish but the two products have certain characteristics which make them different. For example, the texture of fish is more delicate and a foreign odor or flavor is easily detected. Fish is more prone to the development of rancidity than most meat commodities.[24]

There is much less information available on fish radiation than on meat, but the results of a few tests can be presented.

Fish. Fillets of mackerel were sealed in polyethylene bags and radiated with 1,500,000 rep of cathode rays. After twelve days of storage in crushed ice the fish remained practically free from organisms (ten organisms per gram of fish) as compared to the untreated controls

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[23] L. E. Clifcorn, "Radiation Treatment of Foods," Food Technology, Vol. X (Supplement to May, 1956 issue), p. 36.

[24] R. S. Hannan, Food Preservation (New York: Chemical Publishing Company, 1956), p. 116.

stored under the same conditions. The organism count in the controls rose from 8,000 per gram at the time of storage to 5,500,000 per gram after twelve days. There was no report on flavor and odor.[25]

The results of tests with haddock are presented in Table IV. There was no indication of a storage period following radiation, therefore the judging was apparently conducted almost immediately.

Other tests were conducted with haddock, lemon sole, and mackerel. The taste panel found that radiation with 1,000,000 rep had little or no effect on the appearance and odor of the raw fish, or the appearance, odor, and flavor of the cooked fish. After a dosage of 2,000,000 rep, the odor of the raw fish and the odor and flavor of the cooked fish had been impaired. None of the samples were regarded as inedible by any member of the taste panel although the flavors were classified as "somewhat objectionable." Other samples were treated with 2,000,000 rep while frozen and were judged in all respects as similar to those radiated at room temperature. None of the samples were found to be sterile, therefore a higher dosage of radiation is probably required to sterilize fish under the conditions of these tests.[26]

In another series of experiments, frozen halibut was thawed, then radiated with 2,000,000 rep and 2,500,000 rep. A significant flavor

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[25]*Ibid.*, p. 117.

[26]*Ibid.*, pp. 118-19.

change resulted. When fresh halibut steaks were treated with the same energy levels there were no significant flavor changes.[27]

TABLE IV

EFFECT OF CATHODE RAYS ON HADDOCK FILLETS
RAW FISH[1]

Dose (Rep)	Appearance	Texture	Odor
900,000	No change	No change	Slightly cooked
2,700,000	Slight bleaching of surface; tissue fluid exuded	Slightly crumbly	Marked cooked oxidized odor resembling ozone
5,700,000	Surface coagulation, large quantity fluid exuded, surface bleaching to absolute white.	Very crumbly	Very marked cooked odor; strong smell of ozone

FISH BROILED FIFTEEN MINUTES

Dose (Rep)	Judges Preferring Control	Judges Preferring Radiated	Judges unable to detect any difference
900,000	3	1	5
2,700,000	3	2	4
5,700,000	6	1	2

[1]R. S. Hannan, Food Preservation (New York: Chemical Publishing Company, Inc., 1956), p. 117.

Codfish cakes were treated with 2,000,000 rep after packaging under various conditions; air packed at room temperature, vacuum

[27]John T. R. Nickerson, Bernard E. Proctor and Samuel Goldblith, "Ionizing Radiations in the Processing of Plant and Animal Products," Food Technology, Vol. X (July, 1956), p. 309.

packed, and frozen. Taste panels reported that none of the samples had any significant off-flavor or odor, although the vacuum packed specimen received the highest score.[28]

Oysters. Radiation of raw oysters with gamma rays at levels of 3,500,000 rep produced an odor described by judges as "grassy". There was subsequent souring in both the treated and untreated samples which may have been due to enzymes rather than bacteria. Cooked radiated oysters had a different off-odor.[29]

As stated earlier, relatively little work has been done on the radiation of seafood and general conclusions are not available.

The successful radiation sterilization of fresh seafood should enable more residents of inland areas to enjoy a wider variety of salt water products than they have in the past.

Vegetables

The effects of radiating vegetables differ in several practical respects from those of animal products. Adverse flavors from radiation are often slight, but there is usually a general loss of quality which would necessitate certain protective measures. Protective procedures used on meat products, such as freezing, will damage most types of plant life. Certain vegetables are subject to spoilage by sprouting, as well as by decomposition.

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[28] Ibid.

[29] Elizabeth Ann Gardner, and Betty M. Watts, "Effect of Ionizing Radiation on Southern Oysters," Food Technology, Vol. XI (June, 1957), p. 329.

Several tests have been made with radiated vegetables. Some of the results will be discussed in detail below and general conclusions will be presented with regard to various other commodities.

