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Composed of scientists competent in the field of animal products technology, the *Subcommittee on Animal Products* advises the Animal Products Division of the Quartermaster Food and Container Institute. Members are appointed for three-year terms. The symposium on *The Quality and Stability of Canned Meats* was conducted with the assistance and cooperation of the Subcommittee.

The Quality and Stability of CANNED MEATS

A symposium sponsored by the

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Opinions expressed in the symposium on *The Quality and Stability of Canned Meats* are those of the individual contributors and do not necessarily represent the views of the Academy—Research Council or of the Quartermaster Food and Container Institute.

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Proceedings of the Symposium on the QUALITY AND STABILITY OF CANNED MEATS

I. Introduction

TUESDAY MORNING SESSION

March 31, 1953

DR. H. E. ROBINSON, *Presiding*

CHAIRMAN ROBINSON

This symposium today is on factors affecting the quality and stability of canned meats, one of the major subsistence problems of the Armed Forces. You will hear a number of discussions initiated by experts in fields relating to canned meats. All of the rest of you, it is hoped, will offer advice, suggestions, and ask questions during this 2-day period.

Now we will hear something of the purpose and scope of the meeting from Dr. Tressler, the scientific director of the Food and Container Institute. Dr. Tressler.

Purpose and Scope of the Symposium

D. K. TRESSLER

Thank you, Dr. Robinson. This problem of production of canned meats of excellent quality is of great importance to the Quartermaster. It is important to every taxpayer since more than one-half of every dollar spent on food by the Armed Forces is spent on meat. In fact, the serviceman's meals in the field are built around canned meats. Recently, at certain maneuvers held in the West the servicemen taking part were given operational rations for a considerably longer period of time than is ordinarily the case. They had, as an important item of their operational rations, canned meat. We were amazed to find how far down the scale of acceptability our present canned meats in the C Rations slipped during the several weeks of those tests. We came to the conclusion that canned meats were not as acceptable as we had thought. They rated high at the beginning but after several weeks there was only one canned meat item—and that included beans—which rated as high as at the beginning of the test. That brought home forcefully to us that we must do something about improving the acceptability of canned meat items.

One of the men who had charge of the feeding of the soldiers on those maneuvers said, "Well, those rations were rather old. Some of

them were 2 years old." But when men are fighting at a considerable distance from established supply and resupply lines, rations are likely *to be* 2 years old. We must therefore have canned meats not only acceptable when they are freshly prepared but acceptable after 2 years storage.

Merely increasing the number of meat items in the rations is not going to be the whole solution. It is true that if you have 100 items in rations you will not have to eat any one of them so often. The element of monotony, therefore, is not going to be serious. But even so, there is a certain similarity in the texture and the flavor of all canned meat items in the rations today. Until we can improve them so that each canned item is better in texture and has a more distinctive and more acceptable flavor, we will not have items that are fully satisfactory. The only solution seems to be in securing more information applicable to microorganisms which we must control if we are to have a product of excellent quality, safe from the health hazard point of view, and capable of the necessary storage life.

From time to time we are shown hams and other items which are given a minimum of processing. Those products are entirely satisfactory if they can be kept under refrigeration. As you know, canned ham on a grocery shelf and in the meat markets is a fairly satisfactory item, but if you have to ship it to Korea and hold it perhaps for as long as 6 months at 90° to 100° F., that canned ham is a health hazard. It is not satisfactory. It must be processed longer, and when you do that, as you know, you get a texture and flavor which is not desirable.

We must therefore explore the possibilities of more efficient use of the present methods of stabilizing canned meats. That is, we must learn how heat penetrates so that we can obtain faster heat penetration, thereby reducing the danger of overcooking with its bad effect on flavor and texture.

In addition, we must explore the possibilities of stabilizing our canned meats by methods other than those presently used. Assuming we are able to modify our methods of stabilizing canned meats so they are equivalent to properly prepared fresh meats, the chemical change that may occur is a problem that may become critical. Therefore, we must not overlook this aspect of our investigation. If we find that cathode ray sterilization gives an entirely sterile product, we know that certain changes in the proteins occur. We must find out whether or not those changes are deleterious.

The Institute's program of investigation on canned meats will be the basis for the deliberations at this symposium. As a result of the information obtained here, the program can be strengthened and our goal of a canned meat without an objectionable texture and flavor should therefore be more quickly attainable.

CHAIRMAN ROBINSON

Thank you, Dr. Tressler. Now, Mr. B. W. Gardner, who is chief of the Animal Products Division of the Institute, will tell us of the Institute's program of investigation on canned meats.

The Institute's Program of Investigation on Canned Meats

B. W. GARDNER, JR.

The program of investigation conducted at the Institute is based on the premise that the Armed Forces have a more critical need for better canned meats than any other part of our society. Its purpose is to investigate all problems related to the canning of beef, pork, lamb, chicken, turkey, eggs, sea food items and combination of these and/or combinations with vegetables or fruits. Our objective is to eliminate from canned animal products and food items the soft, mushy texture and objectionable canned meat flavor.

Our program is divided into 5 major parts. The first part is developmental work—development of formulation studies, the development of new items, the development of formulas for new items for modifying existing formulas by taking advantage of changes that are being made in industry every day for manufacturing of better products. Even more important than the foregoing developmental phase is the development of processing techniques. This not only includes a study of present techniques to devise means of improving their efficiency, but it also includes an investigation of the possibility of new techniques. It is, indeed, a very important thing if we can get away from hot sterilization and go to cold sterilization, or if we can improve the efficiency of hot sterilization by the use of such revolutionary techniques as radio waves or dielectric heating.

We are also interested in physical studies. How does heat penetrate a can? What can we do to increase the efficiency of heat penetration into the can? We also have to find out what factors, what environmental factors, affect sporulation of the microorganisms with which we are concerned.

Our program also stresses performance studies. Right now all we can do is to measure whether people like or dislike canned meats. One of our contractors has been attempting to develop an objective method for measuring the texture of canned meats. Frankly, it is an almost impossible job. Maybe some day we will have a texture that can be measured objectively, but now we are restricted to the subjective type of testing for quality. Not least important among our objectives is developing methods of utilization of canned meats. Even if we get a canned meat that tastes like a T-bone steak, if it is not prepared well, all developmental effort has been wasted.

Now as to chemical studies, there are 2 questions: first, what are edible chemical additives that would aid in controlling microorganisms or aid in improvement of the texture of canned meats?

Second, when we find a better canned meat, will it have maximum shelf life with maximum acceptability? We know there are chemical changes that occur in other animal products that are not put in a can. This is an area which should be explored, but currently it is not active in the animal products program.

II. Microbiological Factors Affecting Canned Meats

CHAIRMAN ROBINSON

The next section of our symposium concerns microbiological factors affecting canned meats. The first discussion on "Chemical and Physical Factors Affecting the Thermal Resistance of Bacterial Spores" is by Dr. Hiroshi Sugiyama of the University of Chicago.

Chemical and Physical Factors Affecting the Thermal Resistance of Bacterial Spores

HIROSHI SUGIYAMA

The ability of the endospores of certain bacterial species to survive drastic heat treatment is the important factor in the heat preservation of foods. Numerous studies on the thermostability of bacterial spores have resulted in the accumulation of a mass of data; several reviews of this literature are now available (*5*, *40*, *43*).

Factors which determine the thermal tolerance of spores have been considered as intrinsic or extrinsic. Spores of certain species show heat resistance not much greater than that of vegetable cells, whereas others are probably among the most thermostable forms of life. Even within a given species, strain differences can be demonstrated (*9*, *13*). It would seem that there are no practical methods which are foreseeable which can control what might be called the genetic behavior of the microorganisms.

However, it is possible to take a given strain of sporulating bacteria and significantly alter the thermostability of the spores; these may be considered the extrinsic factors.[a] One point of empirical control of the heat tolerance of spores is the environment in which sporulation occurs. Several workers have shown the importance of the temperatures of growth and sporulation as it relates to the heat susceptibilities of the organisms that develop (*24*, *31*, *42*, *44*, *48*). Certain types of peptones, carbohydrates (*48*), fatty acids, and cations (*42*, *48*) in the sporulating medium enhance the thermostability of some spores. Probably to be placed in this category is the higher thermostability of spores of P.A. 3679, which develop in pasteurized or heat sterilized meats, as compared to those developing in raw

[a] At this point it should be stressed that in most cases the organisms involved will not be named for the sake of brevity; however, the fact that spores of a certain species behave in a certain manner does not imply that spores of other species will react similarly when treated in the same way.

meats (*45*). The suitability of the culture medium for growth or for sporulation is not the factor determining the heat resistance of the spores (*48, 50*).

Evidence has been adduced that the heat resistance of vegetative cells are not necessarily related to that of the spores; that is, the vegetative cells may be of relatively high thermal tolerance while that of the homologous spores may be low (*52*). It would be interesting to determine whether the substrates which enhance spore thermostability increase the resistance of the vegetative cells at the same time.

Once the spores are formed, the age of the spores and the conditions of aging become of some importance. Some spores may not reach maximum resistance for 60 days under moderate temperature and moisture (*27*) ; rapid drying *in vacuo* may result in a spore preparation whose heat resistance remains constant over a period of months (*13*). These factors, as well as the separation of a spore suspension into fractions of different heat resistances by centrifugation (*54*), are important in experimental pack studies.

Factors in the control of spores. The immediate goal of the food technologists is the control of spores produced in their natural habitat—spores which can be expected to contaminate the food product being subjected to heat processing. The conditions under which the spores are heated becomes of importance under these circumstances. The pH of the menstruum in which the spores are present is of major concern, the resistances usually being highest near neutrality (*13, 54*), although the nature of the buffer or organic acid used plays a role (*2, 18*). In small amounts ascorbic acid increases while a vitamin K analogue decreases the thermotolerance of *Clostridium botulinum* spores (*35.*) Salt in different concentrations has a variable effect (*2, 13*). Sugars in high concentrations generally increase resistance (*2, 42*). Oily material markedly increases the resistances of spores (*26*) and vegetable cells (*53*).

Spores that cannot germinate and multiply can be considered as being nonviable. Any factor which will decrease the germination of the spores will have the apparent effect of making the spores more sensitive to heat. Although there is a difference of opinion, it would seem that the effect of meat-curing agents belongs in this category, rather than in increasing the lethality of a given heat process (*20, 41, 55*). A lower optimum temperature of incubation than that considered optimum for the growth of the vegetable cells has been found for the germination of heat-processed spores of *Clostridium botulinum* (*51*). Spores that survive severe heat treatment are more fastidious in their nutritional requirements (*8*) and become more sensitive to deleterious effects of rancid fatty acids (*37*) which normally suppress the germination of spores (*14, 32, 33*).

The first report on the successful preservation of a variety of foods with a mild heat processing when subtilin was incorporated in the foods (*1*) seems to have been a temporary sporostatic instead of a sporocidal effect (*3, 49*). The apparently greater thermostability of suspensions of spores containing clumps may be attributed, at least partially, to a greater germination. Thus, the oxidation reduction potential, the concentration of essential nutrients, etc., may be shifted more easily toward the optima in a localized area around a group of spores acting as a unit than when the same number of spores are separated. For example, the pH of *Clostridium welchii* which are centrifuged on a pad is much lower than that of the same cells dispersed in the medium (*30*). Of course, another contributing factor in the seemingly greater heat resistance of suspensions of clumped spores is the strictly numerical aspect—the greater the number of spores, the greater the heat tolerance (e.g. *40*), the original suspension actually containing a greater number of organisms than colony counts would indicate. For the practical heat

processing of meats, the low degree contamination of raw meat products suggests that perhaps the present standards of heat processing based on large inocula of experimental packs may be excessive.

Spores that survive heat or ultraviolet radiation lethal to part of a spore population appear more sensitive to further treatment of the same agent. In suitable combinations of heat and ultraviolet radiation, some spores are sensitized to the effect of heat by the action of light, although the converse does not seem to occur (*12*).

A possible field of experimentation is the use of mild heat treatments of the spores. This type of heating results not only in an acceleration of spore germination but also in an increase in the number of spores that germinate (*7, 36*). This apparent increase in the viability of spores is important in the standardization of spore suspensions for experimental studies. Moreover, the stimulation of metabolic activities can be demonstrated subsequent to these heat shocking treatments. Thus in microrespirometer studies of aerobic spores, with checks made to show that actual germination of the spores does not occur, the Qo_2 is measurably increased (*4*). In view of the fact that growing organisms are more susceptible to deleterious agents it would seem interesting to determine whether spores in the state of heat activation are altered as to heat resistance. Perhaps of some bearing on this point is the observation that spores become more sensitive to the mutagenic effect of ultraviolet irradiation very early (5 minutes) in the period of spore germination (*28*).

The basis of heat tolerance. What is the basis of the heat tolerance of bacterial spores? The most likely explanation would involve the change in the physio-chemical make-up of the vegetative cells in their transition into the spore state, resulting in a spore cytoplasm that becomes uniquely resistant to the thermal inactivation of its biological activities. The rather high temperature coefficients shown in the heat destruction of spores suggest that protein denaturation is the basic mechanism. Thus, moderate hydrostatic pressure accelerates the killing of spores at ordinary temperatures and retards the destruction at high temperatures, an analogous behavior being shown by protein denaturation (*22*). Urethane, a protein denaturing agent, renders spores more sensitive to heat processing (*21*). Many of the observations already cited can be explained from this point of view (*5, 42*).

That there is a difference in the chemical make-up of the spores as compared to the homologous vegetative cells is evident from the differences in the antigenic moities (e.g. *11*), the calcium content (*6*), and the qualitatively different amino acid composition (*10*). Although the specific gravity of spores seems to be uniformly greater than that of the vegetative cells (*25*) and the refractive index higher in spores than in vegetative cells (*34*), the total moisture in the spores is now thought to be of the same magnitude as that in the vegetative cells (*19, 25*) but a larger portion of the moisture in the spores is in the bound form (*15*). Since dry heat is much less efficient than moist heat as a sterilizing agent and since bound water does not participate in chemical reactions, this difference in the bound water content may be one of the basic reasons for the high thermostability of the spores. However, it should be pointed out that the method used in the measurement of the bound water is admittedly open to large experimental errors.

Various studies would indicate a high content of nucleic acids in spores. It has been suggested that the relatively high content of the ribonucleic acid may contribute to the resistance of spores against ultraviolet rays and electrons (*23*). In addition, the fact that the desoxyribonucleates have a high degree of protective action in increasing the thermal stability of egg albumen may be significant (*16*). This latter effect is a function of the weight ratios of the nucleate and protein and the presence or absence of salt.

It has been postulated that the enzymes of spores may be combined in some way which render them inactive and also resistant to heat (*46*). Recently, however, an active enzyme has been found which exists in higher concentration in spores than in the homologous vegetative cells. This alanine racemase catalyses

the conversion of *l*-alanine to *d*-alanine (*39*) and is more heat resistant in the spore than in the vegetative cells. The racemase activity of the spore has been partially resolved into 2 fractions, a heat-resistant particulate fraction and a heat-sensitive soluble fraction. This most significant observation would indicate that the spore heat resistance may reside in the manner in which the spore proteins are bound to particles (*38*). It is interesting that a rather similar theory has been made for the malic dehydrogenase and cytochrome systems extracted as a red fraction from a thermophile; this substance is stable at 56° C. This would indicate that the thermostability may not reside in the inherent structure of the protein molecule but rather in the fact that the red fraction behaves like a compact mass of protein which resembles an organization of molecules (*29*).

Conclusion

From the brief review presented it is evident that a considerable amount of work has already been done on the thermal resistance of bacterial spores. Nevertheless, it is also true that the heat preservation of foods is still more empirical than deductive; processing factors must still be determined with experimental packs in most instances. It seems that only when the basic mechanism underlying the thermal resistance of spores is more fully understood can there be much hope of graduating from the present empirical trial and error methods to that of a sound scientific approach. Thus, much further work is needed; the use of newer techniques and approaches is particularly indicated—such as the recent work of Stewart and Halvorson on the alanine racemase of spores.

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CHAIRMAN ROBINSON

Thank you, Dr. Sugiyama.

The next paper on the microbiologic subjects will be presented by Dr. Williams of the University of Texas.

Factors Causing Sporulation and Vegetation of Spoilage Organisms in Canned Meats

O. B. WILLIAMS

Applied and basic research have recently been differentiated by Newton (*10*) on the grounds that basic research is motivated by natural curiosity—the desire for knowledge, whereas applied research has as its incentive a desire for improvement—improvement of a product, a procedure, or an industry. The program of research on bacterial spores here discussed has both basic and applied aspects. Fundamentally, the research is an integral part of a continuing effort to improve the quality of the preserved meat food items of the ration. Canned meat food products in general heat by conduction and require a long exposure to elevated temperature to destroy the spore contamination. There is a very general belief that physical and chemical changes or deterioration are functions of total time and temperature to which the food is subjected. Presumably, storage life would be extended if less heat could be applied during the processing. Certainly, if the severity of processing could be reduced, a better grade of raw product could be utilized in place of the tougher, less flavorful, tissue required to withstand the current schedules of processing.

One approach to the objective of improved quality of the preserved product is in the use of other methods of sterilization, or preservation, than the conventional exposure of hermetically-sealed containers to an atmosphere of steam under pressure. Exploratory experimentation in this area is in progress, but it is not certain at the present time how soon, if ever, a substitute for steam sterilization will be both possible and practicable. Another approach lies in basic investigations of the biology, in the broadest sense of the word, of bacterial spores. These are the structures which make severe heat treatment necessary. The success of a canning operation depends upon the destruction, or inactivation, of resistant spores, yet comparatively little is known about them. The present state of knowledge as to why some bacteria form spores, for example, is about as it was in 1932 when Cook (*3*) summarized it in the statement ". . . they form spores because they form spores." The situation as to spore germination and sporulation by spore-forming species is comparable. The need for greater knowledge has become more widely recognized in recent years, as is evidenced by the increased volume of published research, and it may be predicted confidently that the jig saw puzzle

of spore biology will begin soon to take definite shape. Process determination was strictly an empirical operation for a hundred years following Appert's discovery. It is still empirical so far as a knowledge of spore biology is concerned, and it will remain empirical until we fill in many of the gaps and expand our understanding of these critical cellular structures. We need to know why some bacteria, but not others, form spores; what conditions favor and what hinder spore formation; what promotes and what interferes with spore germination and subsequent growth; what is concerned in spore resistance to various adverse environmental conditions; what is the distribution of significant spore formers; what may be expected in the way of numbers in food for processing; and many other items of varying degrees of importance. The development of this knowledge is basic research—basic research directed toward an objective of application.

The section of this general field of research with which I have been most closely associated has been concerned chiefly with the formation and the germination of spores. Most of the work has been done with fabricated media because of the technical difficulty of following changes quantitatively when working with a product. Furthermore, it is possible to control the composition of the substrate more accurately with a fabricated medium than with the natural product, and the data which have been developed by ourselves and others emphasize the importance of substrate composition for reproducible results. It is not possible to discuss in a short time, even in a cursory way, all of the work which has been accomplished. Some of the results have been published, and do not deserve more than mention; other work is still in the preliminary or developmental stage and cannot be discussed extensively.

Spore germination. When the current program of spore research was initiated little was known about the factors operative in spore formation, and practically nothing, beyond the morphological changes, about spore germination. The first undertaking was the development of a procedure for the study of spore germination; this was achieved by Wynne (*20*) for *Clostridium botulinum.* He showed for this very important organism that germination follows a course which is essentially logarithmic. Thus, the greater the initial number of spores present in a favorable environment, the longer will be the time necessary for germination to be complete. This observation needs to be extended to other spore-bearing organisms of significance to the food industry, and an effort made to explain the orderly nature of the process.

Through the use of the standard procedure developed it was found that there are species differences in the requirements for germination. *Clostridium botulinum* requires carbon dioxide for germination in a chemically defined medium, or a by-pass for carbon dioxide in complex media, whereas several other species of anaerobes and aerobes did not show the carbon dioxide effect. A further species difference in spore germination was shown in the effect of trace amounts of C_{18} unsaturated fatty acids, which interfered sharply with *Clostridium botulinum,* but to a much lesser extent with the well-known strain P. A. 3679, and not for all aerobic types tested. This observation has been extended by Roth and

Halvorson (*15*) who showed that the inhibitory effect of fatty acids is associated with rancidity, not with the fatty acid *per se*.

The concept of a toxic factor(s) in medium as inhibitory to spore formation originated in the work of Roberts and Baldwin (*13*) who, in 1942, recorded observations made some years earlier which showed that media prepared with certain peptones could be increased in spore productivity by treatment with adsorbing agents, especially charcoal. Starch has long been used to increase the value of media for the growth of certain non-spore-formers. Heated spores are generally thought to be somewhat more exacting in requirements for growth than unheated spores of the same lot. In 1946, Olsen and Scott (*11*) reported that the number of colonies developing from heated spores was significantly increased by incorporation of small amounts of starch in the recovery medium, suggesting that at least one factor concerned in the germination of heated spores was an adsorbable substance, more effective for heated than for unheated spores. We have confirmed many times the value of starch in recovery media for heated spores of both mesophilic and thermophilic aerobic forms. Again there seems to be a species difference since Hays *(5)* has noted beneficial results from charcoal, but not for starch, with strain P. A. 3679.