Potatoes. A satisfactory potato preservative must inhibit spoilage for one year, or from one harvest to the next. Certain better quality potatoes are not available throughout the entire year; for example, the Idaho russet is preferred by many cooks for baking and French fries, but this potato is not marketed during the summer months.

Tests have been conducted to determine the value of radiation for extending the life of Idaho russets. Separate 100 pound burlap bags of potatoes were treated with 7,000, 21,000, and 28,000 rep, and one untreated bag was held as a control. All bags were then stored in a room where the temperature was fifty degrees F and relative humidity was fifty per cent. After one week of storage the unradiated potatoes began to sprout. Two months after storage was started practically all of the untreated samples showed sprouts, but only a few of the radiated potatoes had sprouted regardless of the dosage levels administered.[30]

Minnesota grown Irish cobbler potatoes were given radiation tests under the same conditions described for the russets. After six months of storage twenty times as many of the control group had sprouted as had the treated potatoes. In physical appearance the

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[30] Brownell, Utilization of the Gross Fission Products (December, 1954), pp. 99-102.

controls were wilted, shrunken, and decaying while the radiated samples were much firmer, had fewer skin blemishes, and had lost less water.[31]

Taste panel tests were held on radiated potatoes immediately after being treated. After cooking, the potatoes were peeled and mashed. Milk, butter, and salt were added. The panel showed no preference for either the control or radiated samples although most judges found the treated potatoes to be somewhat sweeter in flavor. After four and one-half months of storage there was still no preference shown although the controls tasted sweeter than the radiated samples, a direct switch from the condition described in the prior tests.[32] Thus, after four and one-half months, the radiated samples and controls were approximately equal in flavor, but the controls were in far poorer physical condition. The taste tests were not continued beyond four and one-half months.[33]

As a result of these and other tests, research personnel were led to state that:

> Relatively low doses of gamma radiation have been observed . . . by this laboratory to delay greatly, if not actually prevent, the sprouting of potatoes . . . . In all probability late-harvested, mature, northern-grown potatoes could be kept throughout the following winter and spring until early harvested mature potatoes become available the following year. Cheaply applied gamma radiation could prevent the considerable financial losses hitherto taken for granted with regard to potatoes still in storage in the spring. Also this process can make quality potatoes such as Idaho russet, Maine or Long Island potatoes available throughout the year.[34]

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[31] *Ibid.*, p. 98.

[32] *Ibid.*, p. 60.

[33] *Ibid.*

[34] *Ibid.*, p. 87.

Dr. D. R. Isleib, Assistant Professor of Farm Crops, Michigan State University, who has participated in experiments on radiated potatoes, believes that while radiation can be used successfully to inhibit sprouting, treatment with chemicals shows more promise. Dr. Isleib states that chemicals can be sprayed on the potatoes in the field or in storage, a procedure which affords more convenience than radiation. The chemicals are cheaper and can prevent sprouting for a year, the maximum period required. Radiation does not prevent potato spoilage by rotting, therefore Dr. Isleib feels that chemicals, while less expensive and more convenient to use, are equal to radiation as a preservative and represent the better process.[35]

With regard to Army logistics, Dr. Isleib believes that dehydrated potatoes are promising. The large reduction in bulk would facilitate handling and transportation, and losses through spoilage would be eliminated. The quality of dehydrated potatoes is so high that many restaurants and institutions are turning away from the fresh product, according to Dr. Isleib.[36]

Onions. Radiation has been used in an attempt to curb the sprouting of onions but the results are not conclusive. Dosages ranged up to 28,000 rep. Immediately after treatment there was no significant difference in the flavor or texture of the radiated and

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[35] Personal interview with Dr. D. R. Isleib, Assistant Professor of Farm Crops, Michigan State University, East Lansing, Michigan.

[36] Ibid.

untreated samples. Following a three month period of storage in polyethylene bags at fifty degrees F and approximately fifty per cent relative humidity, judges showed no preference for the flavor of either group although the radiated samples had lost some of their crispness and sharpness, and were slightly sweeter. Both groups sprouted and were very susceptible to mold after two months storage. The latter condition was attributed to the polyethylene bags.[37]

Other vegetables. Radiation tests with practically all vegetables have been made but a detailed analysis of each commodity does not seem necessary.

Sterilization doses, in many cases, cause excessive damage to vegetables but research personnel feel that radiation will extend the market life of these products through the use of pasteurization doses. Complete sterilization frequently results in a loss of acceptability from the production of off-flavors and odors, and texture changes.