The incorporation of starch in each of several media tested for spore productivity with *Clostridium botulinum* did not increase the spore yield. Whether this means that these media did not contain inhibitory substances is uncertain. There may be a difference in sporulation response to starch among strains of the same organisms, as is suggested by results with *Bacillus stearothermophilus*, strains of which responded unequally to the presence of starch in the medium. It is, however, certain that not only growth but spore formation and spore germination for some types is sharply affected by adsorbable substances in the medium. Hardwick, Guirard, and Foster (*4*) associated the antisporulation factor with certain saturated fatty acids. It may be that here also rancidity of the acid is the determining factor. This idea would appear to be supported by results which show the superiority of media prepared from fresh ingredients over dehydrated media, or possibly also extract media. We have recently noted a marked difference in productivity, i.e., germination and subsequent growth, from heated spores for brain-heart-infusion medium prepared from fresh tissue over the dehydrated product.

Numerous workers have studied spore formation from vegetative cells and spore germination in the presence of one or more nutrient materials under conditions which would not support continued growth. An interesting observation regarding germination was made by Hills (*7*) in the demonstration of the significance of certain specific nutrients, especially L-alanine, for the process. We have been able to confirm this observation for several species, and to extend it by demonstrating that spores produced in a chemically defined medium in general show an accelerated germination when compared with those produced in a complex medium. This observation has not been fully explored so that the constituent(s) of the medium significant in the production of spores susceptible to specific stimulatory effects in germination could be defined.

A comparison by the technique of Hills of spores of strains of the same species of unequal resistance to heat suggests that the more resistant spores have a reduced germination rate.

A phenomenon associated with spore germination which has been very intriguing is that of heat activation. Numerous workers have observed that spore suspensions exposed to nonlethal temperature for a period of time gave appreciably higher counts than before heating. Recently, activation of bacterial spores by a chemical agent has been noted (*9*). A considerable portion of our efforts for the past year has been devoted to an attempt to find out something about this phenomenon. The results to date can be summarized very briefly.

Spore suspensions have been prepared in the usual way, washed and freed of vegetative cells by exposure to high frequency sonic vibration. It has been

established that suspensions exposed to sound waves will gradually decrease to a constant count which is not altered by as much as 90 minutes exposure. Sonic vibration has not been observed to activate the spores.

A considerable number of species, and strains of some species, have been tested under a variety of conditions. Many negative data have been obtained. Contrary to expectations, activation was irregular and inconstant. Appreciable activation was finally noted with a strain of *Bacillus subtilis* obtained from Dr. Harold Curran when it was exposed in commercial peptone solution, acid hydrolyzed casein solution, and especially in skim milk. No activation was obtained with other suspending media.

Experiments are now actively in progress to establish the characteristics of the phenomenon and to determine some of the factors concerned. Results now in hand indicate that a fivefold increase in count is obtained by 10 minutes exposure at from 80° to 95° C., and activation to some extent at a temperature as low as 65° C., within 10 minutes. Maximum effects are observed for both undiluted and 50% skim milk, with a gradual decline in effect as the concentration of milk is lowered, some effect still being apparent at the 5% level. We have a backlog of experience with negative results which is expediting the experiments that do yield positive results.

Spore formation. One of the ideas held by many bacteriologists who are inexperienced in the field, I am sure, is that most of the vegetative cells of a spore-forming species enter the spore state. This idea will be quickly dispelled if one makes spore percentage counts over a period of time. Some species are extremely reluctant to form spores, and even some strains of a species are poor spore formers, whereas other strains, incubated in parallel, regularly produce good spore crops. Percentage counts after 12 days incubation of 5 complex media gave a spread of from 25% to 49% for the well-known strain 62A of *Clostridium botulinum.* Repeated testing with this strain indicates that a yield as high as 40% spores among the countable cells is exceptional. The studies are complicated by the autolysis of many of the vegetative cells so that counts after 5-7 days are inaccurate. A comparison of 50 strains of *Bacillus stearothermophilus* after 5 days incubation in a basamin-mineral salts medium gave a spread of from 1% to 95% spores. One explanation of unequal spore yield possibly is to be found in unequal response among species and strains to antisporulation substances in the medium, but this is certainly not the sole explanation.

It would be very enlightening if the trigger mechanism which sets off the sporulation process could de defined. Recently Charney, Fisher, and Hegarty (*2*) have reported the stimulatory effect of manganese on sporulation by several species of the genus *Bacillus.* Upon examination of some of our old data it was found that a similar observation had been made in 1947 by Ward (*16*) for *Bacillus coagulans,* one of the poor sporulating species. Recently Laskin (*8*) has confirmed the observation for *Clostridium nigrificans,* another poor sporulating type. How general this observation may be, and the significance of other trace minerals, has not yet been established.

Synthetic media, with the close control, both qualitatively and quantitatively, over the constituents, offer an excellent approach to the study of the effect of a specific material on almost any cell activity. As early as 1926 (*17*) I attempted to produce spores of a strain of *Bacillus subtilis* in synthetic media for comparative heat resistance determinations, but without success. Good growth could be secured, but spores could not be detected in any of a number of chemically defined nutrient solutions. Roberts (*12*) was successful in developing a synthetic medium in which this same strain sporulated, and Heiligman (*6*) formulated a modification suitable for *Bacillus cereus.* A synthetic medium for the cultivation of *Clostridium botulinum* was developed by Roessler and Brewer (*14*) but this medium is not productive of spores. Blair (*1*) assumed the task of investigating spore production by *Clostridium botulinum* in synthetic media, starting with the nutrient solution of Roessler and Brewer. An increase in spore yield was

obtained following the addition of any one of several substances, greatest with α-alanine, glutamic acid or ornithine, and to a lesser degree with glycine, sodium butyrate, sodium valerate, arginine or proline. No effect was noted for serine, norleucine, lysine, glutamine, choline, creatine or sodium glyceraldehyde phosphate. Glucose over the range of 0.4% to 1% gave a heavier growth but reduced spore yield. A reduction in spore yield was also recorded for phenylalanine and tyrosine. No correlation between structure and effect was apparent from these preliminary experiments. A more extensive study of the effect of various substances on sporulation in simple media by this organism is now in progress.

Attempts to produce spores, both in complex media and in synthetic media, have not been successful with *Clostridium thermosaccharolyticum*. This organism has potential spoilage significance for meat food products especially those containing cereal. It can be cultivated in synthetic medium, and this fact considered with its meagre sporulation capacity, offers a very fertile field for a study of the effect of both nutritive and environmental factors on sporogenesis since any perceptible number of spores will represent an increase over what is customary. Extensive studies, however, have been consistently negative. No stimulation has been observed for any one of the 18 common acids, nor for any one of the growth factors—thiamine, nicotinamide, pantothenate, pyridoxin, biotin or paraaminobenzoic acid.

The work with synthetic media emphasizes what has long been observed; namely, that good growth without sporulation may be obtained.

Incidentally, it may be noted that the heat resistance of spores of *Bacillus cereus* produced in synthetic media was independent of the luxuriance of both growth and sporulation, and was not conditioned by any one of a number of amino acids, or growth factors. Valine was required for growth. Lack of paraaminobenzoic acid resulted in a sharp drop in the percentage of spores (*20*).

Water and spore activity. One series of experiments which may be mentioned briefly is that concerned with the water content of the substrate and spore germination, growth, and spore formation. A report on this phase of the research recently appeared in *Food Research* (*19*). A great deal of unexpected trouble was encountered in these experiments. The procedure consisted of grinding liver tissue very fine, drying and powdering in a ball mill. The liver powder was sterilized with ethylene oxide, moisture determinations were made in the usual way on a sample, and the desired moisture content was obtained by adding the appropriate volume of *Clostridium botulinum* spore suspension. The mixture was filled into small tubes, a strip of detinned base plate added to rust out residual oxygen, and the tubes sealed in the blast lamp. Observations for spore germination, growth, and spore formation were made in the usual manner. The first experiment gave excellent results. Succeeding experiments were variable. Rarely, a satisfactory series of results would be recorded. More commonly there would be no growth, or good growth in one tube and no growth in a replicate, etc. Eventually it was found that some tubes of liver powder had a pH unfavorable to *Clostridium botulinum*. When the powder was rehydrated in future experiments, provision to adjust and control the pH eliminated the erratic results except in tubes near the limiting moisture concentrations.

One additional point which deserves mention is the method of determining the moisture activity of the various moisture levels

tested. It is generally recognized that the governing factor is not the absolute amount of moisture present in a system, but the moisture activity. In our experiment, moisture activity was determined by taking advantage of the relative humidity of closed systems containing saturated solutions of various salts selected to give a range of values. Such a system is self-adjusting so long as the salt solution remains saturated, and is independent of the volume of gas, liquid or solid.

Our data indicate that at moisture concentrations below 40%, growth and sporulation are unlikely, although spore germination seemingly can take place.

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CHAIRMAN ROBINSON

Thank you, Dr. Williams.

We have 2 more papers this morning, and if we have a few minutes, we will have a short discussion of some of the information given.

Dr. Ayres of Iowa State College is our next speaker.

Microorganisms Associated with the Spoilage of Thermal Processed Meats

JOHN C. AYRES

The microorganisms which may ultimately contaminate and even decompose canned meat are disseminated in and on these products by diverse pathways. For example, they may develop directly in the blood vessels, be transferred to the carcass from the water in the

scald tank or during the washing and rinsing operations, come from the air, or be contributed by the hands and tools of workmen during eviscerating and processing operations.

The hide and hair of meat animals provide excellent lodging places for many types of microorganisms. For example, Jensen and Hess (*19*) indicated the presence of from 100,000 to 1,500,000,000 aerobes and from 10,000 to 2,000,000,000 aerobes on 2 square inches of neck skin of unwashed hogs at the place where the animal's jugular vein generally is stuck. Also, the intestinal tract contains billions of organisms, some of which may penetrate the intestinal wall and be carried to the various parts of the body by the blood. Fortunately, proper handling of the animal during slaughter and dressing minimizes chances for the flora from the hide or viscera of the slaughtered animal coming in contact with the dressed meat. It is difficult to achieve complete freedom from such contamination and, therefore, it is not strange that the organisms associated with the animal's environment and those found in and on meats are the same—or closely related—species.

Various explanations have been offered for the small bacterial load on the surface of the intact carcass. One opinion held among workers in the meat industry seems to be that some reduction in humidity facilitates preservation of all types of meat. However, there is evidence in the literature (*33*, *36*) which indicates that the influence of relative humidity has little effect in delaying microbial growth on meat surfaces. Certainly, in a dry atmosphere the diffusion of water from the interior of meat helps to maintain a higher moisture content near the surface than is indicated by the relative humidity of the surrounding air. Haines (*13*) offered a possible explanation for the growth on uncut surfaces being limited, namely, that the carcass is covered by a layer of fat and connective tissue and has poor nutrient qualities for most organisms. Also, many of the organisms coming in contact with the meat are mesophiles which grow poorly at low temperatures and, when the animal is chilled, die before conditions in and on the meat are again favorable for their growth.

On the other hand, the cut flesh is subject to marked increase in numbers even though stored at refrigeration temperatures. Juices released from the intact cell provide excellent nutrients for the growth of many types of microorganisms. When meats are comminuted, bacteria are afforded an excellent opportunity to develop because grinding not only releases juices but distributes the organisms and provides more aerobic conditions as well as presenting them with a larger area of surface from which to obtain nutrients.

Numbers of organisms associated with fresh meats. Samplings made from the native surfaces of 37 matched sets of knuckle, inside round and outside round of cutter and canner grade beef (*2*) sent to the Iowa State College laboratory from a Chicago meat packing plant indicated that aerobic loads usually ranged from 10,000 to 1,000,000 bacteria per sq. cm. or from 100,000 to 10,000,000 per

gram. For areas that had been sliced at the packing plant just before the meat was shipped, microbial populations ordinarily varied from 10,000 to 1,000,000 per sq. cm. or per gram. It should be pointed out that the surface flora on the native areas was permitted to develop from the time the animal was skinned, while organisms on sliced portions may not have been introduced until after the quarter was dissected. The number of aerobes differed considerably among samplings. For example, 2 surface tests indicated the presence of less than 100 bacteria per sq. cm. while 2 others had 10 million. Since about as many organisms were recovered by swabbing the surface as by mincing a gram of meat with an equivalent amount of surface, the results might be said to confirm Moran's (*28*) statement that spoilage in stored, unfrozen beef is primarily a surface phenomenon.

Types of bacteria found in tissues of slaughtered animals. A large number of investigators (Ayres *et al. 3;* Brooks and Hansford, *6;* Empey and Scott, *8;* Empey and Vickery, *9;* Haines and Scott, *14;* Jensen, *17, 18;* Jensen and Hess, *19;* Kirsch *et al. 22;* Klein, *23;* McBryde, *26;* Niven, *29;* Ogilvy and Ayres, *34;* Yesair, *49*) have studied the taxonomic distribution of microorganisms isolated from carcasses of apparently healthy animals. Members of the following genera have been identified:

Bacteria: *Pseudomonas, Xanthomonas,* Azotobacter type, *Micrococcus, Gaffkya, Sarcina, Neisseria, Diplococcus, Streptococcus, Leuconostoc, Lactobacillus, Eubacterium, Microbacterium, Alcaligenes, Achromobacter, Flavobacterium, Escherichia, Aerobacter, Paracolobactrum, Serratia, Proteus, Salmonella, Bacteroides, Ristella, Hemophilus, Bacterium, Bacillus, Clostridium, Streptomyces, Actinomyces;*

Molds: *Zygorhynchus, Mucor, Thamnidium, Rhizopus, Penicillium, Aspergillus, Sporotrichum, Cladosporium, Alternaria, Geotrichum (Oidium, Oospora, Geotrichoides), Monascus;*

Yeast-like fungi and yeasts: *Candida (Monilia, Blastodendrion, Mycotorula), Torulopsis (Cryptococcus, Torula), Rhodotorula, Debaryomyces (Wardomyces),* and *Sacchoromyces.*

Kinds of organisms associated with meat spoilage. Many of the organisms that have been isolated from inspected meats are quite fastidious in their temperature requirements. On the other hand, some of the bacteria, yeasts, and molds listed do not die if the meat remains unfrozen. Empey and Scott (*8*) found that less than 1% of the microbial population growing on the surfaces of beef at 20° C. were viable at —1° C. and, although bacteria represented 97% of the contamination acquired by beef surfaces at the higher temperature, yeast and molds made up a greater share of the population at —1° C. The 4 principal genera of low temperature bacteria comprising the initial flora were said to be: *Achromobacter,* 90%; *Micrococcus,* 7%; *Flavobacterium,* 3%; and *Pseudomonas,* less than 1%. In an earlier study, Empey and Vickery *(9)* observed that 95% of the initial flora of beef capable of growth at —1°C. consisted of members of the genus *Achromobacter*; the remainder were species of *Pseudomonas* and *Micrococcus.* During storage the relative numbers of *Achromobacter* and *Pseudomonas* increased while those of *Micrococcus* decreased.

In the case of uncured animal tissues, a number of workers (Ayres, *1*; Empey and Scott, *8*; Empey and Vickery, *9*; Haines and Scott, *14*; Jensen, *17*; Moran, *28*; Scott, *36*) have indicated that the formation of surface slime on meat is primarily due to organisms of the *Achromobacter and Pseudomonas* types. As a result of changes in classification made in the more recent editions of Bergey's *Manual* (*5*) a number of types previously isolated from slimy beef by Haines (*13*), Empey and Vickery (*9*), and Empey and Scott (*8*) no doubt would be considered as members of the genus *Pseudomonas* in the present schema since the organisms in question were reported to have monotrichous flagella. Recently Kirsch *et al.* (*22*) advanced this same opinion.

In an examination of colonies isolated from frozen ground beef trimmings (*1*), 78% of the flora were found to be comprised of *Achromobacter* and *Pseudomonas* organisms while they represented but 18% of the isolates from freshly ground beef. At the time of spoilage these 2 genera accounted for 98% of the flora from both meats.

Sulzbacher and McLean (*42*) studied the distribution of bacteria found in fresh pork sausage and found that 75% of the organisms isolated were members of the genera *Pseudomonas*, *Microbacterium*, *Alcaligenes*, *Achromobacter*, *Bacterium*, and *Bacillus*. They observed that species of *Microbacterium* made up a rather large proportion of the flora and, consequently, associated these organisms with the deterioration of sausage during storage. They considered the organisms similar to *Microbacterium lacticum* except that they were non-heat-resistant, surviving heating to 63°C. for 3 minutes but not for 5 minutes. Also, Sulzbacher and McLean recovered 28 cultures of *Bacillus* and 4 of *Xanthomonas;* the spice was believed to contribute most of these.

Members of the genus *Lactobacillus* were recently reported by Kirsch *et al.* (*22*) to be frequent contaminants in refrigerated hamburger.

The joint fluid and bone marrow as well as the flesh of hams from dressed hog carcasses seldom were sterile as early as 45 minutes after slaughter. Boyer (*4*) isolated both aerobic and anaerobic bacteria; among the spore-forming anaerobes which he identified were *Bacillus putrefaciens* (*Clostridium putrefaciens*), *Bacillus histolyticus* (*Clostridium histolyticum*), *Bacillus sporogenes*, (*Clostridium sporogenes*), *Bacillus tertius* (*Clostridium tertium*), and an unidentified organism resembling *Bacillus oedematicus* (*Clostridium novyi*). The last-named organism is probably the same as that described by Haines and Scott (*14*) which they associated with bone taint of beef. Workers at Armour & Company (*15*) used McClung and Toabe's egg-yolk suspension to classify tentatively a number of organisms that they had isolated from freshly ground pork trimmings. According to the reactions obtained, the organisms were considered to be: *Clostridium perfringens*, *Clostridium bifermentans*, *Clostridium novyi* A and B, *Clostridium sporogenes*, and *Clostridium putrefaciens*. Steinkraus and Ayres (*37*) used temperature and oxygen relationships and the ability to grow in the presence of 1-200,000 crystal violet as a screening test for 120 cultures of putrefactive spore-forming organisms found in pork. Of the 21 cultures selected as obligate anaerobes, species tentatively identified by biochemical reactions were considered to be most nearly related to: *Clostridium tetanomorphum*, *Clostridium novyi*, *Clostridium carnis*, *Clostridium paraputrificum*, *Clostridium tetani*, *Clostridium histolyticum*, *Clostridium sporogenes*, and the well-known spoilage organism P. A. 3679. The last-named organism was culturally and serologically similar to putrefactive anaerobes previously isolated by Gross, Vinton, and Stumbo (*12*) as the causative agents in spoilage of canned meats.

Information concerning the microorganisms causing spoilage of cured meats has been advanced by many investigators. With these products not only the flora found in and on the meat but also that introduced with curing salts, sugar, and spices contribute to the total contamination. Sturges and Heideman (*41*) isolated 101 bacterial cultures from curing solution brines. They encountered difficulty when they attempted to classify these organisms according to Bergey's *Manual* (1st ed.) and concluded that classification utilizing the organism's salt relations was less confusing. Heideman (*16*) studied 5 organisms which produced ropiness in curing solutions. He considered the presence of carbohydrate and reaction of the medium of vital importance for the production of a ropy curing solution.

There is general agreement among workers regarding the effect of sodium chloride in checking putrefactive anaerobic spoilage, but various investigators (Niven, *29*; Niven *et al.*, *30*; Norton and Roderick, *31*; Ogilvy and Ayres, *34*) have found micrococci and lactobacilli able to tolerate rather high salt concentrations. Differing opinions have been advanced regarding the preservative action of sodium nitrate and sodium nitrite (*7*, *20*, *38*, *39*, *43*, *44*, *45*, *46*, *50*). Most of the studies that have been made tested the effect of these agents in preventing

spoilage by putrefactive anaerobes. However, Tarr (*47*) tested sodium nitrite using a broader bacterial spectrum and found that the growth of the following genera at pH 5.7-6.0 was either inhibited or prevented by 0.02% $NaNO_2$: *Achromobacter*, *Flavobacterium*, *Pseudomonas*, *Micrococcus*, *Escherichia*, *Aerobacter* and one species of *Torula*. Also, Tarr found that, in this pH range, sodium nitrite inhibited *Clostridium botulinum*, *Clostridium sporogenes*, *Eberthella typhosa* (*Salmonella typhosa*), and *Staphylococcus aureus* (*Micrococcus pyogenes* var. *aureus*).

Discoloration, wherein oxidation pigments were formed, was associated by Greenwood *et al.* (*10*), with action of excess nitrite, oxygen and microorganisms upon cured meat pigments. According to Jensen (*17*) the typical gaseous swell of canned cured meat is generally due to the fermentation of sugar by species of the genus *Bacillus*. Earlier, Jensen *et al.* (*21*) found that only when nitrate, sugar, and cured meat were present together would the bacilli ferment the sugar. Bulman and Ayres (*7*) found that bacilli, forming spores and capable of growing aerobically, were responsible for gas production and discoloration of pork trimmings containing nitrate levels as high as 4.7%. These organisms reduced nitrate to nitrite and were able to tolerate 10% $NaNO_3$.

Evidence which indicates that certain types of *Lactobacillus* and *Leuconostoc* species cause surface and internal discolorations of cured meats has been presented by Niven *et al.* (*30*).

Norton and Roderick (*31*) believed the micrococci were the organisms responsible for slime on sausage. In a study in this laboratory (*34*) not only micrococci but bacilli and sacrinae were numerous in cured meats and lactobacilli and gram-negative bacteria were also present in somewhat smaller numbers. Sometimes sizable populations of yeasts as well were encountered. None of the types of micrococci could be identified definitely with any of the species of *Micrococcus* described in Bergey's *Manual* (*5*). The organisms differed from the micrococci characterized by Norton and Roderick in that they liquefied gelatin and many peptonized milk. Some 30% of the cultures were found to be similar in many respects to *Micrococcus caseolyticus*. The bacilli were frequently found on the surface and always in the interior of fresh frankfurters. The term *lactobacillus*, as used, was employed rather loosely to refer to organisms which may include several members of the family *Lactobacteriaceae*. It is possible that some of the organisms isolated may belong to the genus *Leuconostoc*, although this was not indicated by morphological characteristics. Some cultures grew fairly well aerobically and these, perhaps, would fall into the genus *Microbacterium*. Kraft (*24*) found some of the lactobacilli cultures to be catalase-positive.

Ham souring, *bone stink*, or *bone taint* are terms used in the industry to indicate a putrefactive spoilage of particular importance in large thick pieces such as the hindquarters of pork and beef. In 1908, Klein reported an anaerobic bacillus from "miscured hams" which he called *Bacillus foedans* (*Eubacterium foedans*). Three years later, McBryde (*26*) reported *Bacillus putrefaciens* (*Clostridium putrefaciens*) to be the etiologic agent involved. Tucker implicated *Clostridium putrificum* (*Clostridium lentoputrescens*) and Moran (*27*) showed that *Clostridium sporogenes* could cause ham souring. Jensen and Hess (*19*) catalogued various types of ham sours and asserted that salt-tolerant bacteria which grow at 0° to 3.3°C. in bone marrow can cause any kind of sour. They named these bacteria: *Achromobacter*, *Bacillus*, *Pseudomonas*, *Proteus* group, *Serratia*, *Clostridium*, micrococci, streptobacilli, and a miscellaneous group.

Thermal resistance characteristics of typical spoilage organisms. Although many different groups of bacteria have been found to grow in abundance in meat, their presence in products that are to be heat processed is of less significance if they are not thermoduric. For example, bacteria belonging to the genera *Achromobacter* and *Pseudomonas*, although they have been found to grow to enormous numbers

on chilled meats, failed to survive when incubated at temperatures exceeding 45°C. Jensen (*18*) writes: "We have never isolated the Coliform group of bacteria, *Serratin, Achromobacter, Pseudomonas, Flavobacteria, Chromobacteria, Lactobacilli, Proteus,* and the miscellany of nonsporing rods from canned cured meats which have received a light process."

On the other hand, Niven (*29*) isolated some lactobacilli from cores of sausage which were moderately resistant to heat, surviving temperatures of 65.5°C. for 2 hours and 71°C. for 8 minutes.

In the study of flora in and on beef round referred to earlier in this paper, a surprisingly large number of bacteria survived a 20-minute heating period at 80°C. and still were capable of reproducing when grown under atmospheric conditions. The number of heat-resistant cells or spores growing aerobically differed widely among samples. In some cases there were less than 10 organisms per gram while in others there were more than 100,000. It would not be advisable to consider that all of the surviving organisms were spores. It is quite possible that heat-tolerant micrococci, *Microbacterium, Lactobacilli,* actinomycetes, and other vegetative cells can withstand 80°C. for 20 minutes in a meat substrate. Ruyle and Tanner (*35*) observed that cocci have often been found in canned meats which were given processes considered to be adequate. Verbal reports from representatives of at least 2 of the commercial meat packing plants (*11*) and unpublished findings of work conducted at the Iowa State College laboratories indicate the presence of heat-tolerant aerobes and, in particular, spore-forming bacteria—both in fresh pork trimmings and in products receiving mild processes.

In the past, most spoilage of canned meat has been considered to be caused by the putrefactive anaerobic bacteria. Also, processing schedules advocated for sterilizing the canned product are calculated to destroy large number of *Clostridium botulinum* spores as well as to prevent spoilage by huge populations of extremely heat-resistant putrefactive spores. It is interesting, then, that none of the laboratories which have sampled the raw meat products have encountered any of the *Clostridium botulinum* organisms. Jensen (*18*) states: "During 2 decades of bacteriological control of canned meats, neither we nor any of our colleagues in this work have ever isolated a spontaneously occurring strain of *Clostridium botulinum* from canned meats."

Insofar as the other mesophilic anaerobic spores are concerned, only limited numbers of these organisms have been encountered. In an unpublished survey, one group of workers took samples of freshly ground trimmings from 99 production days over a period of 9 months and found the maximum number of spores to be 42 spores per gram while the average was 1.5.

In this laboratory 80 separate samplings of fresh pork trimmings were obtained from 4 packing plants in Iowa. Less than 3 putrefactive

TABLE 1

INCIDENCE OF TOTAL VIABLE ORGANISMS AND OF SPORES GROWING AEROBICALLY OR ANAEROBICALLY IN PACKAGED RAW BEEF

Kind of Growth	Unit Measured	Surface Examined	Number of Organisms x 100		
			Smallest	Usual Range	Largest
Total Aerobic	no./sq. cm.	uncut	1	100 - 10,000	200,000
		cut	<1	100 - 10,000	33,000
	no./g.	uncut	50	1,000 - 10,000	4,000,000
		cut	75	100 - 10,000	680,000
Total Anaerobic	no./sq. cm.	uncut	1	10 - 1,000	40,000
		cut	<1	10 - 1,000	1,000
	no./g.	uncut	1	1,000 - 10,000	1,600,000
		cut	4	1,000 - 10,000	700,000
Spores Growing Aerobic	no./sq. cm.	uncut	<1	10 - 1,000	24,000
		cut	<1	10 - 1,000	1,700
	no./g.	uncut	<1	10 - 1,000	140,000
		cut	<1	10 - 1,000	19,000
Spores Growing Anaerobic	no./100 g.		<0.6	0.7 - 6.0	140

anaerobic spores per gram were recovered from 92% of the samples. Only 3 lots of trimmings had more than 8 spores per gram; the maximum spore count in any sample tested was 51. Ten samples of fresh beef from one packing plant contained an average of 6.5 spores per gram after the meat had been comminuted. Also, of 111 samplings from the 37 matched sets of knuckle, inside round, and outside round of cutter and canner grade beef, none of the putrefactive anaerobic spore counts exceeded 1.4 spores per gram (see Table 1).

TABLE 2

RETORT TEMPERATURE—PROCESSING TIME SCHEDULE

Row	Retort Temperature (°F.) Time in minutes at:					
	225°	243°	261°	279°	297°	315°
1	10	8	7	5	3	2
2	20	17	14	10	7	4
3	30	25	21	16	11	6
4	40	34	27	21	14	8
5	50	42	34	26	18	10
6	60	50	41	31	21	12
7	70	59	48	36	25	14
8	80	67	54	42	29	16
9	90	76	61	47	32	18
10	100	84	68	52	36	20
11	110	93	75	57	40	22
12	120	101	82	62	43	24

TABLE 3

SURVIVAL TIMES FOR ORGANISMS OR SPORES IN CORE (A) AND OUTSIDE PORTIONS (B) OF CANNED BEEF PROCESSED IN 300x308 CANS

Incidence [a]	Kind of Growth	225 A	225 B	243 A	243 B	261 A	261 B	279 A	279 B	297 A	297 B	315 A	315 B
Less than one organism/10 g. survived processing times longer than:	I. total aerobic growth	50	60	50	50	41	34	38	26	14	21	12	10
	II. total anaerobic growth	20	30	8	25	41	21	5	16	3	3	2	2
No spores survived processing times longer than:	III. aerobic growth	40	10	34	34	34	21	10	16	7	18	4	6
	IV. Anaerobic [b] growth	20	30	25	8	21	7	10	10	11	3	2	2

[a] Results report survival time from the most resistant of 3 samplings.
[b] Based on M. P. N. for 100 g. of beef.

Rectangular chunks of meat were forced into 300 x 308 tin cans and, after subjecting the canned product to the several retort temperatures shown in Table 2, bacteriological tests were made of core and peripheral portions of the processed meat. The thermal processes which were required to destroy all spores from 100 g. of beef or to reduce total counts of organisms growing aerobically or anaerobically to less than one organism in 10 g. of meat are shown in Table 3. No spores were recovered either from aerobic or anaerobic cultures from beef that had received processes exceeding those recorded in the 4th or 5th row of retort time designations shown in Table 2. Also, cultures which survived the 20-minute heating period at 80°C. and subsequently grew under anaerobic conditions were not subcultured from meat that had been processed for times exceeding those shown in the 3rd row of process-time designations. On the other hand, total aerobic growth persisted in many cans of processed beef from which anaerobic spores could no longer be isolated. It is probable that these cans contained no heat-resistant spores. In view of the low numbers of putrefactive anaerobic spores recovered in raw beef, these findings are in agreement. It is not known whether this same condition prevails in the industry but, if it does, it would appear to indicate that it is possible to successfully utilize a thermal process known to be inadequate to destroy spores of some of the more heat-resistant anaerobes.

It is significant that viable organisms were found in cans from which no anaerobic spores were recovered. Work in this laboratory and elsewhere indicates that members of the genus *Bacillus* are commonly found in cured perishable canned meat products. Their role in canned beef is not known and has received insufficient study.

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CHAIRMAN ROBINSON

Thank you, Dr. Ayres.

Now we shall hear from Dr. Gross.

Study of the Incidence of Spoilage Organisms in Canned Meat Products Manufactured under Commercial Conditions [a]

C. E. GROSS

This discussion will be limited to the so-called "commercially sterile" or shelf-type canned meat items. They will be considered in contrast to those receiving pasteurization processes, in the trade termed "perishable," which must be held under refrigeration. Further, only those canned meats made solely from meats and meat by-products as defined by the *Regulations Governing the Meat Inspection of the USDA* (*12*) with approved curing agents added, will be considered. The more complex mixtures of meats and cereals and/or vegetables introduce more complex bacteriological problems and should receive separate study. The group of canned meats specifically covered in this discussion are the pork luncheon meats.

Even in this limited field there are complex bacteriological problems not fully understood. Problems involving technique are likewise difficult. Only the exploratory phases of the indicated research needed have been conducted and published. The major considerations appear to be to make safe products from both the public health and spoilage loss standpoints and in so doing preserve the utmost possible desirable qualities of flavor, texture, and appearance. These considerations are much like those of the commercial canning industry generally. However, the problems are more acute in low-acid products heated by conduction, under which classification are the canned meats.

The bacteriological problem is to destroy or cause to remain dormant any viable organisms that may be present as well as to inactivate enzyme systems. Essentially that is what is meant by a "commercially sterile" process. In this discussion an attempt has been made to point out the limits of the over-all problem with respect to aerobic and anaerobic spore-forming organisms. The purposes have been to evaluate the lethal effect of a range of thermal processes and to determine whether there has been effective inhibition of growth of viable spores when present. The technique used might be termed *fractionation by thermal methods*. Data are derived from samples of product handled in plant-scale operations as well as from competitors' products purchased on the open market.

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[a] This paper is in the nature of a review of data presented earlier; added to it are the findings of the year 1952. It closely follows the form and outline of a paper presented at the Fourth Research Conference at the University of Chicago last year.

Experimental Methods

Although the technique used has been covered in the literature and in considerable detail by Stumbo, Gross, and Vinton (*13*), a short review and comments on deviations or other special handling may be appropriate. Unprocessed cans of product were obtained from the production line by chance selection. Product shipped from another plant was selected the same way and immediately packed with dry ice sufficient to deliver to destination with a small surplus. The cans of frozen product were defrosted by flowing tap water over them for a sufficient period to defrost, but keeping the temperature under 40°F. Two hours have been found sufficient for properly defrosting a 6-pound can.

The cans were opened in the usual manner with good aseptic bacteriological technique. After removing the top portion, a sterile Alemite gun was filled from the center of the can. The desired number of clean, sterile 10x75 mm. chemical test tubes were then filled with approximately one g. of meat. The tubes were sealed in a blast lamp. A 5-minute preliminary process in an oil bath at 175°F. was used to ensure that all tubes were the same initial temperature when processing began. Processing was done in an oil bath controlled to plus or minus 0.1°C. and upon removal immediately transferring to cooling water at 70°F. Part of the tubes used at each heating level were subcultured into glucose brain broth, and the remainder were to be held under 25° to 30°C. incubation conditions for a minimum of 5 years. The number of tubes used varied at different periods in the investigation but was never less than a total of 6. The results of subculture were judged by the usual criteria including examination of microscopic slides. The tubes under incubation were checked by visual inspection at gradually increasing time intervals. Any tubes not appearing normal were classed "suspect" and opened. By organoleptic tests, microscopic examination, and subculture a decision was made as to whether there had been any bacterial activity or, in rare cases, leakage. At the end of 5 or more years under incubation conditions all tubes were to be opened and rated for condition by organoleptic tests and microscopic examination. In any doubtful cases more extensive tests were to be made. The processing values used were expressed in terms of F_o units. [b]

Another method of approach to the problem was to fill 3¼-ounce cans (208x109) with the product being sampled for the standard thermal fractionation procedure and to process them to reach a center temperature of 156°F. by heating 48½ minutes in a water bath controlled at 160°F. This pasteurization process is comparable to those given to perishable products which must be held under refrigeration. The number of viable organisms surviving this pasteurization process gives an estimate of the number of viable organisms, probably in spore form, which the normal "shelf-type" processes would have to inactivate. Gross and Schaub (*4*) proposed a system of nomenclature for pasteurization processes similar to that of Ball (*1*) for the highest temperature processes. The above process would be designated as a process value of $F'=34$.

In Table 1 are shown the lethal effect of various processes. The number of samples containing viable bacteria varies indirectly with level of processing. During the 1944-47 period very high processes were required to reach any high percentage of sterility. It has since been established that the main reason for this was that a large number of the samples contained spores of P.A. 3679 which are known to have a high thermal resistance. The incidence of P.A. 3679 decreased from approximately 40% in the 1944-47 period, to 5% in 1949, to 0.9% in 1950-51, and to 0% in 1952. As the incidence of P.A. 3679 dropped, the number of samples positive at given processing values dropped also. In the 1949 through 1952 period a process of $F_o=0.6$ sterilized from 89% to 95% of the product with an apparent tendency for the percentage sterility to increase from year to year. The point

[b] A thorough discussion of this method of expressing thermal processing results can be found in the *Canned Food Reference Manual* (*14*).

TABLE 1

EFFECT OF THERMAL PROCESSING

Period	No. of Samples	Per Cent Samples Positive for Viable Bacteria[c]				
		Processing Level in F_0 Values				
		0.05	0.2	0.6	1.0	2.0
1944-47	380	98	87	67	40	19
1949	337	79	43	11	0	0
1950-51	218	78	43	9	1.4	—
1952	138	77	36	5	0	—

[c] Incidence of P.A. 3679: 1944-47—approx. 40%; 1949—5%; 1950-51—0.9%; 1952—0%.

for 100% sterilization during the 1949 through 1952 period apparently lay somewhere between F_0=0.6 and 1.0. The 3 samples not sterilized at F_0=1 in the 1950-51 period contained more resistant organisms, two of which were P.A. 3679 and the third *Clostridium sporogenes*. During the 1952 work no P.A. 3679 was found. Even though spores of P.A. 3679 are still present—and may be isolated from scalding tub water—it now appears that the numbers now present are much lower.

The extra tubes not subcultured immediately after processing were to be held under 25° to 30°C. incubation conditions for a minimum of 5 years. The actual holding period on the product reported in Table 1 varied from one month to over 7 years. The group of samples listed as 1944-47 were held a minimum of 51 months and a maximum of 87 months. With the exception of a very few selected samples which are to be held still longer, all tubes for the 1944-47 period were opened. Samples representing each month of the 1944-47 period were examined for viability of the organisms which were known to be present by subculture immediately after processing.

The duplicate tubes from each processing level on each sample of the 1944-47 series were examined at intervals. Any tubes that were discolored or for any other reason appeared to have changed appearance were examined by organoleptic tests and examination of microscopic slides. These tubes were then subcultured into glucose brain broth to check viability. These checks were made in March and August 1946, January 1947, March 1948, and February 1952.

All samples examined microscopically and by organoleptic tests were found to be unaltered at all inspection times, and there was no microscopic evidence of bacterial growth on any. It is interesting that at lower processing levels the contents of the tubes when opened showed no evidence of microbial action by organoleptic tests; the aroma was pleasant and similar to that of product opened a few days after processing. Negative results in themselves are sometimes considered inconclusive, but additional evidence may be cited indicating that the methods are satisfactory. In other such processing and incubation tests on more complex canned meat products such as a liver loaf, spoilage was observed on the lower processing levels after prolonged incubation. The spoilage was detectable by changes in appearance and by a vile, putrefactive odor when the tube was opened. Viable organisms were present when subcultured. Also in this series there was one period when a high percentage of all samples changed to gray and green. This was conclusively traced to microscopic leaks due to off quality of the glass in one lot of test tubes.

TABLE 2

VIABILITY OF SPORES AFTER INCUBATION

Process F_o	Months Incubation	Viable Organisms Present			
		Immed. after Process		After Incubation	
		Yes	No	Yes	No
0.01	5-18	19	0	1	18
	19-30	10	1	5	6
	73-78	36	0	0	36
0.2	6-18	16	2	2	16
	20-37	12	1 [d]	4 [d]	9
	50-70	18	0	2	16
	71-87	29	3	0	32
0.6	13-21	6	5 [d]	4 [d]	7
	26-39	3	1	2	2
	40-60	14	4	0	18
	70-87	35	5	0	40
1.0	13-24	2	6	2	6
	28-36	6	3	2	12
	40-60	27	2	1	28
	60-80	55	4	0	59
	81-86	21	2	0	23
2.0	6-12	1	3	0	4
	20-33	1	1	1	1
	50-60	19	1	0	20
	60-71	22	6	0	28

[d] Sample was negative immediately after processing and positive after incubation —total of 2 samples.

Table 2 shows the results of the subculture of the incubated tubes compared with the results of subculture immediately after processing. In 2 instances viable organisms were found in tubes in a series which were negative immediately after processing. The reverse is also true; this is to be expected since very small numbers of organisms are involved. In spite of these variations there appears to be a trend of loss of viability after prolonged incubation. This is especially marked after about 3 years of incubation.

Samples were selected from the 1944-47 series which had shown viable organisms on subculturing immediately after processing. These samples were subcultured with results as shown in Table 3. No viable organisms were found. Appropriate controls and checks had been used on the media and technique so that these negative results are thought to be significant. The data show that apparently all viable organisms at all processing levels had lost their viability during the 51- to 87-month incubation period. These results were checked on the 1950-51 series of tests and checks made at more frequent time intervals in order to attempt to check the time when viability is apparently lost. Present data would seem to indicate that time to be between 26 and 36 months although 2 samples showed viable organisms after 52 and 61 months, respectively.

TABLE 3

VIABILITY OF ORGANISMS AFTER PROLONGED INCUBATION

Process F_o	Months Incubation	No. Samples [e]	Viable Organisms Present	
			Immed. after Process	Subcultured Feb. 1952
			Yes	No
0.05	51-87	34	34	0
0.2	51-87	37	37	0
0.6	51-87	52	52	0
1.0	51-87	95	95	0
2.0	51-87	40	40	0

[e] Samples selected that were positive after processing.

Table 4 shows data on the effect of thermal processing on meats for canning covering plants in 7 midwestern states. These data were reported at the Fourth Annual Meeting of the Associates, Food and Container Institute (*11*). An industry cooperative group, using a technique similar to that used in the Morrell Laboratory, made the survey. Only one sample of the 177 examined was presumed to be P.A. 3679 or approximately 0.6%. Data in Table 4 correlate well with those in Table 1 indicating that Morrell Laboratory experience is not specific or unusual. In at least an important segment of the total industry the level of thermal processing for a given percentage of samples to be sterile is approximately the same for different plants located in 7 midwestern states. After an incubation period of 30 to 36 months there has been only one tube showing visual evidence of spoilage. One tube processed at F_o=0.05 showed definite digestion of the meat in March 1953. When opened, typical putrefactive odors were present. Microscopic examination and subculturing demonstrated that a

TABLE 4

EFFECT OF THERMAL PROCESSING LEVELS [f]

Plant	No. of Samples	Samples Positive for Viable Bacteria [g]			
		Processing Level in F_o Values			
		0.05	0.2	0.6	1.0
1	57	45	17	0	0
2	29	20	9	3	0
3	25	23	12	1	1
4	21	18	13	1	0
5	18	16	6	0	0
6	16	12	6	0	0
7	11	10	5	0	0
Total	177	144	68	5	1
Total as per cent		81.4	38.4	2.8	0.6

[f] From Associates' survey of 1950 covering 7 states.
[g] One sample was presumed to be P.A. 3679 or 0.56%.

TABLE 5

SURVEY OF 12-OUNCE LUNCHEON MEAT 1949-52

Company	No. of Samples	Subculture		P.A. 3679 present [h]	
		Positive	Negative	Samples	Per Cent
A	35	6	29	4	11.4
B	19	6	13	0	0
C	17	10	7	2	11.8
D	13	5	8	0	0
E	17	3	14	1	5.9
F	17	2	15	1	5.9
X [i]	38	10	28	2	5.3
Total	156	42	114	10	
Total per cent		27	73		6.4

[h] Checked by serological methods.
[i] Represents several samples from each of 6 different companies.

viable organism was present. In the original examination this organism was shown to be *Clostridium sporogenes*. On this sample all the tubes from the various processing levels were then opened and subcultured. No evidence of any off condition was noted when they were opened after the 31-month incubation period. However, on subculture 50% of those positive after processing were now found to be negative.