Certain items which produce undesirable qualities when radiated at room temperature yield better results when treated while frozen, in a vacuum, in an atmosphere of nitrogen, isolated from oxygen, or in some combination of these conditions. For example, broccoli radiated in a frozen state at 2,000,000 rep showed no significant quality changes but treatment while vacuum packed, or packed in an atmosphere of nitrogen did not preclude flavor and odor alterations.[38]

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[37] Brownell, Utilization of the Gross Fission Products (December, 1954), pp. 64-65.

[38] Nickerson, op. cit., p. 307.

Table V represents, without details as to the radiation dosages used or the conditions under which the treatments were administered, the results of tests on vegetables conducted by various research teams.

TABLE V

QUALITY OF VARIOUS VEGETABLES FOLLOWING RADIATION

Good	Poor
Potatoes	Celery
Carrots	Lettuce
Broccoli	Tomatoes
Asparagus	Cabbage
Cauliflower	Corn
Brussels Sprouts	Endive
Green Beans	Peas
Lima Beans	Rhubarb
Spinach	
Sweet Potatoes	

Many of the off-flavors and odors of radiated vegetables may be attributable to enzymatic actions. Extensive research projects are in progress to determine the actual dosages required to achieve the desired results.

Fruits

Radiation tests with fruits have produced results similar to those derived from experiments with vegetables.

Many fruits contain acids, and bacteria do not grow in acid-bearing products. Energy levels of about 1,000,000 rep are sufficient to inhibit the growth of yeasts and molds but such dosages produce changes in texture, color, and flavor. The over-all response of different fruit products has shown wider variation than in the case of vegetables.[39]

Apples. Apples of the Delicious variety were pared, sliced, and radiated with doses of 5,000 to 2,000,000 rep. Immediately after treatment, the radiated samples were softer in texture, with greater texture changes accompanying larger doses. The flavor of the radiated portions was different from that of the controls; lower dosages produced an almond-like bitterness, and at higher energy levels the fruit had a flavor somewhat like rotten apples.[40]

Navel oranges. Navel oranges which were subjected to dosages of 500,000 and 600,000 rep were preferred by taste panel members to untreated controls and samples that received higher dosages. The two latter groups were more bitter, and the oranges given the greater dosages were more bitter than the controls.[41] No conclusion was drawn with regard to extended shelf life.

Peaches. Radiated whole peaches were given satisfactory scores by taste panels when dosage levels were less than 1,000,000 rep. Peach

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[39] Hannan, *op. cit.*, p. 127.

[40] Brownell, *Utilization of the Gross Fission Products* (April, 1954), p. 91.

[41] *Ibid.*, p. 94.

halves and slices in syrup received acceptable scores following 2,000,000 rep dosages.[42]

At the present stage of research, peaches have shown the most promising results of all radiated fruits tested. The effects of radiating fruits are broadly similar to those described for vegetables, but radiated flavors and bleaching are often greater.

Miscellaneous Foods

Eggs. Eggs were treated with dosages ranging up to 3,000,000 rep and all were found to have an unnatural odor. The severity increased with the dosage. There was also a change in the character of the albumen.[43]

Cake mixes. An appreciable reduction in the number of bacteria was obtained at 5,000 rep in dry white and spice cake mixes. After being baked the white cakes had acceptable flavor, and the spice cakes had no off-flavor when made from mixes that had been treated with 100,000 rep. At 500,000 rep the spice cake was slightly off-color, off-odor, and compact.[44]

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[42] "Food Radiation Roundup," Food Engineering, Vol. XXVII (August, 1955), p. 46.

[43] Richard W. Parsons, and W. J. Stadelman, "Ionizing Irradiation of Fresh Shell Eggs," Poultry Science, Vol. XXXVI (March, 1957), p. 321.

[44] Howard E. Bauman, "Effect of Gamma Irradiation on Cake Mixes at High and Low Moisture Levels," Food Technology, Vol. XI (March, 1957), pp. 195-96.

Coffee. Coffee was given 10,000, 100,000, and 1,000,000 rep of gamma radiation and then brewed in four dripolators using the three radiated samples and an untreated control. The coffee was tasted while hot and ranked by paired comparisons. The general opinion of the judges was that the radiated samples did not have a fresh coffee aroma and tasted like stale coffee.[45]

Dairy products. Milk and products with high milk content generally develop intense, unpleasant flavors from even mild dose levels of radiation. Removal of oxygen from the radiation enviroment protects both flavor and color to a certain extent, but one writer feels that "it is doubtful whether the required conditions could be achieved economically on a commercial scale, particularly with large masses of the product."[46]

Grains. A relatively low level of treatment, 20,000 rep, has been found to prevent reproduction of the insects which infest wheat and other grains. There is no impairment of quality at this dose level.[47]

Summary

There are few cases in which radiation, without supplementary preservation media, has been used to prolong appreciably the life of

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[45]Brownell, Utilization of the Gross Fission Products (December, 1954), pp. 72-73.