The results of bacteriological examination of cans of 12-ounce luncheon meat available on the retail market throughout the country are shown in Table 5. The data include samples from the production of 12 companies although those of 6 companies were listed together because of the limited number of samples for each. The over-all average shows that these data are comparable to those in Table 1 for the 1949, 1950-51, and 1952 periods, and in Table 4. The exact thermal processes used on the market product are of course not available but are presumed to lie in the range 0.2 to 0.6 F_0. Three samples from a total of 130 competitors' samples examined during 1952 contained P.A. 3679 or 2.3%. Among Morrell products one such sample was found in 166 samples examined or 0.6%. Thus, it would appear that the 1952 period shows a decline in the percentage of samples containing P.A. 3679.

TABLE 6

TOTAL SPORE LOAD IN TRIMMINGS

Plant	Samples	Range of Viable Spores after Pasteurization					
		0 to 10		11 to 100		over 100	
		Samples	Per Cent	Samples	Per Cent	Samples	Per Cent
1951 A	65	24	37	23	35	18	28
B	32	11	34	14	44	7	22
1952 A	130	33	25	67	52	30	23
B	33	9	27	21	64	3	9
Total	260	77	30	125	48	58	22

Some work was done on determining the total number of spores present in normal well-handled meats such as are used to make canned luncheon meat. The Armour (*6*) and Iowa State College (*2*) groups have found very small numbers of putrefactive anaerobes normally present. The total load of spores would be of importance in thermal processing and so in Table 6 are data from the survey; routine bacteriological methods were used and the counts were made after pasteurization to destroy vegetative cells. Most counts were made on samples later used to show the effect of thermal processing (Table 1). These data confirm the general observations in the literature that the total numbers of spore-forming bacteria may be quite high in normal, well-handled trimmings such as are used to make canned luncheon meats. On the other hand these numbers are quite low compared to the levels normally used in inoculated pack studies.

Discussion

The purpose of the conventional thermal processing of canned meats is to destroy microbial life so that the product may be kept at ordinary storage temperatures without deterioration due to microbial action. There is considerable evidence to show that complete destruction of microbial life is not always essential. In many instances actual viable organisms are present that remain dormant or are inhibited from germination by some factor(s). Thus, a so-called safe commercial process does not always require the complete destruction of life but in some instances only a complete and proved inhibition of future microbial growth during the desired maximum shelf life of the product.

Usually the thermal processing required by conventional procedures for absolute sterility is so high that the desirable organoleptic characteristics are adversely affected. In attempting to reduce the excessive thermal processing required, attention has been directed to ways and means of producing satisfactory products as determined by test pack procedures and actual production experience rather than by theoretical bacteriological considerations and arbitrarily ruling that each and every can of every product must be completely sterile.

Among the theoretical considerations is usually the fact that 3 putrefactive anaerobes have great significance because of the high thermal resistance of the spores and the possible public health significance of one of them. The 3 usually considered in meat canning technology are *Clostridium sporogenes, Clostridium botulinum,* and P.A. 3679. Directly affecting this consideration is the fact that numbers of organisms present affect the thermal processes required to destroy them. Data on the normal numbers of spores of putrefactive anaerobes present would be of great value. The work of the Armour (*6*) and Iowa State College (*2*) groups has been of great value in indicating that the numbers are normally very low. Data from papers by Esty and Meyer (*3*) and Houston (*7*) indicate that the thermal death-time of small numbers of spores of *Clostridium botulinum* is very low. Unpublished data from this laboratory indicate that the thermal death-time of small numbers of spores of *Clostridium sporo-*

genes in meat products is relatively low, in the range F_o—0.2 to 0.5. On the other hand, Gross and co-workers (*5*) have reported that very high thermal processes are required to destroy very small numbers of spores of P.A. 3679. Normal processes given canned meat products do not destroy small numbers of spores of P.A. 3679. Data in the literature (*10*) indicate that spores of other common putrefactive anaerobes have a lower thermal resistance than *Clostridium sporogenes.* From these considerations it would seem that the required thermal processes could be drastically reduced if spores of P.A. 3679 could be eliminated and the number of spores of *Clostridium sporogenes* and other putrefactive anaerobes were very low. The fact is that in most normal meats the spore load of putrefactive anaerobes *is* very low. If P.A. 3679 were absent, then the required thermal process should be very low. From the data given in this report such is not the case. Other investigators, especially Jansen and Aschehoug (*8*), have concluded that in many cases aerobic spore formers of the genus *bacilli* are important factors in spoilage of canned meats. Jensen (*9*) reported that such organisms were important in the spoilage of the perishable class of canned meat items. Various sources report that much greater numbers of such organisms are normally present in meat. The Morrell Laboratory has found under normal conditions of operation and handling that total spore loads in the hundreds are not uncommon as shown in Table 6. Unpublished work has shown that the resistance of such numbers of spores of some aerobic organisms may be as high as 0.2 F_O. This resistance is considerably higher than is reported in the literature but it has been found that in a meat substrate the thermal resistances may frequently be much higher.

One problem that may not have been explored sufficiently is the point of temperature or total thermal process where the organoleptic properties deteriorate seriously. If this information were available, a reasonable estimate of the possibilities of processing to commercial sterility conditions with conventional thermal processing procedures could be made. The small amount of data available would seem to indicate that the possibilities of improvement of organoleptic qualities through thermal process reduction appear to be very limited by the conventional procedures. If this can be confirmed, it should only serve to still further stimulate the existing research efforts on other possible procedures such as electronic heating and high-energy radiation.

It is interesting that even though as much as 98% of the product processed at F_o=0.05 was not sterile, there was no evidence of germination of spores, subsequent growth, and spoilage, until recently. Perhaps this one exception is in itself significant. One tube out of 4 from the 0.05 processing level of plant 4 in Table 4 showed typical digestion and reddening at some time between 18 and 30 months under

incubation at 30°C. This sample was positive immediately after process through F_0 0.6 and a putrefactive anaerobe was isolated which was identified by serological methods as *Clostridium sporogenes*. To this date no other samples have ever germinated and grown from any of the extensive series of experiments on normal production-line pork luncheon meat products. Many of these were known to contain viable spores of both P.A. 3679 and *Clostridium sporogenes*. Apparently the standard curing agents used are effective inhibiting agents, or perhaps, more accurately, bacteriostatic agents. This is especially noteworthy when the incubation time of up to 87 months at 30° C. is considered.

It was known and demonstrated that in many of these samples viable spores of P.A. 3679 were present as well as *Clostridium sporogenes* and aerobic spore formers. The effectiveness of bacteriostatic action with respect to viable spores of anaerobes is no longer definite since the one case of germination and growth of *Clostridium sporogenes* has been found. Another bacteriostatic factor in addition to curing agents is also present and may seriously exert an effect in restricting the germination of some organisms. This factor is a lowered oxygen tension. The oxidation-reduction potential of cured meats no doubt has some effect, either favorable or adverse, depending on the class of organism. One fact becomes all the more important: namely, the factors affecting spore formation, germination, and inhibition which must be studied and understood. The reasons as to why there was an almost completely effective inhibition of germination need to be known before the safety and reliability of depending on such inhibition can be judged.

Another interesting observation was the demonstrated viability of spores in canned meat products over long periods of time under conditions of 30° C. incubation but with an eventual loss of viability at still longer times. Apparently from 26 to 31 months under such conditions is the normal period of loss of viability although 2 exceptions surviving a processing level of 0.2 were viable after 52 and 61 months.

Summary and Conclusions

The level of thermal processes required to reach sterility in cured canned luncheon meat products has been lowered in the past few years. The incidence of occurrence of P.A. 3679 has decreased from that of great importance at 40% to relative unimportance of from 0.6% to 2.3% on Morrell and competitors' products, respectively, in 1952. During one extensive survey in 1952 covering 2 plants no P.A. 3679 was found in pork luncheon meat products. The percentage of product sterile at a processing level of F_0 0.6 increased from 33% in the 1944-47 period to 95% in 1952. Similar figures for a processing level of F_0=0.02 would be 13% to 63%. On the other hand, at the lowest level of F_0=0.05 the increase was only 2% to 27%.

Processes to assure sterility of a very high percentage of the product would have to exceed F_o=0.6. This is supported by the findings on a 12-ounce market product presumed to be processed in the range F_o=0.2 to 0.6.

There was only one instance of spoilage due to germination and growth of viable spores surviving thermal processes during the 9 years of this survey work. This was due to one tube out of 4 processed at F_o=0.05 spoiling sometime between 18 and 30 months incubation at 30° C. The spoilage was due to germination and growth of spores of *Clostridium sporogenes*. None of the other tubes at that processing level or at the 0.2 or 0.6 levels have shown evidence of growth after 30 months incubation at 30° C. The tubes from all other samples were incubated as long as 87 months and spores were shown to be viable as long as 61 months. The loss of viability of spores surviving thermal processes apparently usually took place during 26 to 31 months of incubation at 30° C., although 2 samples showed survival periods of 52 and 61 months.

There appears to be evidence that aerobic spore formers are an important factor and perhaps a limiting factor in attempting to lower thermal processes. The point to which processes may be lowered is in doubt as is also whether or not the final point would be at a level yielding worth-while improvement in organoleptic properties.

Further fundamental work is indicated as necessary in order to understand and control the apparent inhibitory or bacteriostatic action of curing agents on viable spores present in a rather substantial percentage of commercial cured canned luncheon meats. Work is also needed to determine whether or not improvement in organoleptic properties can be realized by lowering thermal processes at all, using the normal thermal processing procedures. Conversely, increased attention should be given to unorthodox procedures such as electronic heating, high-short processes, and high-energy radiation.

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III. Mode and Rate of Heat Transfer in Canned Meats

TUESDAY AFTERNOON SESSION

March 31, 1953

The meeting reconvened at 1:15 o'clock with Dr. Robinson presiding.

CHAIRMAN ROBINSON

This afternoon while the subject is still fresh in your minds we would like to call on Dr. Halvorson of the University of Illinois to comment on his impression of the morning session. Dr. Halvorson.

H. O. HALVORSON

The purpose of this meeting, I take it, is to review our knowledge to see where we are at this time and to see whether we can do anything else to approach the goal—how to obtain sterile products that have not been overcooked. Such meetings as this are very useful for that purpose. And now my observations on the papers:

Dr. Gross made an impressive point when he showed that even now a fairly large percentage—from 40% to 60%—of the so-called pasteurized meat products that have been cooked at a relatively low temperature are sterile. I am sure if he dared, he could well go to his management and say, "Now, look and see what we have done. By improving our housekeeping, we have eliminated these bad organisms, and therefore improved our products." Perhaps that is the reason—housekeeping—but I am afraid there may be more subtle reasons that we don't know or understand as yet. Some people, probably some in management, would say, "If you can do this to 44% of the cans, why can't you do it to all of them?" Perhaps we can, but at present we lack some essential information. What this industry needs, I think, is the appropriation of funds for more fundamental work, and I am very happy to see from the papers given this morning that more fundamental work is being done. I spent some 20 years serving as a consultant to this industry, making use largely of the information that was available at the beginning of that time. During those years I did no fundamental research. As a result, I didn't contribute anything.

If the Armed Forces want to solve this problem, I think it is absolutely essential that they appropriate some of their money to support fundamental research. When we get enough fundamental data, we can then apply it, and perhaps solve the problem.

Also, I think the industry or the Armed Forces, whoever has the funds, should appropriate money so that you can bring together people who are doing fundamental research on spores—12 or 15 people, not

any more. They can sit and argue about what they have been doing, take their hair down, and call each other names. When they come home from such a meeting, they will then be stimulated to further work; then they can meet before you and let you know what they have accomplished. To sum up, I would like to see more funds devoted to fundamental research and more funds devoted to these small conferences. They are extremely useful.

CHAIRMAN ROBINSON

Thank you very much, Dr. Halvorson.

Now we come to another phase of this consideration of the quality and stability of canned meats. That has to do with the mode of heat transfer in canned meats, and our first speaker on that this afternoon will discuss "The Effect of Processing Temperature upon the Rate and Pattern of Heat Distribution within a Can of Beef." He is Dr. Tischer, formerly of Iowa State College, now director, Food Laboratories, Quartermaster Food & Container Institute for the Armed Forces.

The Effect of Processing Temperature upon the Rate and Pattern of Heat Distribution within a Can of Beef

ROBERT G. TISCHER

The work to be described was undertaken as part of a project designed to illustrate the effect of processing temperature, especially in ranges higher than those usually employed in the processing of meat, on the ultimate quality of canned beef. The distribution of isothermal surfaces in the container during processing at various temperatures was studied to learn, if possible, the actual occurrences in beef and to discover whether these occurrences are identical with those predicted from theoretical considerations.

Experimental procedure. The experimental design used contained 6 equally spaced processing temperatures ranging from 225° to 315° F. At each temperature a set of times was used appropriate for that temperature. The times at 225° F. ranged from 10 to 120 minutes; the times at 315° F. were 2 to 24 minutes and the times for the remaining temperatures were located between these 2 sets. The temperature points measured in the container were 25 in number and were measured at the rate of 7 per experimental unit. The placement of the points within the container is shown in Figure 1 indicating that the points were systematically placed on vertical axes of the can from the center toward the outside and covering most of the half-plane of the can. Measurements were made with a multipoint recording potentiometer. The processes were controlled with an automatic time-temperature program controller.

Discussion

The temperature curves derived for each point in the processes were interpolated by means of graphical methods to yield isothermal lines within the container.

In a consideration of isotropic media heating by conduction, the normal theoretical expectations for isothermals would begin with a cylindrical distribution at

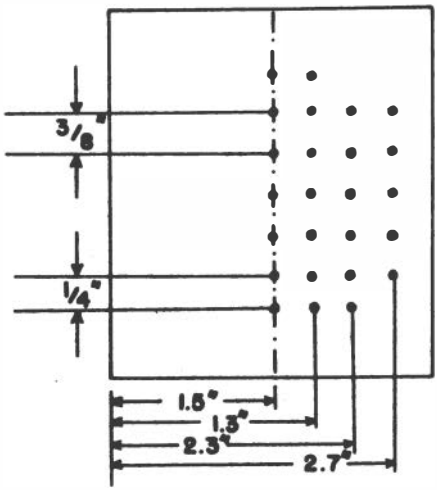

FIGURE 1.

PLACEMENT OF POINTS IN A CYLINDRICAL CONTAINER. TEMPERATURES WERE REPEATEDLY MEASURED AT THE POINTS SHOWN DURING EACH PROCESS AND FOR THE DURATION OF THE PROCESS.

time zero followed by ellipsoidal distributions as time progresses and ending in a small sphere or a true geometric point at some later time in the process. These occurrences are illustrated in Figure 2 in which the periphery of the half-plane of the can may be taken as a representative of the cylindrical distribution; the egg-shaped isothermal shell shown in the can represents one of the infinite number of the isothermal ellipsoids which might normally be expected.

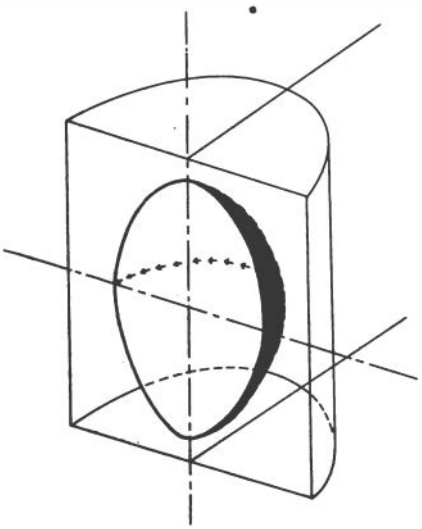

FIGURE 2.

HALF-PLANE DIAGRAM OF A CYLINDRICAL ISOTHERMAL ELLIPSOID DISTRIBUTION.

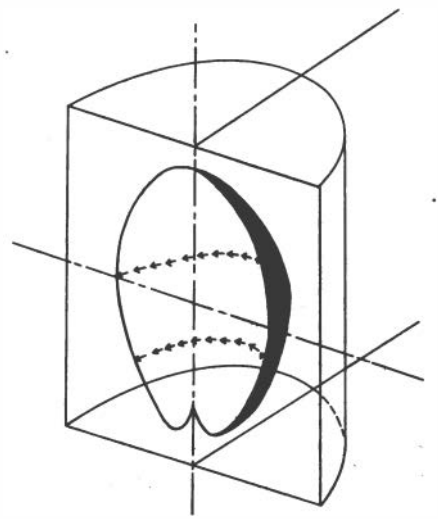

FIGURE 3.

ELLIPSOID ISOTHERMAL SHOWING CARDIOID TENDENCY AT LOWER END.

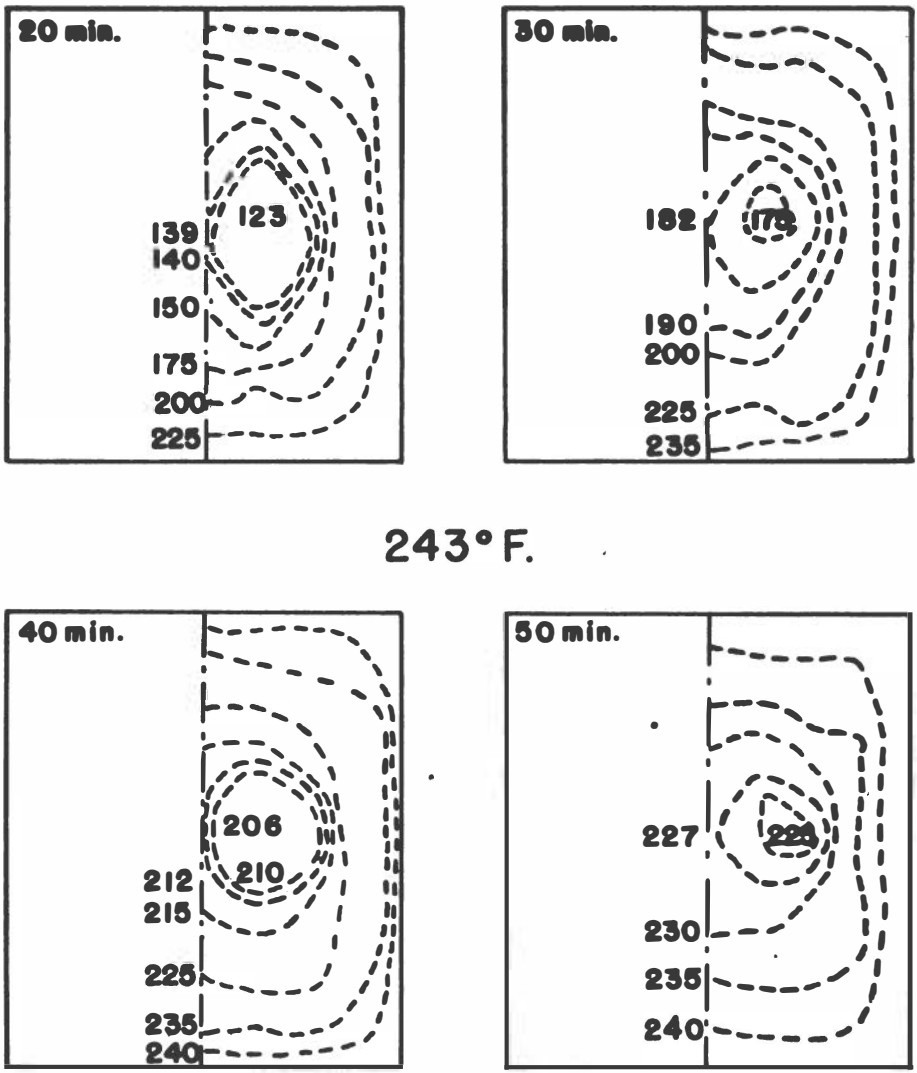

FIGURE 4.

DISTRIBUTION OF ISOTHERMAL LINES IN THE HALF PLANE OF A CONTAINER BEING PROCESSED AT 243° F. AT 4 TIMES; 20, 30, 40, AND 50 MINUTES. THIS FIGURE SHOWS THE AREAS OF SLOWEST HEATING FROM WHICH THE TORUS MAY BE DEVELOPED BY ROTATION THROUGH 360° F. AN ILLUSTRATION OF THIS DEVELOPMENT IS APPARENT FROM OBSERVATION OF THE 225° F. ISOTHERMS AT SUCCEEDING TIMES. NOTE THAT THE ISOTHERM MOVES TOWARD THE CENTER LINE AND FINALLY FOLDS IN TO FORM A ROUGHLY CIRCULAR AREA FROM WHICH THE TORUS IS DEVELOPED.