[46]Hannan, op. cit., p. 120. [47]Ibid., p. 222.

fresh food products while maintaining desirable odor, flavor, color, and texture. Meat has produced the best results in laboratory tests, although sterilization dosages have severely affected its palatability. Dairy products have shown more adverse reactions to radiation than have other food groups.

CHAPTER V

PACKAGING RADIATED FOODS

One of the advantages of the food radiation process is that the products can be sterilized in their final containers, within the limits set by the penetrating power of the energy source.

No object can remain sterile unless isolated from other micro-organisms, therefore much of the success of radiation preservation depends upon the package being airtight, but capable of allowing gamma or beta rays to readily pass through and into the product within the container.

Experiments with the radiation of foods behooves research personnel to test present packaging methods and materials, and to look for new ideas where current practices are proved inadequate.

Metal Cans

Scientists forsee no difficulty in the use of gamma rays for food packaged in the standard type of tin containers with diameters up to twelve inches. Cesium-137 is capable of deep penetrations and is long lived, and therefore may eventually be the prime source for this type of process.[1]

The shape of the container will depend on the design of the radiating facility. Rectangular shaped cans may be used to ensure a

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[1]R. S. Hannan, Food Preservation (New York: Chemical Publishing Company, Inc., 1956), p. 33.

more efficient utilization of the energy source. In processes using beta rays, the length and breadth of the package can be practically unlimited, but the depth must be restricted because of the limited penetrating power of the source.

The radiation process will place less stress on the can than is exerted during thermal sterilization, and this may lead to the use of thinner metal. The can needs only to be strong enough to withstand the rigors of distribution handling.

Glass Containers

Liquids in standard types of bottles can be radiated with gamma rays but there are two difficulties involved; (1) at high dose rates glass tends to shatter, and (2) most common forms of glass turn brown following radiation. Heating of the glass prevents the latter condition but this process would probably necessitate the heating of the contents also. Dark colored glass could be used except for the psychological effect that it might have on the consumer. Certain chemicals can be added to the glass to overcome part of the discoloration.[2]

Other Containers

Since radiation is effected without an appreciable rise in the temperature of the material being treated, the possibility exists of using containers such as cardboard or fiber. Film containers have

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[2] *Ibid.*, p. 136.

shown promise of becoming a major packaging material by meeting the following requirements:

1. The package must be resistant to handling stress.
2. The film must be impermeable to oxygen.
3. The film must withstand the radiation process. This includes damage which is immediately apparent, such as discoloration, as well as subsequent deterioration.
4. For processes which involve radiation while frozen, the film must withstand low temperatures. Many plastic films become brittle under such conditions.[3]

Some clear plastics become stronger following radiation, and others grow weaker. Certain films cause the food to spoil, and there are foods which cause the deterioration of certain plastics. The most important problem in the use of plastics for the packaging of radiated foods has been defined as the tendency of films to transmit oxygen, carbon dioxide, and water vapor.[4]

Scientists have found that for fresh meat the free transmission of oxygen is necessary to preserve the red color of the product. Free passage of carbon dioxide, and some transmission of moisture are essential for fruits and vegetables. As yet there is no clear indication of what degree of transmission is most desirable for various radiated food products.[5]

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[3] Ibid., pp. 136-37.

[4] "What to Expect in Irradiated Foods," Packaging Parade, Vol. XXVI (May, 1958), pp. 147-48.

[5] Ibid., p. 148.

The most satisfactory film tested to date is polyethylene, though lacking in certain requisite characteristics. The consensus is that a lamination of two or more films may be the eventual solution. A laminate of polyethylene and polyester, combining the low gas transmission of the latter with the low moisture transmission of polyethylene, is a possibility. Moisture transmission could be further reduced by adding a layer of aluminum foil.[6]

Scientists are still searching for a substance that possesses all of the desirable packaging attributes. Some of the materials that have been studied or are now in the testing process are polystyrene, mylar and polyethylene-mylar, laminated halogenated plastics, celluosics, and parafin.[7]

Current commercial packages will probably be adequate for products receiving pasteurization and sprout inhibition treatments, but improved containers are required for grain products, dried fruits, and dried milk, which easily become reinfested by insects.