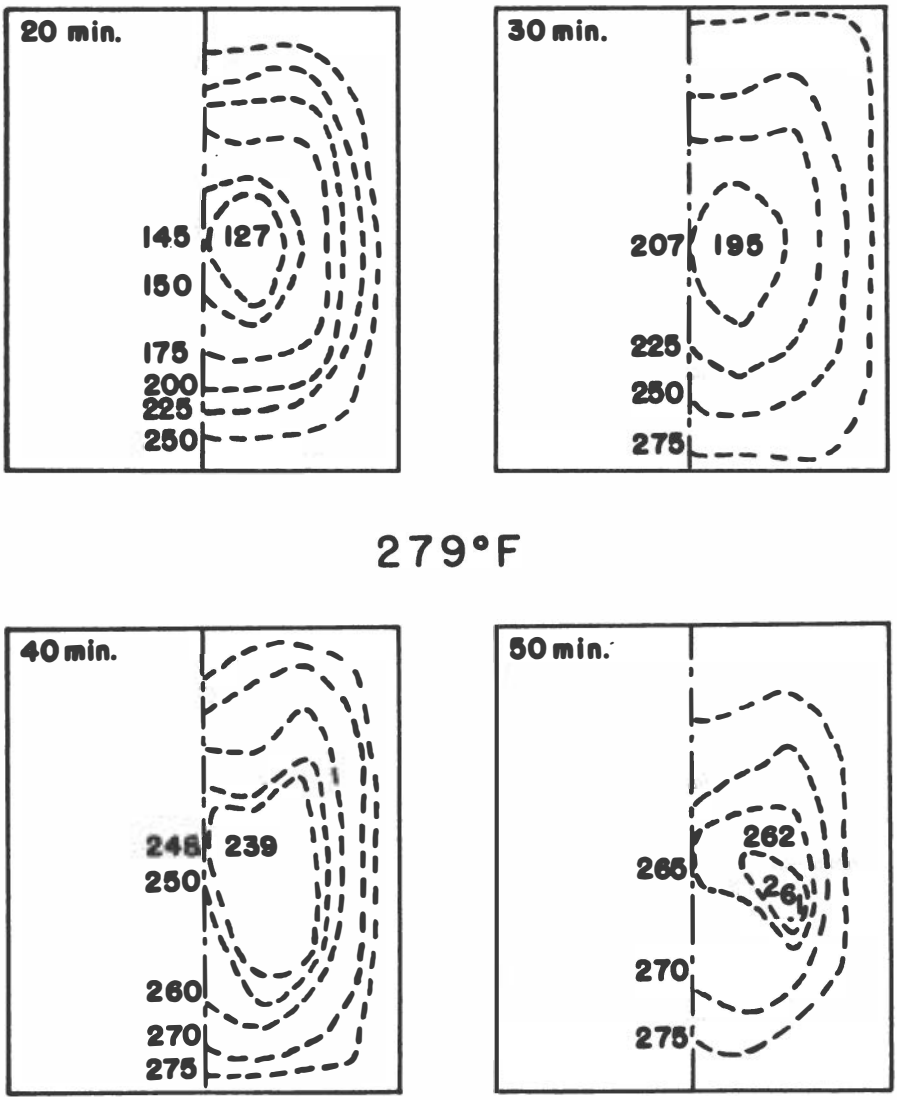

FIGURE 5.

DISTRIBUTION OF ISOTHERMAL LINES IN THE HALF PLANE OF A CONTAINER BEING PROCESSED AT 279° F. AT 4 TIMES; 20, 30, 40, AND 50 MINUTES. IN THIS FIGURE THE 250° F. ISOTHERMAL LINE MOVES TOWARD THE CENTER AS TIME ADVANCES. BETWEEN 40 AND 50 MINUTES, HOWEVER, THE EMBRYONIC 250° TORUS PASSES OUT OF EXISTENCE DUE TO THE EFFECT OF INCREASED PROCESSING TEMPERATURE. AT 50 MINUTES, THE LOWEST ISOTHERM IS THAT FOR 261° F., LOCATED CONSIDERABLY AWAY FROM THE CENTER LINE OF THE CONTAINER.

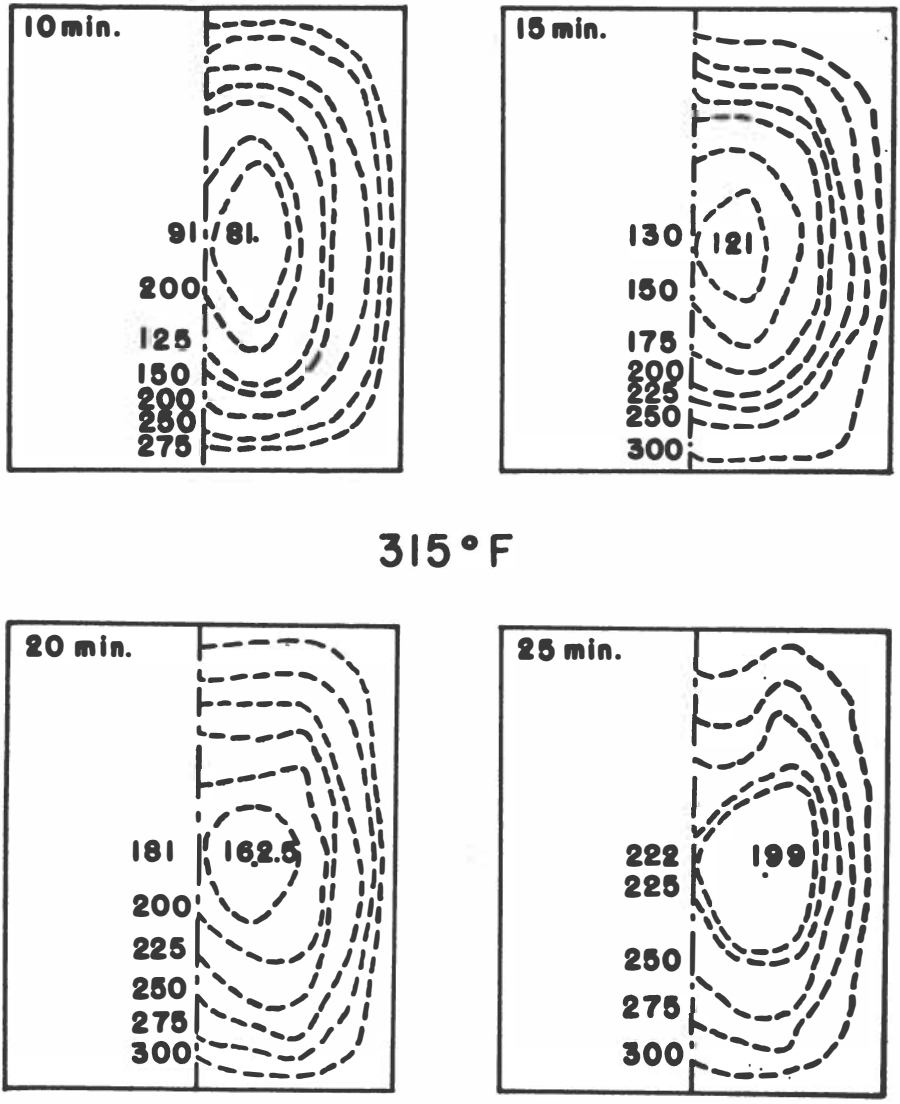

FIGURE 6.

DISTRIBUTION OF ISOTHERMAL LINES IN THE HALF PLANE OF A CONTAINER BEING PROCESSED AT 315° F. AT 4 TIMES; 10, 15, 20, AND 25 MINUTES. AT THIS HIGH PROCESSING TEMPERATURE THE GREATLY INCREASED TEMPERATURE DIFFERENTIAL FROM THE OUTSIDE TO THE CENTER OF THE CONTAINER IS IMMEDIATELY APPARENT, BEING OF THE ORDER OF 100° F. AT 50 MINUTES AS COMPARED WITH APPROXIMATELY 15° F. FOR THE LOWER PROCESSING TEMPERATURES. ANOTHER EFFECT OF HIGH PROCESSING TEMPERATURE APPEARS IN THE FORM OF SOMEWHAT ENLARGED AREAS OF SLOWEST HEATING WHICH PERSIST THROUGHOUT THE TIMES SHOWN.

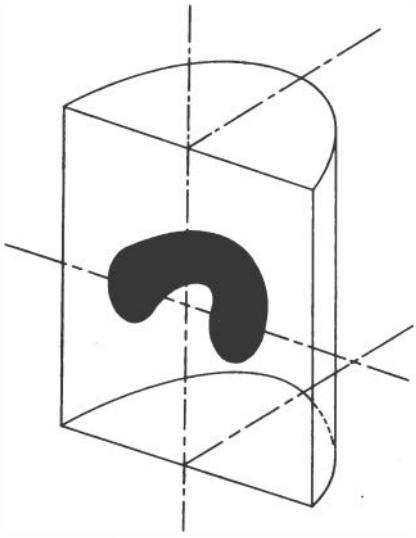

FIGURE 7.

IDEALIZED CIRCULAR HALF-TORUS DISTRIBUTION OF LOWEST TEMPERATURES.

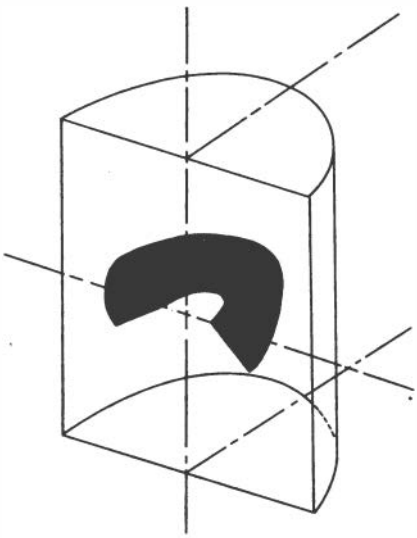

FIGURE 8.

IDEALIZED TRIANGULAR HALF-TORUS DISTRIBUTION OF LOWEST TEMPERATURES.

In the event that some anisotropy exists in the medium a distribution of the form shown in Figure 3 might be expected in which a cardioid distribution would result with either one or both ends depressed. The existence of the cardioid is supported by experimental findings.

The actual data from this experiment follow the pattern shown in Figures 4, 5, and 6. These figures illustrate the progression of isothermal lines in the half-plane of the container at 3 of the 6 processing temperatures used and for 4 times. Observation of each of these 3 figures indicates that for a great share of the time during the process the isothermal lines, if rotated through the 180° F., would tend to form roughly ellipsoidal shells. As time progresses at each temperature it should be noted that the isothermal lines tend to close at the center forming a roughly circular area located to the right of the can center and either on the horizontal central axis of the can or somewhat above or below it. These effects appear to be approximately the same at each of the representative processing temperatures used, suggesting that the effect of processing temperatures on this occurrence may be negligible.

If the circular isothermal areas resulting from these processes were rotated through 180° F. in the can, the result would appear as shown in Figure 7, a solid geometric figure resembling half a doughnut. Geometrically, this is termed a *torus* or in this case a half torus and represents what might be termed an "isothermal volume of lowest temperature" at the time of observation. In actuality, it is difficult to explain this occurrence except on the basis of anisotropy in the medium being heated. If this effect does exist, it might be considered in terms of a distortion of the normal ellipsoidal distribution. Consider, for instance, the effect of the ends of the container on the distribution of temperature in the case where the distribution at the top may be concave upward and that at the bottom concave downward. In this case, the progression of portions of isothermals toward the center would result in the formation of a roughly triangular area somewhat off the center of the can which, were it to be rotated through 180° F. in the can, would form a torus resembling that in Figure 8.

While it is difficult to prove rigorously on the basis of existing data whether the torus described actually exists, the data from this experiment are concordant in that in almost every case this phenomenon was noted. If the existence of the torus may be taken as a fact, this phenomenon might be of considerable importance in determining the sterility of a container of meat. In addition, the effect of such a temperature gradient upon the ultimate quality of the product, measured in terms of tenderness, juiciness, flavor or otherwise, might be worth consideration.

CHAIRMAN ROBINSON

Thank you, Dr. Tischer.

The next paper on the afternoon program will describe the effect of ingredient arrangement on the rate of heat transfer in canned meat products. We are very happy to have with us Dr. C. Olin Ball of Rutgers University, who will discuss this subject.

Effect of Ingredient Arrangement on the Rate of Heat Transfer in Canned Meat Products

C. OLIN BALL

In conventional practice, a product requires severe heating during the sterilizing process because heat is transmitted through the product by conduction and therefore travels very slowly. However, when the formulation of the product is not completed by mixing the ingredients prior to filling into the can, one may take advantage of this fact to obtain an increased rate of heat penetration into the product during the sterilizing process. This is made possible by putting the ingredients into the container under a special arrangement so that heat will flow through a part of the ingredients by convection. This technique had its first commercial application in 1950 on cream style corn in No. 10 cans—producing a sterile product of a quality as good as that produced by conventional processes inadequate to destroy thermophilic spores. It is designed for use with products which constitute a mixture of discrete particles with a finely divided component of either the same or a different species of food.

Procedures with cream style corn. As mentioned, the only product on which there is commercial experience is cream style corn. The procedure is as follows: the concentrated cream component, consisting of triturated whole corn kernels, is kept separated from the whole kernels and brine until after the sterilization is accomplished. Afterwards, the cream component is mixed with the brine and kernels either by shaking the sealed container or by stirring after the container is opened.

In filling this product, the cream component, of course, is put into the container separately from the kernels and brine; then sterilization is carried out while the cream is kept stratified in a layer separate from the kernels and brine. The stratification of components is illustrated in a cross-section diagram of a can of cream style corn shown in Figure 1. About two-thirds of the can is filled with kernels of corn surrounded by water or brine and the layer above the kernels consists of finely ground corn kernels containing a small amount of water and possibly

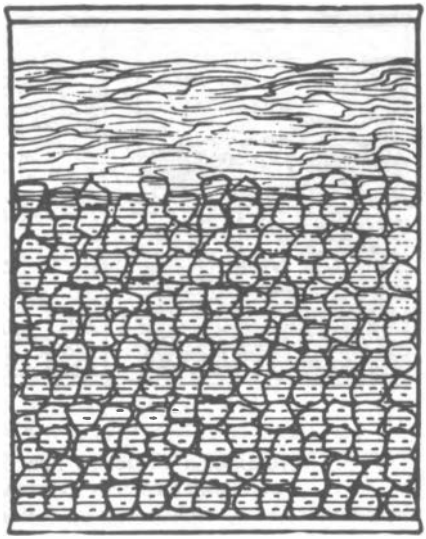

FIGURE 1.

STRATIFICATION OF COMPONENT PARTS OF CREAM STYLE CORN IN THE CAN.

Courtesy *of Food Industries* (now *Food Engineering*)

some sugar and salt. During processing, heat flows into the product by convection and conduction along paths roughly indicated by the arrows in Figure 2. The mixture of thin liquid and kernels heats quite rapidly by convection while the layer of fine solid material heats slowly by conduction. Since the vertical dimension of this layer is small, however, heat is transferred to the center of the layer

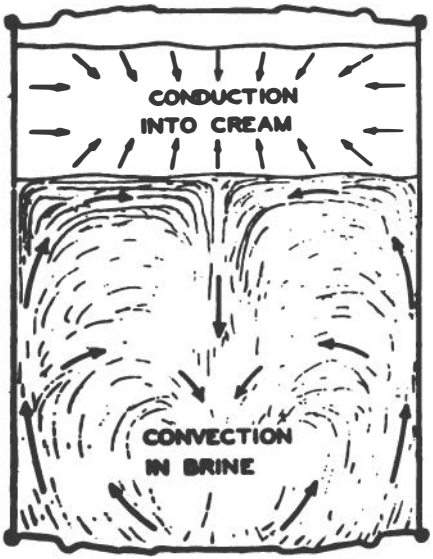

FIGURE 2.

ARROWS INDICATE PATHS OF HEAT FLOW BY CONVECTION AND CONDUCTION INTO STRATIFIED PRODUCT.

Courtesy *of Food Industries* (now *Food Engineering*)

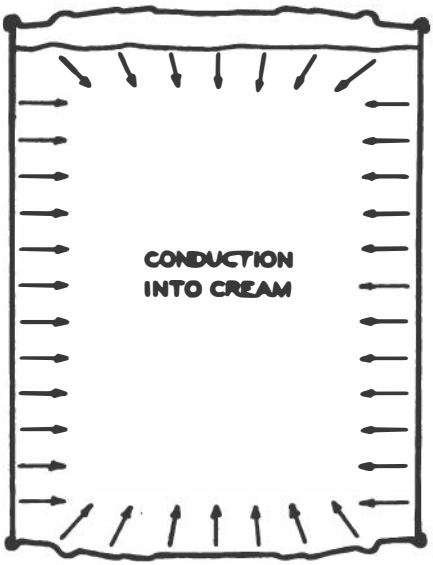

FIGURE 3.

ARROWS INDICATE PATHS OF HEAT FLOW BY CONDUCTION INTO PREMIXED PRODUCT.

Courtesy *of Food Industries* (now *Food Engineering*)

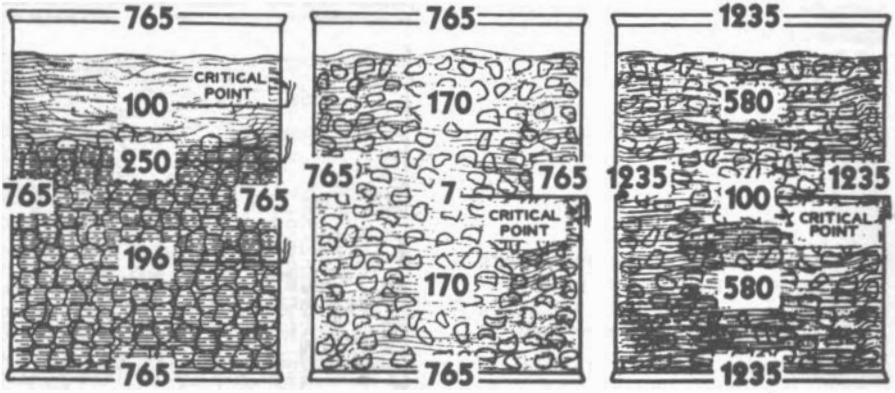

FIGURE 4

NUMERALS INDICATE PER CENT OF LETHAL HEAT REACHING DIFFERENT POINTS IN STRATIFIED AND PREMIXED PRODUCTS.

Courtesy of *Food Industries* (now *Food Engineering*)

in much less time than it takes to transfer heat to the center of a can containing a premixed product of sufficiently heavy consistency to necessitate all of the heating being done by conduction, as indicated by the arrows in Figure 3.

The relationship between premixed cream style corn and the stratified pack in respect to sterilizing values is shown in Figure 4. The boxed numerals in the 3 diagrams indicate what percentage of the lethal heat that is necessary to sterilize the corn reaches each of several points in each can during a specified process. The first can, containing the stratified product, and the second can, containing the premixed product, are presumed to have received the same process—a process which is sufficient to apply to the surface of the container 765% of the amount of heat necessary to sterilize the surface layer of corn. During this process, the stratified corn is sterilized at its critical point, whereas, at the critical point in the premixed product, only 7% of the lethal heat necessary to sterilize the corn is effective. To sterilize the premixed corn at the critical point, the third diagram shows that surface layer would have to be subjected to 1235% of the amount of lethal heat necessary to sterilize the corn. Obviously, the quality of the premixed corn would be impaired much more during its sterilization than would the quality of the stratified corn during its sterilization. Equivalent processes at 250° F. for these 2 types of product in No. 2 cans are 74 minutes and 46 minutes, respectively. Relative rates of heat penetration in the 2 products in 4 different sizes of cans are shown by the curves in Figure 5.

Procedures with meat (laboratory experiments only). What I shall say about meat products is based on laboratory experiments only. Four different formulated meat products were studied at Rutgers University in a project sponsored by the Quartermaster Food and Container Institute for the Armed Forces. These were *ham and beans in molasses sauce, frankfurters and beans in tomato sauce, beef and vegetables in gravy,* and *meat balls and spaghetti.* Temperature measurements in the can were made with thermocouples specially designed for this kind of work *(4)*. In the calibration of the thermocouples an oil bath was used. With a thermocouple and a standardized mercury-glass thermometer placed close together in the oil, the bath was heated slowly and cooled slowly through the range of temperature of the calibration. Precisely timed readings were taken on both instruments throughout the periods of rise and fall of temperature and the time-temperature relationship of each was plotted on rectangular coordinate paper. For each temperature, the correction indicated by the rising curve was

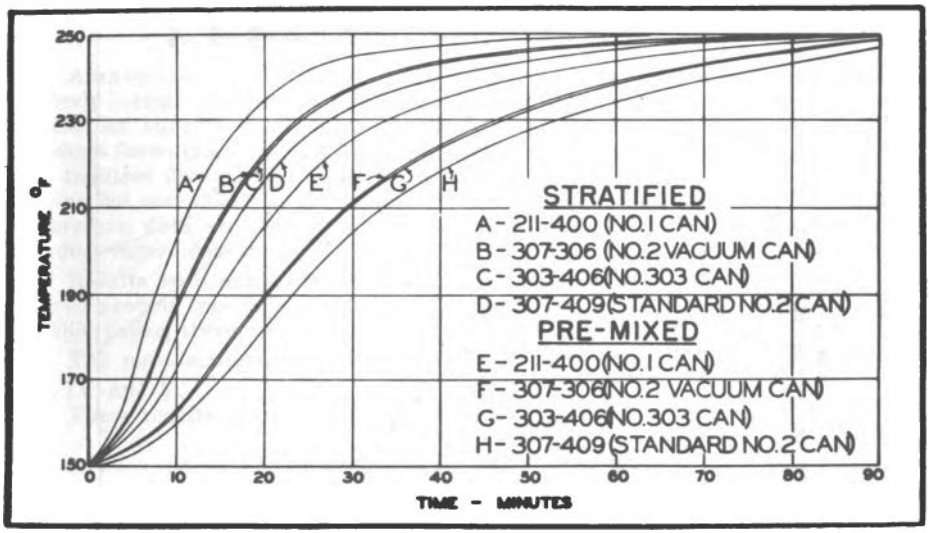

FIGURE 5.

RELATIVE RATES OF HEAT PENETRATION INTO STRATIFIED AND PRE-MIXED CREAM STYLE CORN IN CANS OF 4 SIZES.

Courtesy of *Food Industries* (now *Food Engineering*)

averaged with that indicated by the falling curve and the calibration curve for the thermocouple was made by plotting, in a smooth curve, these corrections against temperature. No significant correction was required in any case with the thermocouples used in these tests.

Temperatures measured by the thermocouples were recorded on a Brown Electronik 12-point Strip Chart Recording Potentiometer having a chart speed of 20 inches per hour and a temperature range of from 0° to 350° F.

Each product was studied, first, when formulated and packed according to Military specifications, second, when the method of packing the components in the container is altered—either without or with alteration in formulation from that of Military specifications. The initial objective was always to study the effect of rearrangement of component parts in the container without altering the nature and the proportions of the ingredients from those called for in the specifications. Then the investigation was extended to cover variations in the nature and, in one or two instances, the proportions of the ingredients for the purpose of seeking a modified formulation which will give best results with a modified arrangement of ingredients in the container.

The rise of temperature was measured at several points in each can; measurements were made at as many as 9 points in a can. This made it possible to construct isothermal and isochronal diagrams of a can to help determine the location of the critical point, and to compare the relative heat effects on the ingredients in different locations. Studies on specific products are reported as follows:

Ham and beans in molasses sauce. This product was studied for rate of heat penetration with 5 different arrangements of components in the 404 x 404 can. These were:

I. (a) *on the bottom*: raw ham slices, ½-inch thick.
   (b) *above the ham slices and extending into the upper portion of the can*: blanched kidney beans.
   (c) water withheld from the sauce preparation (178.8 ml.) was poured over the beans.

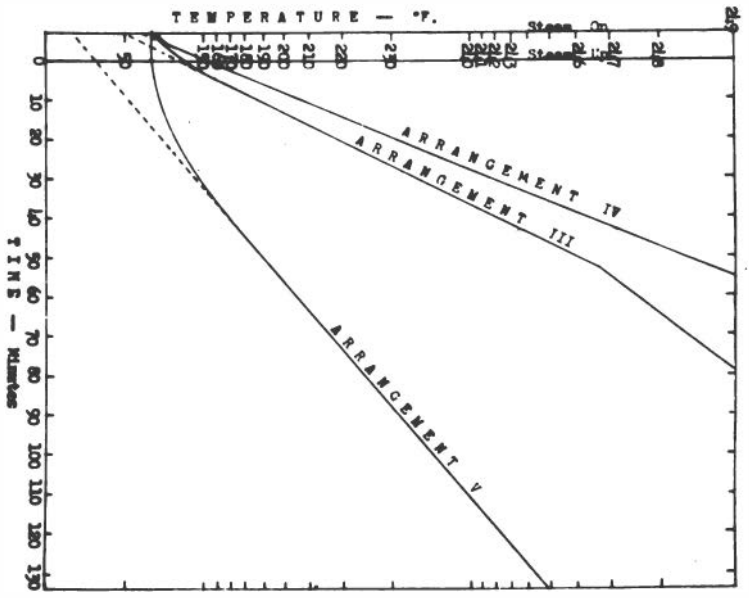

FIGURE 6.

RATE OF HEAT PENETRATION AT POINT OF SLOWEST HEATING IN EACH OF 3 CANS (1ST, 3RD, AND 4TH CANS OF TABLE 1) OF HAM AND BEANS IN MOLASSES SAUCE.

(d) thick sauce (formulated without water) was spread evenly on top of the beans which were just covered with water.

II. (a) *on the bottom*: one layer of ham slice, ½-inch thick.
(b) *above the ham slice and extending past the middle of the can*: blanched kidney beans mixed with a portion of the ham cut into pieces approximately ¾-inch x ¾-inch x ½-inch in size.
(c) water withheld from the sauce preparation (178.8 ml.) was poured over the beans, not quite covering the beans.
(d) thick sauce (formulated without added water) was spread evenly over the beans.
(e) the remainder of the ham, a slice ½-inch thick, was laid on top of the sauce.

III. (a) *on the bottom and filling the major part of the can:* blanched kidney beans mixed uniformly with ham cut into pieces approximately ¾-inch x ¾-inch x ½-inch in size.
(b) water withheld from the sauce preparation (178.8 ml.) was poured over the mixture of ham and beans, not quite covering the mixture.
(c) thick sauce (formulated without added water) was spread evenly over the ham and bean mixture.

IV. (a) *on the bottom and filling the major part of the can:* blanched kidney beans mixed uniformly with ham cut into pieces varying from approximately ¾-inch x 1-inch x 1-inch to approximately ¾-inch x 1½-inch x 1½-inch in size.
(b) water withheld from the sauce preparation (178.8 ml.) was poured over the mixture of ham and beans, not quite covering the mixture.
(c) thick sauce (formulated without added water) was spread evenly over the ham and bean mixture.

V. Formulated and packed according to Military specifications.

Results

Arrangement I gave a rather indefinite result and one which did not seem entirely logical; the critical point was indicated to be approximately in the center of the can but still the rate of heating was considerably higher than that of the product formulated and packed according to the Military specifications. Since the required process indicated by the test on one can was in the medium range, it was not considered worth while to take the time to clear up the inconsistency. Therefore, data are not available to show the effect of this arrangement of the product ingredients in the can.

Results with arrangement II appeared to be reliable but here also the required process was indicated to be one in the medium range. For the purpose of this paper, therefore, it will be passed by.

The most significant results seem to be those obtained with arrangements III, IV, and V.

These results are presented in Table 1.

TABLE 1

HEAT PENETRATION AND PROCESS DATA—HAM AND BEANS IN MOLASSES SAUCE

Arrangement ——————>	III	IV		V
f_{h1}	34	24	27	80
f_2	51.5			
x'_{bh}	59			
j	0.938	0.759	0.855	1.815
Process (min.)	50.5	28.8	31.6	95.6

Heating curves for the cans represented in the 2nd, 4th, and 5th columns of Table 1 are shown in Figure 6.

The processes listed in Table 1 are based on the following specifications (1, 2, 3):

$z = 18°$ F.
$F = 5$ min.
$RT = 250°$ F.
$IT = 150°$ F.
$CW = 60°$ F.

These data indicate that the process at 250° F. required for sterilization of this product when filled into 404 x 404 cans in accordance with arrangement IV is less than one-third as long as that required when the filling is under arrangement V, i.e., in accordance with Military specifications. The process required under the filling procedure III is slightly more than half as long as that required when the filling is under arrangement V. Thus, the possibility of a considerably greater reduction in process through a particular arrangement of ingredients in the can is shown for ham and beans in molasses sauce than in corn.

Frankfurters and beans in tomato sauce (307x306 cans). Heat penetration tests, made with 3 different arrangements of component parts in the 307 x 306 can, were as follows:

I. (a) *on the bottom and filling the major part of the can*: frankfurter pieces (½-inch) and soaked and blanched beans. (These were put into the can and then shaken to mix thoroughly.)
   (b) water withheld from the sauce preparation (99.3 ml.) was poured over the mixture of frankfurters and beans, practically covering the mixture.

(c) thick sauce (formulated without water) was spread evenly over the frankfurter and bean mixture.

II. (a) *on the bottom and filling the lower part of the can*: ½-inch pieces of frankfurter.
(b) soaked and blanched beans were filled on top of the frankfurter pieces.
(c) water withheld from the sauce preparation (99.3 ml.) was poured over the beans, filling the interstices among the frankfurters and beans.
(d) thick sauce (formulated without water) was spread evenly over the beans.

III. Product was formulated and packed according to Military specifications.

Results. In one respect, frankfurters and beans in tomato sauce is an ideal type of product to benefit from controlled arrangement of component parts in the can; the layer that heats by conduction (the sauce layer) is relatively thin dimensionally, and when this layer is in the top end of the can its center heats at practically the same rate as the critical point within the convection heating region containing the beans and frankfurter pieces. For example, in one of the 2 runs made with this arrangement of components, the slowest heating point was within the bean-frankfurter portion; in the other run it was in the sauce layer. Calculated required processes in the 2 instances were 14.6 and 13.9 minutes, respectively—essentially the same.

The indicated required process for arrangement II was slightly longer than those indicated for arrangement I. The process was 16.1 minutes and was based on the interior of the sauce layer. The longest process required within the convection region was 11.5 minutes.

In 2 runs with arrangement III (Military specifications), the required processes were indicated to be 41.2 and 35.9 minutes, respectively.

The above results, together with heat penetration data, are given in Table 2.

TABLE 2

HEAT PENETRATION AND PROCESS DATA—FRANKFURTERS AND BEANS IN TOMATO SAUCE

Arrangement——————>	I		II	III	
f_{h1}	8.2	5.6	7.7	34	22.5
f_2	27.5	23.4			29.7
x'_{bh}	4.5	5.4			30.4
j	0.241	0.512	0.874	0.492	1.076
Process (min. /250° F.)	14.6	13.9	16.1	41.2	35.9

The processes listed in Table 2 are based on the following specifications:

$z = 18°$ F.
$F = 5$ min.
RT = 250° F.
IT = 70° F.
CW = 70° F.

These data indicate that the process at 250° F. required for sterilization of this product in 307 x 306 cans in accordance with arrangement I is slightly more than one-third as long as that required when the filling is under arrangement III, i.e., in accordance with Military specifications. The process required under II filling procedure is about two-fifths as long as that required when the filling is under arrangement III. Thus, the percentage of possible reduction in process obtainable through a particular arrangement of ingredients in the can is indicated to be about the same for frankfurters and beans in tomato sauce as in ham and beans in molasses sauce.

Heat penetration was studied in a product identical to the above except that only half of the specified amount of tomato pulp was put into the sauce. Cans of 307 x 306 size were used. Results obtained with this product are given in Table 3.

TABLE 3

HEAT PENETRATION AND PROCESS DATA—FRANKFURTERS AND BEANS IN TOMATO SAUCE (50% OF SPECIFIED TOMATO PULP)

Arrangement——————>	I		II	III	
f_{h1}	10.7	10.5	6.4	17.8	17.8
f_2	18.0		28.5	29.8	40.8
x'_{bh}	88.33		5.4	16.8	21.5
j	0.346	0.396	0.340	0.922	0.950
Process (min.)	16.5	16.3	13.5	31.3	29.6

The processes listed in Table 3 are based on the following specifications:

$z = 18°$ F.
$F = 5$ min.
$RT = 250°$ F.
$IT = 65°$ F.
$CW = 70°$ F.

That there was some convection in the cans having filling arrangement III is shown by the fact that the rate of heating of the product containing only 50% of the specified amount of tomato pulp is higher than that for the product containing the full specified amount of pulp. (Compare Table 3 with Table 2.) As further evidence of convection in the former product, the critical point was found to be near the bottom of the can, which is a typical condition in cans that heat by convection. The process required for sterilization of this product, filled in accordance with arrangement I is slightly longer than that for filling arrangement II. This relationship is the reverse of that found for the product having the specified amount of tomato pulp in the sauce. Also, the locations of the critical points differ in the 2 formulations, as shown in Table 4. A partial explanation of this difference may rest in the difference in thickness of the 2 sauce layers.

TABLE 4

LOCATIONS OF CRITICAL POINTS—FRANKFURTERS AND BEANS IN TOMATO SAUCE

Amount Tomato Pulp	Arrangement I		Arrangement II
100% Specification	Sauce Layer	Near Bottom	Sauce Layer
50% Specification	Sauce Layer	Sauce Layer	Near Bottom

For the product having 50% of the specified amount of tomato pulp, the required process when filling arrangement either I or II is used is approximately one-half as long as that required when the product is formulated and packed according to Military specifications (arrangement III). The processes required for arrangements I and II are approximately the same as those required for the same arrangements in the product containing the specified amount of tomato pulp in the sauce.

Beef and vegetables in gravy. Heat penetration tests were made with 4 different arrangements of component parts in the 404 x 404 can, viz.,

I. (a) *on the bottom, and filling about one-half of the can*: meat pieces prepared by cutting raw trimmed beef into 1½-inch cubes and then cooking in one-half its weight of water until approximately a 35% shrink had been obtained.
   (b) *on top of the meat*: raw carrot slices ½-inch thick.
   (c) *on top of the carrots*: ¾-inch to 1-inch cubes of partially cooked (blanched) potatoes.
   (d) beef broth equal in amount to that called for in the specifications plus that equal to 37% of the water specified for the gravy (222.25 ml. total) was poured over the potatoes, carrots, and meat.
   (e) gravy paste made by adding 34.02 ml. (63% of the specified amount) of water to the dry ingredients was spread evenly over the top of the potatoes.

II. (a) *on the bottom and filling most of the can*: a mixture of cooked meat pieces, raw carrot slices, and cubes of blanched potatoes. (The meat pieces, carrot slices, and potato cubes were prepared in the same manner as for arrangement I.)
   (b) beef broth (the same amount as for arrangement I) was poured over the mixture of meat, carrot, and potato pieces.
   (c) gravy paste made by adding 63% of the specified amount of water to the dry ingredients was spread evenly over the top of the mixture of the pieces of meat and vegetables.

III. Can was filled and sealed in same manner as for arrangement II; then the can was inverted for processing.

IV. (a) pieces of meat, carrots, and potatoes, prepared as for arrangement I, were put into the can in the manner of arrangement I.
   (b) gravy prepared in accordance with Military specifications was poured hot over the potatoes, carrots, and meat.

Results. As in frankfurters and beans in tomato sauce, the heavy sauce layer in beef and vegetables in gravy is quite thin dimensionally; thus, when this layer is in the top end of the can, the center point of the layer heats almost as rapidly as the critical point in the convection heating region containing the meat and vegetables. For example, in the product filled under arrangement I, the critical point was near the top of the can, whereas, with filling arrangement II, the critical point was near the bottom. With filling arrangement III, the critical point was near the bottom as is to be expected when the heavy sauce layer is in the bottom. A heavy sauce layer in the bottom of the can does not heat as rapidly as a similar layer in the top of the can.

An interesting aspect of the results with arrangement I was that the point which heated most slowly was not on the longitudinal axis of the can, although it was in the heavy sauce layer. This indicated that the sauce layer was not of uniform thickness and that a thick part was away from the axis.

Heat penetration data and calculated processes are shown in Table 5.

TABLE 5

HEAT PENETRATION AND PROCESS DATA—BEEF AND VEGETABLES WITH GRAVY

Arrangement ——————>	I	II	III	IV		
f_{h1}	31.7	29.3	38.0	87.7	77.0	79.5
f_2				167.5		
x'_{bh}				135.3		
j	0.351	0.607	0.787	1.84	1.98	2.03
Process (min.)	23.6	29.2	39.1	103.9	95.5	98.6

The processes listed in Table 5 are based on the following specifications:

$z = 18°$ F.
$F = 5$ min.
RT = 250° F.
IT = 70° F.
CW = 70° F.

It is seen from Table 5 that the required process for beef and vegetables with gravy is reduced by stratification of the components approximately as much as for the 2 products previously discussed.

Spaghetti and meat balls. The last of the formulated meat products to be studied, spaghetti and meat balls, gave variable results. In filling arrangement I, the bottom layer was meat balls prepared according to Military specifications, followed by a layer of blanched spaghetti, over which was poured the water withheld from the sauce. In the top was the sauce paste layer. The product with this arrangement was too bulky to permit proper sealing of the can.

In filling arrangement II, the order of the 2 layers (meat balls and spaghetti) was reversed; otherwise, was like arrangement I. This arrangement produced no increase in the rate of heating over that of the product formulated and packed under Military specifications.

In filling arrangement III, the meat balls and spaghetti were mixed and formed a single layer over which was spread the sauce paste. This arrangement showed a 31% reduction in length of process, but the product could not be reconstituted except by the addition of water after the product was removed from the can. The water put into the can with the spaghetti and meat balls was all absorbed by the spaghetti. It should be noted, however, that the process used in this test was considerably longer than that required for sterilization of the product.

Discussion of results. Samples of all of the products discussed except spaghetti and meat balls, packed with the modified arrangements of component parts were pronounced by taste test panels to be superior in flavor and appearance to the similar products packed in accordance with Military specifications. For the products containing beans, however, the over-all preference was tempered by opinions that the beans showed unsatisfactory absorption of sauce flavor and were not sufficiently cooked.

A complete remedy for this defect may be found only in a modified pretreatment of the beans, in which a precook of increased severity is used under conditions which permit the beans to absorb desired flavors. However, a partial remedy can no doubt be obtained by putting a small quantity of the flavoring ingredients of the sauce into the water which covers the beans during the processing. This will cause some reduction in the rate of convection heating which takes place, but it need not increase the process required for sterilization. In fact, it might reduce the required process slightly because the dimensional thickness of the conduction heating layer would be reduced by the transfer of solids from that layer to the liquid in the convection heating region while still not causing a sufficient reduction in the rate of convection heating to reduce the rate of acquisition of lethal heat at the critical point in this region below that at the critical point in

the conduction heating layer. In other words, this change in procedure causes the critical point in the conduction heating layer to acquire lethal heat more rapidly and the critical point in the convection heating region to acquire lethal heat more slowly, causing the 2 rates to approach each other in value.

When this packing and processing procedure was introduced a few years ago, justifiable skepticism was expressed as to whether or not the stratified layers would remain stratified during the heat sterilizing process. Experience not only with corn but also with the meat products discussed herein has shown that this skepticism was not justified; on the other hand, the only problem involved here points in the opposite direction—the difficulty of reconstituting the product. Reconstitution by shaking the can is always facilitated by higher temperatures in the product; when the product is cold, that is, at room temperature, violent shaking is required to destroy the stratification and thoroughly mix the ingredients. The greater the head space in the can, of course, the more easily the product is mixed by shaking.

Under regulations promulgated by food control authorities, there is a limit to the maximum amount of head space permitted; also, in most packing plants, it is not feasible to shake the cans until after they have been completely cooled. It is doubtful whether some products can be put into homogeneous state by shaking the cooled cans. Ham and beans in molasses sauce and beef and vegetables in gravy are in this category because the heat of processing causes the heavy sauce layer to assume a rubbery texture after cooling. This texture is quickly destroyed by heat, however, so that by heating moderately in a kettle with stirring, the formation of a homogeneous mixture is easily accomplished; better still, if the product is being prepared for eating, heating it in a kettle by convection before stirring speeds the heating process just as it does in the can during sterilization. After it reaches boiling temperature, it may be quickly mixed by stirring. Whenever it is feasible to shake the sealed container while the contents are warm, a preferred temperature for the product is generally within the range of from 150° to 200° F.

Various factors, such as the order of filling the various layers of ingredients, the size of pieces of the fleshy components, and the amount of thin liquid used were shown to affect the rate of heat penetration to the critical points in the cans. For example, ham and beans in molasses sauce heated more rapidly when pieces of ham measuring ¾-inch x 1-inch x 1-inch were mixed with the beans than when smaller pieces of ham were mixed with the beans. The numerical comparisons presented in Tables 1 to 5, however, should merely be regarded as approximate, since a comparatively few cans of each product were included in the experiments. More extensive experiments would be required to establish accurately the ranges of the heat penetration

and process factors. The values given, however, are, no doubt, typical of the true results, since the work was done with meticulous care.

In the experiments with the 4 meat products, closing temperatures varied considerably in the stratified products. The component parts of ham and beans in molasses sauce were filled at room temperature, then the open cans were exhausted in steam until the average temperature of the contents was from 160° to 180° F. The cans were then sealed. For the frankfurters and beans in tomato sauce, the beans were blanched at 180° F. for 20 minutes just before filling but the other ingredients were filled at room temperature. The cans were then sealed under 23-inch - 25-inch vacuum. The ingredients of beef and vegetables in gravy, except the water, were heated to at least 150° F. just before filling. The cans were sealed at atmospheric pressure. Meat balls and spaghetti ingredients were filled at room temperature and the cans sealed under atmospheric pressure. It is thought that the temperature conditions at the time of sealing had no material effect upon the results of the experiments.

In addition to check runs on the tests already made, a study of additional variables might yield information more interesting than that already obtained. Among the additional variables would be the mixing of a part of the sauce solids into the liquid of the convection region and mild agitation of the can during processing. Depending upon the nature of the stratification, slight agitation, such as very slow rotation, of the can may further increase the rate of heating of the stratified product and at the same time bring about a partial reconstitution of the product during processing.

Summary

Heat penetration tests were made of 4 formulated meat products, used as ration items by the Armed Forces, in which the component parts were stratified in the can during processing so that the portion in the center of the can would be heated by convection and the portion in one or both ends of the can would be heated by conduction.

Processes calculated from the heat penetration results showed that sterilization can be accomplished in the stratified products in much less time than in the same products formulated and packed in accordance with Military specifications. Reduction in processing time at 250° F. amounted to from 47% to 70% for ham and beans in molasses sauce, from 44% to 65% in frankfurters and beans in tomato sauce, from 59% to 77% in beef and vegetables in gravy, and approximately 30% in spaghetti and meat balls.

Flavor and appearance of the products sterilized in stratified state were improved over flavor and appearance of the same products packed according to Military specifications.

Acknowledgement

The results presented herein of results of tests on meat products were taken from reports prepared by Messrs. Richard C. Kennedy and Abner Salant, who carried out the experimental work. The author's indebtedness to Messrs. Kennedy and Salant is hereby acknowledged with sincere thanks.

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CHAIRMAN ROBINSON

Thank you very much, Dr. Ball.

The final paper on this afternoon's program, prior to our round-table discussion, will be presented by Mr. James M. Blair, QMFCI; co-author is Dr. K. T. Swartz.