Experiments are being conducted with chemical treatments aimed at making packages insect resistant, and concomitant tests are underway to determine the effects of radiation on chemically treated packages.

The Southern Research Institute, which has conducted an experimental program for the Quartermaster Corps, forsees some added

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[6] Ibid.

[7] The Interdepartmental Radiation Preservation of Food Program, Office of Technical Services, United States Department of Commerce, (Washington, D. C., February 15, 1957), p. 18.

conveniences in the preparation of meals. The housewife will be able to cook electronically each item of radiated food in its sealed plastic package. All the natural juices, flavors, and vitamins will remain unimpaired. The food will be served by cutting open the package and placing the contents on plates. After dinner, there will be no pots and pans to scour, just an electronic cooker to put away.[8]

Summary

Low dosage radiation is not expected to necessitate many radical changes in food packaging, but sterilization will call for highly specialized containers. Metal packages may be thinner and lighter than those in present use, and may even be made of aluminum, but they seem certain to take on new shapes in order to maximize the efficiency of the radiating source.

[8]"What to Expect in Irradiated Foods," loc. cit.

CHAPTER VI

THE POSSIBLE BENEFITS TO BE DERIVED FROM FOOD RADIATION

Research men have been experimenting with food radiation on a significant scale since the late 1940's. As of now there has been no practical use made of radiated food, unless the Army's feeding tests could be considered as such. The materials used in the many laboratory tests, and the salaries of the research personnel have called for large cash expenditures, mostly by the United States Government. Despite the lack of concrete proof that this preservation process will ever have commercial applications, the research continues.

The Army was one of the first to recognize the potentialities of a food preservative that can keep perishables fresh without refrigeration, but several civilian enterprises are now at work to determine the possible commercial applications of radiation.

Advantages to The Military

There are six prerequisites that the radiation of food must satisfy to be of benefit to the Army:

1. The food must be free of parasites, insects, and contaminating bacteria.

2. The radiated food must not be toxic to man.

3. The food must have good flavor, texture, and appearance.

4. The food must have nutritional value and provide an adequate diet.

5. The food must be stable under severe conditions of transportation, storage, and weather.

6. The process must be economically practicable.[1]

During World War II and the Korean conflict, soldiers in the field had to rely upon canned foods such as B-rations and C-rations. These menus contained a number of repetitions of the basic meat items and continued subsistence on such diets often led to poor morale. There were no refrigeration facilities at the front, therefore canned rations represented the best food available under the circumstances.

Troops will be fast moving and well dispersed in future conflicts, and air transport is likely to be an important supply medium. The problems related to the distribution of perishables will be magnified since refrigeration equipment is so heavy and bulky.

The perfection of the food radiation process will permit the distribution of fresh foods at the front, thus providing a diet more tasty and varied than that afforded by canned rations. Morale should be improved accordingly. Other important advantages such as reduction of food spoilage, decreased refrigeration facilities in transportation and at storage points, and reductions in handling personnel were discussed in Chapter III.

The Navy is interested in food radiation for reasons which are similar to the Army's. Atomic powered ships of the future will be able

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[1]Robert Ryer, "Influence of Radiation Preservation of Foods on Military Feeding," Food Technology, Vol. X (November, 1956), p. 516.

to cruise for long periods without refueling, and the use of radiated food will preclude frequent stops for taking perishables aboard.

Scientists know that the radiation process can satisfy some of the Army's food preservation requirements listed above. Radiated foods are not radioactive, but are free of parasites, insects, and contaminating bacteria when adequate dosages are used. The Fort Lee troop feeding tests will indicate the nutritional qualities and palatibility of radiated foods when given to a large group. The stability of the commodities under severe conditions will depend to a large extent on the packages, a consideration which is being taken into account in laboratories. The costs of the radiation process relative to preservatives in current use probably will not be determined for some time. Initial costs are sure to be high, but in the long run a net saving may be realized.

Advantages to Civilians

The Quartermaster Corps is sponsoring most of the research projects being conducted by colleges and industries, but various groups of civilians may realize extensive benefits from radiation preservation.

Farmers. Radiation may result in the distribution of food at the consumer level on a more economical basis. The inhibition of sprouting of potatoes and onions could facilitate the marketing of these products since their storage life may be significantly extended. Farmer cooperatives may have facilities for radiation, thus minimizing the need for disposing of potatoes at distress prices.

The extension of food shelf life without refrigeration may expand foreign markets that are now closed because inhabitants do not own the requisite refrigeration facilities.

Grain assemblers. The deinfestation of grains at a relatively low radiation level can be achieved at a cost of a few cents per 100 pounds. The grain brokers' customers may be willing to pay a slightly higher price for grain that is insect free.

Food processors, retailers, and consumers. Food processors should also share in extended foreign markets and in enlarged domestic markets to some extent. Perishable foods which now have a limited marketable life may receive wider distribution. Seafood for residents of inland regions has already been cited as an advantage that may accrue to distributors and consumers.

A problem of potato chip manufacturers is the sugar concentration which evolves from the starch content of the potatoes. Radiated potatoes may be held at higher temperatures and for longer periods without sugar formation. A lighter chip will result which is more acceptable to consumers.[2]

In the forefront of commercial utilization of radiated foods is the high processing costs involved due to the amount of technical equipment and the number of trained personnel required. Food processors can

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[2] W. D. Jackson, Status Report to Management on Radiation Preservation of Food, Office of Technical Services, United States Department of Commerce (Washington: Office of the Quartermaster General, July 1, 1957), p. 3.

be expected to channel merchandise through central radiation locations which may be starting points for greatly altered distribution procedures.

New system for distribution of meat. One disadvantage of self-service meat distribution is the necessity of selling the merchandise quickly in order to prevent loss through spoilage. An uncut carcass can be stored under refrigeration for a reasonably long period and the meat will remain relatively sterile. As the animal is broken down into retail cuts, more surfaces are exposed to human hands, cutting tools, and air, all of which leave microorganisms on the meat wherever there is contact. The trimmings from which ground meat is made have high degrees of surface exposure and contamination, and the grinding machines, unless given frequent and thorough cleanings, transfer bacteria to the meat which passes through. As a result, the shelf life of ground meat is brief.

Radiation pasteurization or sterilization of meat may be used to overcome partially or totally this and similar spoilage drawbacks at the retail level while streamlining meat distribution in general. Scientists and businessmen forsee central meat processing houses where carcasses will be broken down into retail cuts, packaged, weighed, radiated, and sent to the various retail chains under brand names of the central packing houses.

The meat will be packaged in laminated wrappers of polyethylene, aluminum foil, and Kraft paper, or in a clear plastic package when suitable films are developed. A transparent window might be provided

in the laminated wrapper. Packaging and weight-marking functions will be carried out by machines. The selling price will be marked on the package by the retailer.[3]

Several advantages could accrue to the retailer from this proposed method of meat distribution:

1. More butchers would be employed in the packing houses where mass processing techniques would lead to more labor efficiency. Fewer butchers would be required at the retail level, and some stores might dispense with meat cutting entirely.

2. The handling of bones and meat scraps would be removed from retailer to wholesaler.

3. Personnel would not be required for wrapping retail meat departments.

4. Less floor space would be required to handle meats.

5. Less refrigerator space would be needed.

6. Mass handling of meats could reduce prices.

7. Fresh pork could be made free of trichinae; consumption of pork might increase.

8. Losses due to spoilage would be reduced.[4]

This system of marketing meats would not be without possible disadvantages. Meat cutters' unions might be opposed since increased efficiency would lessen the required number of butchers. Consumers would be removed even further from meat cutting operations and custom

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[3] L. E. Brownell, J. V. Nehemias, and J. J. Bulmer, "Proposed New Method of Wholesaling Fresh Meat Based on Pasteurization by Gamma Radiation," Proceedings (Conference on Nuclear Engineering April, 27-29, 1955, University of California, Los Angeles), p. 2.

[4] Ibid.

cuts would be a rarity. Housewives might be unable to purchase certain retail cuts to which they were accustomed since cutting techniques vary with geographical regions. Customer resistance could be expected by persons who feared the deleterious effects of radiation, a problem that might be overcome by marketing the meat under a new process name, just as poultry treated with antibiotics is called "acronized" or "biostat" poultry. Resistance might be further overcome by intelligent promotions which stated that the new system was adopted because customers would derive these benefits:

1. The threat of contracting trichinosis from fresh pork is eliminated.

2. Pasteurized meat has longer life, therefore consumers can buy larger quantities and shop less frequently.

3. Mass processing and fewer losses due to repeated trimmings and spoilage could lead to reduced meat prices.

4. Other less common parasites found in meat, such as tapeworms, would be rendered harmless.[5]

The refrigerated case life of fresh pasteurized meat will probably be from thirty to sixty days, as opposed to the current shelf life of about six days.[6] Sterilized meat can be kept fresh indefinitely without refrigeration. There will be no need for refrigerated storage boxes or meat cases, and centralized processing will eliminate cutting areas. Reduced equipment requirements will lower investments and fixed operating costs.