Preliminary Observations on the Effect of Can Movement During Thermal Processing

JAMES M. BLAIR

It has been obvious for many years that the conventional methods of stabilizing canned meats by heating with steam have been very deleterious to the quality of the product. Greenwood *et al.* (*4*) clearly demonstrated that in canned pork luncheon meat good vitamin retention is dependent upon rapid, uniform heating of the entire contents of the can. Uniform heating reduces the temperature differential between the inner and outer portions of the material.

Various devices and methods used to reduce the heating time required to sterilize various canned vegetables and fluid goods have been considered for some time and in some instances are used industrially with considerable success. By means of these procedures and mechanical devices, there have been produced rather fluid, free-flowing foods possessing a texture, flavor, and appearance superior to those qualities in the same material when heated conventionally.

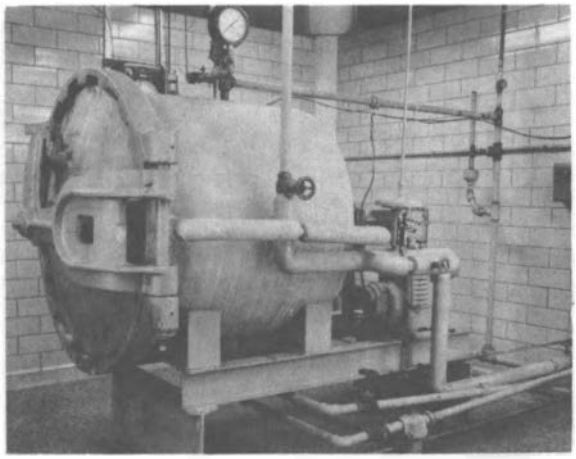

FIGURE 1.

THE RETORT USED IN THESE EXPERIMENTS PERMITTED ROTATIONAL AGITATION OF CANS IN VARIOUS POSITIONS AT SELECTED ROTATING SPEEDS.

The procedures usually employed in increasing the rate of heat penetration in free-flowing canned food products have essentially involved some type of agitation of the food during the sterilizing heating period. Clifcorn *et al.* (*1*) and Conley *et al.* (*2*) have presented some of the characteristics of agitating retort operation and have firmly established fundamentals essential to the successful application of this process. The major portion of the work by these authors deals, however, with free-flowing materials such as water, tomato juice, and brine-packed corn and peas.

In the case of canned meats, relatively few attempts have been made to reduce required heat-sterilization periods by means of can agitation. Very likely, this lack of investigation has been due to the common and perhaps justified belief that the more or less solid or viscous canned meat products transmit heat slowly and, because of

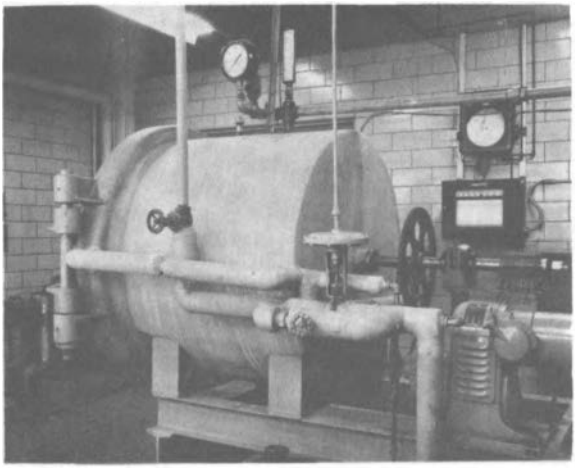

FIGURE 2.

REAR OF RETORT WITH CONSTANT TEMPERATURE CONTROLLER AND AUTOMATICALLY RECORDING POTENTIOMETER IN THE BACKGROUND.

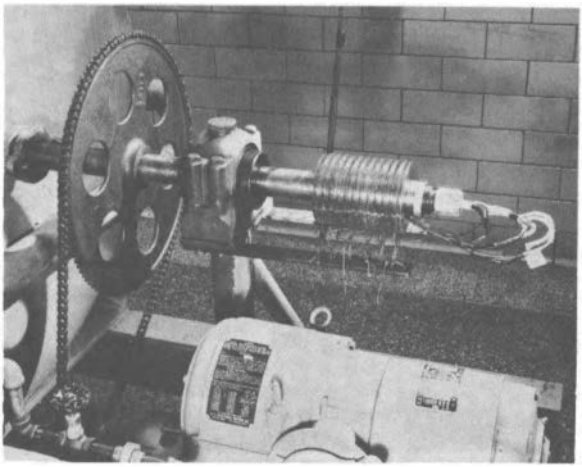

FIGURE 3.

AGITATING DRIVE MECHANISM AND SLIP-RING, FRICTION TYPE COMMUTATOR.

their physical attributes, resist any form of agitation intended to increase the rate of heat penetration into the mass as a whole.

The purpose of this investigation has been to consider the principles of agitation of canned meats and to determine the extent to which they can be utilized to improve canned meats. The data obtained to date are preliminary in nature, but with the accumulation of additional experience, it is anticipated that it will be possible to determine the extent to which agitating processing will improve the general quality of canned meats. It is also anticipated that it will be possible to formulate canned meat items that will be conducive to a more rapid heat transfer during an agitation process.

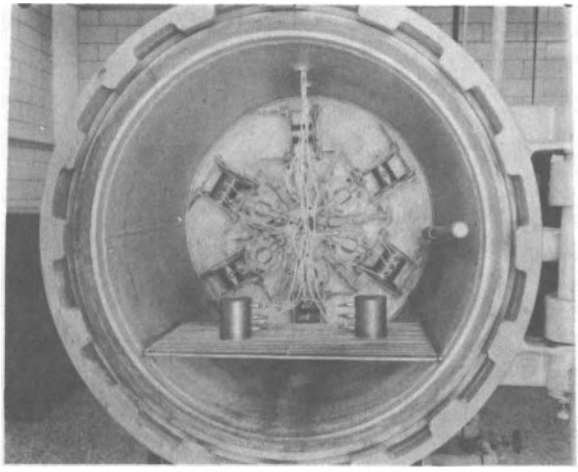

FIGURE 4.

INTERIOR OF RETORT WITH CANS POSITIONED FOR SIMULTANEOUS STILL AND AGITATING COOKS.

Experimental

Equipment. The equipment used in these studies has been designed to permit considerable flexibility in experimental methods. The retort permits rotational agitation of cans in various positions ("on-side" or "end-over-end") at rotating speeds ranging from 4 to 104 r.p.m. The rotational radius for each can used in these experiments was 14 inches (range of 7 to 14 inches permitted) from the center of the rotating axle to the can center. Thermocouple leads (copper, constantan) pass through the hollow axle of the agitating device and at the rear of the retort make contact with potentiometer leads by means of a slip-ring friction-type commutator. A shelf in the front portion of the retort is designed to hold cans that are to be *still-cooked* simultaneously with the agitated cans. Thermocouple leads for these still-cook cans pass through a port in the top of the retort. The capacity of the retort permits simultaneous processing of 12 agitated cans (size 300 x 200 to 603 x 700, 6 fitted with thermocouples) and 6 thermocouple-fitted still-cook cans. Temperature is limited by a steam supply with a pressure of 35 p.s.i., but in the near future a steam generator capable of supplying pressures up to 100 p.s.i. will be available. Suitable water and compressed air inlets permit pressure cooling of cans. The operation of the retort is manual except for the use of a constant temperature controller. Details of the mechanical apparatus are pictured in Figures 1, 2, 3, 4. The thermocouples used are of the type described by Ecklund (*3*), and temperature and time are automatically recorded by a 12-point recording potentiometer.

Methods. Bentonite dispersions were prepared essentially as described by Jackson and Olson (*5*). Powdered laboratory-grade bentonite was added, with

TABLE 1

SUMMARY OF TEST PROCEDURES USED TO DETERMINE THE EFFECT OF END-OVER-END AGITATION OF THE RATE OF HEAT PENETRATION IN VARIOUS MATERIALS

Purpose of Experiment	Test Material	Test Conditions
To determine optimum r.p.m. for agitated heating of test materials	5% Bentonite [a] (3 thermocouples per can)	"Still-cooked" cans—0 r.p.m. Agitated cans—36 & 81 r.p.m. (12 r.p.m. during cooling)
To determine rate of heat penetration in different materials during agitated heating	1, 5, and 10% Bentonite [b]	"Still-cooked" cans—0 r.p.m. Agitated cans—36 r.p.m. (12 r.p.m. during cooling)
	Luncheon Meat [c]	"Still-cooked" cans—0 r.p.m. Agitated cans—36 r.p.m. (12 r.p.m. during cooling)
	Frankfurters [d]	"Still-cooked" cans—0 r.p.m. Agitated cans—28 r.p.m. (12 r.p.m. during cooling)

[a] Data are presented in Figure 5.
[b] Data are presented in Figure 6.
[c] Data are presented in Figure 7.
[d] Data are presented in Figure 8.

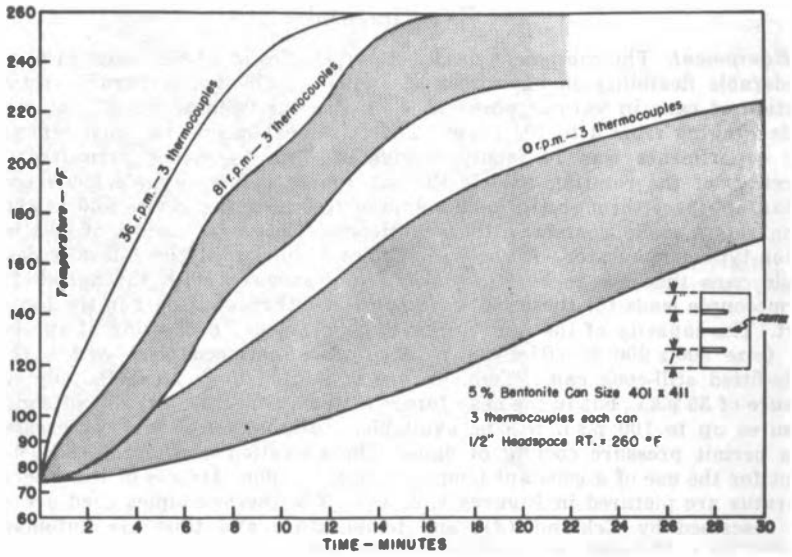

FIGURE 5

EFFECT OF RATE OF AGITATION ON RATE OF HEAT PENETRATION IN 5% BENTONITE DISPERSIONS

constant mechanical mixing, to a specific amount of water. After thorough mechanical mixing to eliminate all noticeable lumps, the dispersion was allowed to stand for 4 hours before filling into cans. At the time of filling, careful consideration was made of gross head space, net weight, position of thermocouple, and closing vacuum. The cans were then given a preliminary heating to the retort test temperature. The 2 food products tested, frankfurters and pork luncheon meat, were prepared according to Military specifications covering the manufacture of these items. Again, net weight, gross head space, vacuum, and thermocouple position were carefully noted.

The sealed test cans were placed in the agitating device of the retort in such a manner as to provide *end-over-end* type agitation. Identical test cans were placed in a vertical position on the shelf in the forepart of the retort and served as controls in determining the effect of agitation on the rate of heat penetration into the cans. The retort was operated in such a manner as to provide the most rapid *come-up* time possible with the relatively low steam pressure available. The time required for the retort to attain 250° F. was 10 minutes. The agitating device was operated at a constant speed throughout the process,* except during cooling, when the rotational speed was decreased to 12 r.p.m. to prevent possible damage to equipment by creating excessive turbulence in the cooling water. Time and temperature measurements were made throughout the entire heating and cooling periods.

The experimental test procedure is summarized in Table 1.

Results

Early in the experimental phase of this investigation, it was apparent that many conditions could very likely affect the heating characteristics of any substance being agitated during heating. The 2 factors considered to be most impor-

* Differing, of course, with each process in accordance with the test requirements.

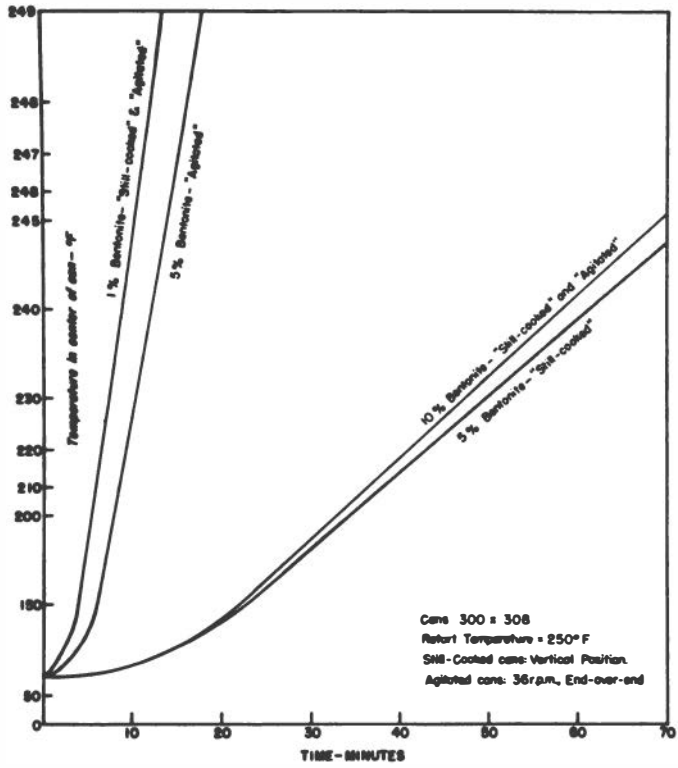

FIGURE 6

RATE OF HEAT PENETRATION IN BENTONITE DISPERSIONS DURING "AGITATED" AND "STILL" COOKS

tant in affecting the rate of heat penetration into cans being subjected to end-over-end agitation were the amount of head space and speed of rotation. The amount of net head space used was arbitrarily determined at ⅜-inch for 401 x 411 size cans, and ¼-inch for 300 x 308 size cans. This head space was considered to be realistic with regard to a reasonable fill for the container and yet sufficient to permit a satisfactory amount of movement of the contents during agitation.

The approximate speed of rotation of the agitating device, which would permit the most rapid rate of heat penetration into a 5% bentonite dispersion, was determined experimentally. To do this, 401 x 411 size cans were fitted with 3 thermocouples each. The thermocouple hot junctions were located on the long axis of the cans with one thermocouple 13/16-inch from each can end and the 3rd located at the can center. Figure 5 indicates the range of temperature differences recorded by the 3 thermocouples during still and agitated (36 and 81 r.p.m.) cooks. The graph illustrates the wide range of temperature differentials recorded by the 3 thermocouples in the still-cooked cans and in the agitated cans rotated 81 r.p.m. In contrast, the cans rotated 36 r.p.m. heated at a greater rate than did both the still-cook and 81 r.p.m. agitated cans, and the 3 thermocouples recorded essentially the same temperatures during the heating period. On the basis of this and other similar determinations, the agitation speed considered to be optimum in resulting in the greatest rate of heat penetration in products similar in density to a 5% bentonite dispersion is in the range of 36 r.p.m. This method of deter-

mining optimum r.p.m. is considered to be a practical means of determining, during actual heating, the optimum conditions of agitation for any test material. The basic assumption of this procedure is, of course, that during heating the temperature will be uniform throughout the mass of a well-agitated material.

The study of the effect of agitation on the rate of heat penetration in various materials has resolved itself into a consideration of 4 different heating conditions.

Strict convection heating. This terminology is applied to the heating condition where the method of heat transfer throughout the can is principally by convection, both during agitated and still-cooks. Figure 6 indicates that, with the relatively fluid and free-flowing 1% bentonite dispersion, the rate of heat transfer to the center of the still-cooked can is nearly as rapid as in the agitated can. Although this does not imply that the temperature distribution in the still-cooked is as uniform as that in the agitated can, it does suggest that naturally-induced convection currents are quite strong, and that agitation of an item of such consistency offers no advantages over conventional still cooking in increasing the rate of heat penetration to the center of the can.

Induced convection heating. Induced convection heating is a term applied to the heating characteristics of a substance with such a viscosity as to cause the product to exhibit conduction-type heating characteristics when still cooked and yet be of thin enough consistency to permit flowing when agitated and thus dem-

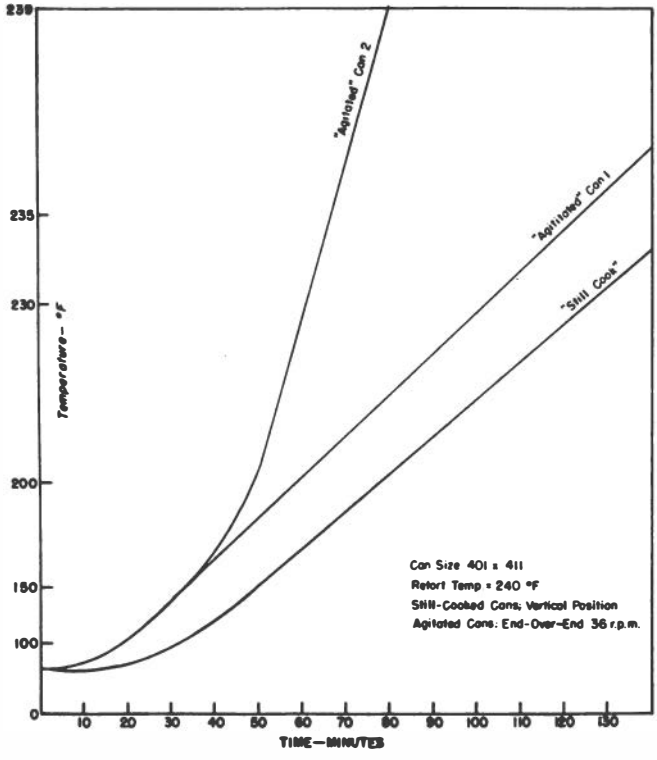

FIGURE 7

RATE OF HEAT PENETRATION IN LUNCHEON MEAT DURING "AGITATED" AND "STILL" COOKS

onstrate convection-type heating characteristics. Figure 6 illustrates this by comparison of the rates of heat penetration to the center of the can of 5% bentonite when both agitated and still cooked. The difference in the slopes of the 2 curves is considerable, with the still-cooked cans exhibiting convection-type heating characteristics that very nearly resemble those of the 1% bentonite (both agitated and still cooked).

Strict conduction heating. This term has been applied to the heating characteristics of products that exhibit no appreciable difference in rate of heating when either agitated or still cooked. The heating characteristics of a 10% bentonite dispersion (Figure 6) illustrate this classification. Here, both the agitated and still-cooked cans heated at essentially the same rate. Thus, the physical nature of a 10% bentonite dispersion is representative of products for which agitation will offer little advantage in increasing the rate of heat penetration.

Luncheon meat, as indicated by can No. 1 in Figure 7 apparently represents strict conduction heating.

Combination conduction-convection heating. The heating characteristics of most food items probably fall into this classification. Most canned foods consist of rather dense particles surrounded by a fluid, free-flowing medium. This fluid medium can be either an added specific ingredient or consist of juices and melted fat rendered from the product during the early stages of the process. The success

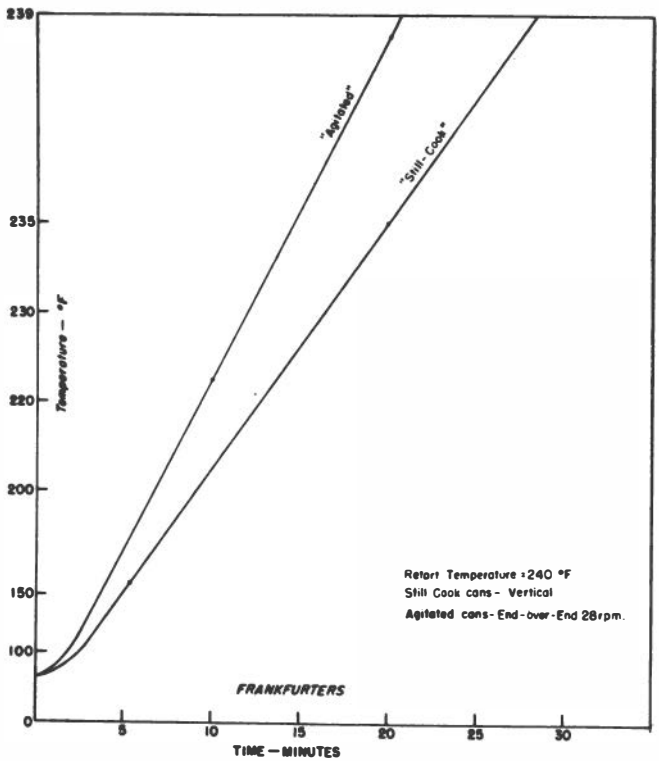

FIGURE 8

RATE OF HEAT PENETRATION IN FRANKFURTERS DURING "AGITATED" AND "STILL" COOKS

of an agitated cook in increasing the rate of heat penetration in these items would depend upon a rapid transfer of heat to the fluid portion by induction of convectional currents that otherwise would not exist. The hot fluid would then transmit heat to the solid portions which would in turn heat by conduction. Thus, the heating time required by the slowest heating portion of the contents of the can would be less than if the entire material heated by conduction only.

Luncheon meat, as illustrated by can No. 2 in Figure 7, represents the type of heating whereby hot juices, rendered from the product, can force their way through the meat mass and cause a convection-type transfer of heat to solid particles. This channeling of the hot juices is apparently enhanced by agitation of the can during cooking, but it is likely that this effect can also take place in still-cooked material. The development of fissures in bulk-pack meat items such as luncheon meat makes it difficult to determine if the temperature measured is representative of the slowest heating portion of the mass. These fissures also render the yield and appearance of the product undesirable. It remains to be seen whether or not the development of fissures and poor yield will be a typical problem peculiar to the agitation cooking of products of this type.