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[5] *Ibid.*, p. 3.

[6] "Effect of Irradiated Foods at Retail Seen Considerable," *Supermarket News*, Vol. VI (November 18, 1957), p. 30.

Total elimination of refrigeration facilities in the meat department seems unlikely. Should a package become damaged the meat would no longer be sterile and refrigeration would be necessary to maintain freshness until the cut was sold. Likewise, limited wrapping facilities may be a necessity.

Distribution procedures of radiated produce similar to that just described for meat are a possibility. Fresh fruits and vegetables could be cleaned and trimmed as needed, packaged, radiated, and distributed from the central processing plant under brand names. The task of trimming and packaging at the store level would be eliminated except for occasional rewraps of damaged merchandise. Fewer produce clerks would be required in the stores and the size of work areas could be reduced. The duties of produce clerks would closely resemble those of grocery personnel in that general procedure would involve opening cases, price marking the packages, and placing them on produce racks. The same can be said of meat clerks under the new distribution system.

The University of Michigan is developing a box car which will be equipped with a radiation facility designed to be used as a mobile radiation unit. Several private industries such as citrus and wheat growers have shown interest in this experimental unit which may be taken to the fields and groves for treatment of the products.[7]

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[7]"Irradiated Foods on Shelf Depends on Speed of Research, Production," Supermarket News, Vol. VI (December 2, 1957), p. 30.

Advantages to Other Countries

The radiation preservation of food may eventually provide a greater service to certain highly populated nations that are technically backward compared to the United States. Residents of countries with few refrigeration facilities often must live near the source of the perishable food supply, or else be deprived of these commodities. Without refrigeration at storage points and in transit, the distribution of perishables is severely restricted. In some cases animals are herded through city streets to slaughterhouses where they are butchered and distributed to the public for fast consumption before spoilage can take place.

Radiation sterilization would theoretically make possible world-wide distribution of perishable food, although from a practical standpoint the costs involved might be prohibitive. Pasteurization by antibiotics may prove to be more adaptable to conditions as described above since this process is expected to be less expensive than radiation, and capable of being administered without a large number of highly trained operators. The area of distribution would have practical limitations since pasteurized food needs refrigeration, or some other supplementary preservative.

Laboratory tests have indicated that low dosage radiation of 100,000 rep, when combined with ten parts per million of the antibody oxytedracycline, acts as a stronger deterrant to the growth of bacteria in fresh meat than does radiation when used alone.[8] Various combinations of radiation dosages and antibiotic solutions may have extensive commercial application abroad and also in the United States.

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[8]C. F. Niven, Jr. and W. R. Chesbro, "Complementary Action of Antibiotics and Irradiation in the Preservation of Fresh Meats," Antibiotics Annual, 1956-1957 (New York: Medical Encyclopedia, Inc., 1957), p. 856.

CHAPTER VII

SUMMARY AND CONCLUSION

The preservation of food, one of man's greatest blessings, permits him to carry the harvest over from one season to another and thereby derive more nutrition and enjoyment from the act of eating. Since discovering the arts of drying, preserving, pickling, and curing, man has been able to accumulate sufficient quantities of food to sustain himself until the next harvest and to transport commodities into areas where deficiencies exist. During the nineteenth century, thermal sterilization and packaging in metal cans were perfected. The process necessitated the cooking of the products and led to a subsequent change in flavor, but the variety of foods which could be preserved was increased. Refrigeration made possible the keeping of food in a fresh state, and later led to the distribution of frozen foods. Recent years have seen the commercial application of antibiotics and the laboratory testing of radiation preservation.

Radiation can be administered by several energy sources, any one of which is able to pasteurize or sterilize the target object. Results obtained vary (1) from commodity to commodity, (2) with the dosage level, (3) with the enviroment in which radiation takes place, and (4) to some extent, even where the commodity, dose, and enviroment are held constant.

As a general rule, meats respond to radiation more favorably than fruits, vegetables, prepared foods, or grain and cereal products, and dairy items develop more undesirable characteristics than any of the other groups. Changes in the flavor, odor, appearance, and texture of the food are regarded as the major problems to be overcome in the radiation process. The high cost of radiation is a factor which may be offset by savings derived from mass processing and reduced spoilage. Optimum packaging and the actions of enzymes in foods are problems which are expected to be more easily surmounted than some of the others that have been encountered.

The perfection of the food radiation process will permit new patterns of distribution with emphasis on the centralized preparation and packaging of retail quantities. Mass production techniques could lead to lower prices for consumers but shoppers might not be able to purchase certain cuts of meat. Regional variations in retail cuts would tend to diminish. Trichinae larvae and other harmful organisms found in meat would be destroyed.

The greatest beneficiaries of radiated food may eventually be the people living in countries with little or no refrigeration facilities. The prolonged life of perishables would permit their wider distribution, and the populace could enjoy better nourishment and wider variety in their diets.

Work Remaining to be Done

Improvements are needed in the radiation process. Some have already been mentioned or implied, but other have not.

There will be need for a device which automatically adjusts to variations in size, shape, and density of packages being radiated so that each will receive the exact amount of energy required. Another device which will automatically eject packages that receive improper dosages will be a necessity. As yet, there is no means of accurately measuring the radiation dosage a package receives, as a thermometer indicates heat levels in the thermal sterilization process.

In order to facilitate the development of better techniques and accurate devices, the United States Army has designed a production-type facility to be built near Stockton, California, and to be called the United States Army Ionizing Radiation Center. The Center will have the following objectives:

1. To produce a great deal more radiated food for research and testing.

2. To prove out, technologically, the various processing parameters and variables.

3. To obtain measurable cost data that can be extrapolated to industrial-type facilities.[1]

The Army's interest in gearing food radiation to private industry is borne out by the third objective of the Center.

The design calls for office and laboratory spaces, a processing plant for all foods, a gamma radiation source, and a beta radiation source. The processing area will be designed so that a large variety

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[1] George E. Danald, "Food Irradiation Makes Strides," Food Engineering, Vol. XXIX (December, 1957), p. 59.

of products may be handled, and so that maximum flexibility in the processing lines can be maintained. The plant may be in operation by late 1958.[2]

The radiating facilities will be capable of delivering a dose of 2,000,000 rep to approximately 1,000 tons of solid, semi-solid, or liquid foodstuffs per month. This dose must be capable of deliverance to a food package approximately six inches thick, sixteen inches wide, and twenty inches long in such a way as to insure that no point within the package receives less than the required dose in a single pass, and that no point receives over twenty-five per cent more than the required dose.[3]

Conclusion

The question that is most offten asked with regard to radiation of food is, "Will it work?" The answer probably deserves a qualified yes.

Some writers forsee commercial utilization of the radiation process by 1960, but such clairvoyance is usually devoid of details and readers might envision a full line of fresh meats and produce on unrefrigerated shelves in two years.

Radiated foods are almost sure to be adopted slowly, item by item, and in combination with other preservatives, probably

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[2]*Ibid.*

[3]*The Interdepartmental Radiation Preservation of Food Program*, United States Department of Commerce (Washington: Office of Technical Services, February 15, 1957), p. 19.

refrigeration. Radiated pork shows promise of being the first item to win acceptance although treatment will be with low dosages barely sufficient to prevent reproduction of trichinae larvae. Other meat items will follow pork but in pasteurized forms only at first.

The day when perishables will be sold from uncooled shelving is probably in the distant future. The problems to be overcome are both technological and psychological in nature. Scientists will probably develop measures to sustain the desirable qualities of radiated foods, but the costs involved may be prohibitive. If high quality is maintained at competitive cost levels additional creative minds will be required to convince the consumer that meat stored at room temperature is equally as wholesome as when held under refrigeration. The latter barrier may be more difficult to overcome than the technological problems.

Centralized processing of perishables will not require sterilization of the products. As techniques are improved whereby foods can be pasteurized without concomitant degradations in quality, the retail food industry may seek the economies offered by mass processing through highly automated plants. The operators of the radiation centers will need to be assured of a market for the plants' full production to enable the expensive facilities to operate at capacity levels.

The readiness of private industry to accept radiation preservation cannot be accurately predicted. The interests of stockholders vary considerably; some like a large income and are willing to accept some risk to get that income, while others are satisfied with a small, steady return on their investments. Questions which both stockholders and management should be asking themselves are: Will radiation preservation be competitive with other preservatives? Can radiation replace other methods of preserving food? Is there something else on the horizon which might make radiation obsolete within a few years?

The fact that millions of dollars have been spent for research is not reason enough to persuade the stockholders and management to exploit the radiation process. The food industry is well established and will carefully study any radical change.

The pressure to make food radiation feasible is presently with the research function. As scientists learn the answers, and scientists usually do, the burden of responsibility will be shifted to marketing managers. Some serious thinking today by businessmen on the consequences of atomic radiation of food would not be premature.

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