The heating characteristics of frankfurters illustrate this combination conduction-convection method of heat transfer with much less variability than does luncheon meat. One pound and 6 ounces of frankfurters, in 401 x 411 size cans, topped to within ½-inch of the top of the can with water, heated at the same rate when both agitated and still cooked. This is illustrated in Figure 8. Here, temperature was determined at the center of the frankfurter. It is likely that the water portion of the contents of the cans exhibits the characteristics of strict convection-heating items described previously, whereas, the frankfurters alone heat as strict conduction-heating items. This is suggested by the similar rates of heat penetration into both the still-cooked and agitated cans and probably results from the orderly arrangement of frankfurters in the can, which permits almost uninhibited flow of juices.

A 3rd type of product which is yet to be investigated should be included in this classification. This material consists of irregularly-shaped solid conduction-heating particles arranged at random in a fluid, convection-heating medium. These solid particles would inhibit the flow of natural convection currents induced during still-cooked heating, and yet, during an agitated cook, could aid in the generation of rather vigorous convection currents.

Discussion

These preliminary observations on the effect of can movement, or agitation, during heat processing have been primarily intended to indicate the procedures to be used in the experimental agitated processing of canned meat products. Bentonite dispersions of various concentrations have proved to be useful in establishing some of the fundamental characteristics of agitating-retort procedures. However, the use of these materials will be more limited when consideration is to be given to materials possessing more complex physical characteristics.

One observation pertaining to agitated heat-penetration characteristics does stand out, however. Materials similar in consistency to 1% bentonite dispersion heat rapidly when still-cooked by means of natural convection currents that are almost as strong as those produced by agitation. Thus, agitation would appear to be of no benefit in appreciably shortening the required process time for these materials. It is possible, however, that delicate items subject to surface

burning are benefited by agitation, but very likely this does not apply to canned meats since the fluid portions of these products that resemble a 1% bentonite dispersion are primarily water or brine. For products in this category, the nature and arrangement in the can of the solid particles is critical.

The type of heat transfer represented by passage of currents of vapor throughout a vacuum-pack can during heat processing has not been considered here. This method of heat transfer can be considered as a convection type, but it is believed not to be applicable to most meats.

Canned meat products which possess, either wholly or in some component part, a physical consistency comparable to that of a 5% concentration of bentonite in water are very likely those products in which it will be possible to effect an appreciably greater rate of heat penetration by means of agitation during retorting. With products of this nature, much attention should be allotted to the nature of the fluid portion and the form and distribution of the solid portion.

Canned meat products essentially solid and uniform throughout deserve specific consideration because of the particularly excessive amounts of heat required for their sterilization during conventional retorting. As indicated by the unaffected rates of heat penetration obtained in 10% bentonite suspensions during agitated retorting, it appears likely that agitation will be of no value in decreasing required heating time in canned meats possessing similar consistency. It is yet to be determined if solid-pack canned meats do possess the heating characteristics of a 10% bentonite dispersion. Agitation heat-penetration studies on some of these items are complicated by the channeling of juices and melted fat which probably results in an irregular distribution of temperature throughout the mass. Possibly other factors also affect the rate of heat penetration into solid particles, and all should be considered before agitated retorting is discounted as a means of improving the quality of such items.

Summary

It has been demonstrated that agitation of the can will not appreciably increase the rate of heat penetration in a 1% bentonite dispersion. Materials of similar consistency are therefore classed as *strict convection-heating* types since the application of heat alone will establish strong convection currents.

The rate of heat penetration in a 5% dispersion of bentonite can be greatly increased by means of agitation. Materials of this consistency are identified by the term *induced convection heating* in that strong convection currents cannot be formed by the application of heat but can be established by agitation. Thus, when agitated, the rate of heat penetration in this material resembles that of a strict convection-heating material.

A 10% suspension of bentonite in water will demonstrate the same rate of heat penetration when agitated as when still retorted. This rate of heat penetration resembles that of the still-cooked 5% bentonite dispersions. Materials similar in consistency to a 10% bentonite dispersion are therefore classified as *strict conduction-heating* types.

The heating characteristics of most canned meat items involve a combination of methods of heat transfer described above and are classified as *combination conduction-convection heating* types. The characteristics of each particular item in this category determine whether or not agitation can be effective in increasing the rate of heat penetration.

A method of using 3 thermocouples in one can has been found effective in determining the optimum conditions of agitation.

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Discussion

CHAIRMAN ROBINSON

Thank you very much, Mr. Blair.

To start out the panel this afternoon, I am going to call on Dr. Dack, chairman of the National Research Council Committee on Foods, which is advisory to the Quartermaster Food and Container Institute. The committee represented here today is one of the subcommittees of Dr. Dack's Committee on Foods. Dr. Dack.

GAIL M. DACK

Dr. Ayres, when you reported those counts in the raw meat products, why were they so low? I was wondering whether consideration had been given to some of the work done in the 19th century—for example, to that of Louis Pasteur or to that of Claude Bernard. The latter noticed that freshly drawn blood did not putrefy or spoil for

some period of time. There is a considerable normal bactericidal property present in blood. Has any consideration been given to that fact in relation to fresh meats? Is there any normal bactericidal mechanism and has it been tested, say, against fecal contamination? Certainly, in dressing any carcass, we would expect a more liberal fecal spread of organisms than is sometimes indicated in some of the counts that have been given.

AYRES

There are, of course, many reports concerning the bactericidal action of blood. However, the meat that we studied wasn't as fresh as even 2 or 3 hours, and so the counts reported do not reflect the living animal condition at all. The counts of putrefactive anaerobes were made low in order to eliminate anaerobic organisms—the only way we thought it possible was to heat the material to 80°C. for 20 minutes. That eliminated the non-spore-forming organisms, supposedly, and so the putrefactive anaerobic spores would have to go through that preliminary heating process. It does not necessarily mean that we have all of the putrefactive anaerobic spores when we report our counts on those particular organisms. We have just those that are able initially to go through 80°C. for 20 minutes; in many instances that heat was worse than the process that was given to them later on. In regard to some of the processing times Dr. Tischer has shown, I would imagine the actual value was of such order that it would have been less than the heat necessary even to separate the spore formers, from the non-spore-former organisms.

TISCHER

May I add a comment to that? Going on with Dr. Ayres' discussion, one other important point in answer to Dr. Dack's question is that in the rather wide range of processes, the fact should be kept in mind that in these lower times some of the large differences in sterilizing values probably occurred in the higher temperatures in the shorter time because, as is rather obvious, the temperature gradient in the can would be magnified considerably. Under these conditions one might consider all the concepts of bacteriology together.

The gradient in the can would again be an important aspect in deciding exactly what the end result. Results depend also upon the location in the container of the points being considered and upon the existence of the gradient. I don't see how you can make an answer which would bear any weight unless you specify some restrictions on the location within the container.

AYRES

I might say, too, the counts here were so low that we had to go to the *most probable number* technique; in doing that in some of the trials we had to use the entire contents of the can even to get a count.

G. R. MANDELS (Philadelphia QM Depot)

What is the bacterial content of this type of meat? If you sterilize a piece of meat before it has a chance to stand around, what would the bacterial count of that be—anything like that in the normal tissue?

AYRES

I would like to know that, too. I would say that the count can range over wide gradients. We have found in some samples less than one organism. That's total count. I am talking about an entirely different thing when I am talking about putrefactive anaerobes counting 200 or 300 g. and not getting a count. But usually the count ranged between 10,000 and a million on the surface. Below the surface there aren't many organisms, or we haven't found many organisms; with the fresh meat, we found very, very few organisms, even slightly below the surface. Most of the organisms are those that seem to come in contact with the meat during the slaughtering operations, from hands of workmen, and from other sources such as that. There are some that could get in by way of the intestinal tract and then through the intestinal walls. There are some that could get in by still other pathways, such as the air.

MANDELS

Is it entirely out of the question to surface-sterilize a piece of meat and then place it in a sterile can—that is, do this more or less aseptically? They handle drugs that way. Is it feasible to do it in the packing industry?

AYRES

It is not at all out of the question. I think a lot of people would like to know how to do it successfully in the packing plants.

TRESSLER

I would like to ask Mr. Blair or Dr. Swartz whether or not that 10% bentonite solution was in effect a jelly or whether it was a viscous liquid. It would seem to me if it were a viscous liquid, the answer to their problem is either more rapid agitation or more violent agitation. If it is a jelly so that there can be substantially no convection currents, then I assume that all you can expect is to heat it by conduction rather than convection.

BLAIR

Actually the 10% bentonite is of very thick jelly-like consistency. In fact, if you were to thump the side of a can with your finger, it would have a sort of ring to it. It is really a solid and, I think, is very characteristic of a strict conduction-heating substance.

I have never thoroughly tried all types of agitation or various speeds of agitation with that material, but it would seem that pos-

sibly the material does approach a condition of a truly conduction-heating chunk of meat. I can visualize a chunk of meat with some passage of juices through the material, and I rather doubt, although I don't know, that such would be the case with that 10% bentonite.

A. STUART HUNTER (OQMG)

Dr. Ball, I would like to ask 2 questions. Did you check the acceptability of the products out of the 2 cans—the one heated 4 times as long as the first one to get sterilization? Second, assuming you were to adopt the rapid method, wouldn't you encounter the necessity of very careful product control? If something happened to break up stratification in the can, the treatment wouldn't sterilize the unit, and you would be in for trouble.

BALL

We did check, by means of a taste panel, the organoleptic quality. It was put through regular panel procedures, and they said there was quite a distinct difference. Dr. Swartz said that they made a couple of difference tests at the Institute. On the first one they did not seem to find any difference. On the second, if I remember rightly, there was a difference.

As to the control that is necessary, it would appear that there might be some rather difficult problems, but it has not been found true in the case of corn. It is comparatively simple to get uniform conditions. Mechanical fillers fill the different components. The accuracy of those fillers is well known. The processes are established on such a basis that any variation will be taken care of. It is not very difficult because you know the variations pretty well.

J. T. R. NICKERSON (M. I. T.)

Dr. Ayres, the Australians say a good deal of the contamination on the surface of the carcass comes from the hide. They have suggested that the cattle be given a chlorine dip prior to slaughter.

HALVORSON

I would like to comment on that point from observations I made a number of years ago. Probably many of you remember that several years ago the American Meat Institute reported they could find viable spores in the tissue of living animals. That may well be the case. But any way, it intrigued me, and I thought I would try to prove that that might have been due to faulty technique. I took some kidneys and sterilized the outer cavity. The capsule was left on. I dipped some of them into a bacterial culture; one was *Staphylococcus aureus.* I immediately took the kidneys out and dipped them into a solution of chlorine; others into bichloride of mercury. Then I took them out with sterile instruments and dipped them into a solution of counteracting

germicide. I had hypochloride, I had thiosulfate, and with bichloride of mercury, a sulfite solution.

From there the kidneys were taken on to a sterile cloth, opened with a sterile knife, and with another sterile knife I cut out a piece of center. In every instance I found the contaminating organism on the dipped kidney and inside of the kidney. I concluded it would be difficult to sterilize the outside surface of a piece of meat and avoid contamination when you went in with instruments later on. It would be extremely difficult to sterilize the outside of a hog by dipping in solution.

AYRES

Knowing the difficulty of getting a chlorine residual in a swimming pool, I can imagine what it would be on the surface of a living animal in contact with a lot of organic material.

GEORGE BRISSEY (Swift & Company)

I would like to ask Dr. Gross if he has any theories or facts concerning the apparent auto-sterilization of the long-incubated samples of lunch meat.

GROSS

I wish I had, but I haven't a single thought on the subject. We never expected any such thing in view of the statements in the literature that some of these spores had been known to survive 20 decades. Those conditions of survival were unusually adverse to any possible germination. We have done a little thinking ourselves, but I even hesitate to voice it here except to say that we thought there might be the possibility, an approach, let's say, to favorable conditions for the growth of some of these. Under these favorable conditions the organisms attempt to germinate, and when they do, they remain in that stage; neither go forward nor backward, and eventually die there. I wonder if Dr. Halvorson has any thoughts on the subject.

HALVORSON

The experiments we did on spores in rancid fats—reported by Jackson and Foster—show that the fatty acid inhibits the germination of spores. We thought we had confirmed that to show it was due to rancid fats. Later work which we haven't published yet threw some doubt upon this. We determined germination by plating the spore suspension on suitable media where they could grow, and if the organism did not form a colony, we assumed it didn't germinate.

We have now repeated that work and observed germination through the microscope. We find the rancid fatty acids did not prevent germination, but killed the newly formed vegetative cell; therefore, it can't form colonies.

It is our opinion that the newly formed vegetative cells are more sensitive than the regularly growing cell. You sometimes report inhibitors as inhibiting germination when, in fact, they are inhibitors that killed the newly-formed cell. Maybe some of your curing ingredients would not necessarily prevent germination of the spore, but they might kill off the newly formed cells.

GROSS

Mr. Chairman, to add one statement to what I said this morning —one tube in the several thousands did germinate on incubation; that was at the critical point where they either die out or are completely inhibited from further growth, whatever you want to call it. When we examined all the rest of the tubes from that lot which were still under incubation, we found 50% had ceased to be viable. In other words, that one came up right at that critical point. For some reason it got over the hump. These tubes had no rancid fats in them. We know that—which bears out the remarks of Dr. Halvorson.

EVAN WHEATON (American Can Company)

In regard to Mr. Brissey's question—we ran into the same thing in the luncheon meat, entirely separate packs, where on long storage we got no spoilage, and there wasn't any survival. Apparently, the organisms were non-viable. Of course, they incubated samples. Along the same line, we did some work with thermophilic organisms in vegetables, and those packs were stored at temperatures below the growth range of the organisms. There we definitely got sterilization with that type of organism. Of course, that wasn't on incubation, and so we can substantiate what you have found there. This brings to mind one question I would like to ask Dr. Williams. Some years ago I think work was done on P. A. 3679 in shrimp. Was it not concluded that the highly-resistant organisms didn't germinate?

WILLIAMS

That is a general concept. The general concept is that the highly-resistant organism and low-resistant organisms do not germinate in the same way. One is much more resistant than the other.

WHEATON

I was wondering if this could possibly be tied in—although highly-resistant organisms do not germinate in a highly-resistant medium, they would in a less favorable medium.

WILLIAMS

I think that might well be. We have a lot of sugar samples which originally were very heavily contaminated with thermophilic spores over a period of about 10 years, essentially negative for any bacterial content; we ran them again. The thermophilic spores had died out in dry sugar—why, I don't know. There is nothing inhibitory there,

because there is no moisture for them to grow on. They have just died of old age, I suppose.

CLARENCE SCHMIDT (Continental Can Company)

I was very glad to hear Dr. Halvorson's remarks about the potential inhibitory effect being against the cell which may have germinated from the spore rather than against the actual germination of the spore because the experiment confirms a point that I had been reaching out for from the standpoint of some theoretical considerations.

The other point is that we shouldn't, perhaps, consider spores as completely without metabolism during any given time of storage. It is evident that during storage under dry or under somewhat moist conditions—even storage under conditions which would prevent the development of a vegetative cell—a slight metabolism takes place. We might almost say that some slight metabolism *must* take place to maintain life. This can eventually lead to exhaustion and failure to germinate when suitable conditions for germination are provided.

Maybe we need to develop techniques which will define more strictly what we mean by germination. Actually, at the present time, our concepts are being defined by the techniques which we are using to make these determinations.

BALL

There is a question in regard to microbiology I should like to have brought out. It was dealt with to a considerable extent by Dr. Sugiyama and implied in Dr. Gross' talk; it is a question pertaining to the injury to the cells by heat. I have been wondering whether or not it is accepted generally by microbiologists that such injury actually does take place. Are spores which have been subjected to heat insufficient to completely inactivate them nevertheless affected to such an extent that they are slow in germinating and perhaps much easier to kill?

Applying this to Dr. Gross' work, it would suggest that an experiment be tried in which some of the tubes would be prepared with a number of cells, viable according to his culture tests after heating, and additional tubes be prepared into which are inoculated an equal number of fresh spores. Just how that would be done, he could decide, but the objective would be to see whether or not the results from those 2 sets of tubes would be the same in regard to growth after a period of incubation. I would like to throw that question out to any microbiologist just to satisfy my own curiosity. I have understood there was some disagreement, at least, as to whether or not such injury to cells does take place and if it has the effect that I have mentioned.

WILLIAMS

In supplement to Dr. Ball's question and Dr. Gross' answer, there are a number of papers on the addition of enriching materials to

facilitate the germination of heated spores. Dr. Scott from Australia, who was in this country 2 or 3 years back, discussed the addition of starch as facilitating germination of heated botulinum spores. You get much higher germination if you incorporate starch than if you do not incorporate starch, where you are using heated spores.

There are, however, several publications on the use of enriching substances, nutrients, in the medium to favor the germination of heated spores over unheated spores. There is definitely an injury.

SUGIYAMA

Mr. Chairman, along that line, it has been proved many times that spores subjected to rather severe heat treatments are much more fastidious in their nutritional requirements for growth to take place. It would suggest that some of the enzyme system may have been partially inactivated as to the form of products necessary for the germination to take place.

BALL

Also, I suppose they would succumb to unfavorable conditions more readily than the other.

CHAIRMAN ROBINSON

Dr. Williams, am I right in my concept, not being a bacteriologist, that studies made using isolated organisms inoculated in the natural food products may give false indications as regards thermal processing times and temperatures if it is assumed that they are the same as so-called natural contamination? Now, that's something I have heard for a long time. Is it true that the so-called natural contamination is liable to be more resistant than something that has been transferred?

WILLIAMS

There is one item that bears on that, Dr. Robinson. The question you are asking really is whether the native *versus* the college-educated bacteria have a difference. The item which has particular applicability, I should say, in this connection, deals with thermophiles rather than the bacteria with which we are most concerned. As early as 1930 Cameron showed that the organisms in sugar had exactly the same resistance. The same organisms isolated out and a spore crop produced on artificial media, had sugar heavily contaminated, and on this heat-resistance studies could be done. You could make up the same concentration of spores, produced under heated conditions *versus* those that came from natural conditions. The resistance was the same, indicating cultivation in the laboratory did not cause an immediate change.

Now, everybody who has had experience in heat resistance knows that organisms vary in heat resistance. We have a strain of the 1518 thermophile, which is so well known, in our laboratory; one of my

students who is working with that has established its resistance at over 50 minutes at 250°F. But you simply could not kill that organism in any food product and have anything left fit to eat. You would burn the food up.

BRISSEY

I think we can infer from the papers presented by Dr. Sugiyama and Dr. Williams this morning that some workers have found an influence on thermal resistance of free water *versus* bound water. We know that we can influence the amount of bound water present. Do we know what the varying types are that are in spores, and do they have a wide range of iso-electric points, for example?

WILLIAMS

I can't answer that question because I do not know. With regard to bound water, I wonder if Dr. Halvorson wouldn't comment on that because I think he probably knows better than anyone else around here about bound water.

HALVORSON

We are currently studying a project planned by the Quartermaster Corps on this bound- and free-water question. I would much rather talk about it if I didn't have to use the term "bound water." I think it is a misnomer, dependent on an experimental setup. I don't know myself what it means. I can say this, that if one determines the moisture content and the equilibrium vapor pressure of spores at different moisture levels and of vegetative cells at different moisture levels, we come to the conclusion that the vegetative cell likes water better than the spore does. The vegetative cell is more lyophilic than the spore. The spore is more lyophobic.

To illustrate—if we follow a horizontal axis, grams of water per gram of dry substance—against the equilibrium vapor pressure of spores and of vegetative cells we can obtain curves for both spores and vegetative cells. The grams of water per gram of dry substance decrease. Finally, when we have almost perfect dryness we have curves that show the vegetative cells cling to the water better than the spore does. Let me repeat: The spore does not cling to water as well as do the vegetative cells, indicating that the bound water or the affinity of water for spore material is less than for the vegetative cell. Therefore, I think the concept that the water in spores is bound and therefore the spores are heat resistant is false. We have, I think, a better explanation for heat resistance in spores than this concept, and that comes from the studies we made on alanine racemase. This enzyme found in spores is heat resistant—has a heat resistance that is relative to that of the spore itself. The same enzyme found in vegetative cells is thermolytic. If we subject the enzyme in the spore to sonic oscillations, we can rupture the particle to some extent, and separate from the particle a heat-sensitive portion, an enzyme, and

another portion that is heat resistant. If we subject this so treated spore enzyme preparation to fractional centrifugation, we can throw down a fraction at 45,000 G. that is heat resistant. Now, we are just getting into this, and I am talking prematurely. Maybe a year from now we will know more about it.

SCHMIDT

To add one further comment on this bound water question—I believe this difference between bound water of vegetative cells and spores has arisen from 1 or 2 articles in the literature that report work done by a specific chemical technique which has certain questionable aspects. But, nevertheless, these articles have formed the only source of our discussion; there are continual repetitions, reviews, citations and discussions as to the nature of spore resistance. It is still attributed to the bound water content of the spores. I believe that the question should be investigated either by an attempt to repeat the original type of experiment to show if the method is validly interpretable in terms of bound water or to continue the types of experiments that Dr. Halvorson has cited. I am very glad to see that whole question opened again.

RICHARD I. MEYER (QMFCI)

Aside from the bacteriological problems discussed here today, I wonder if any thought has been given to just what can be done with canned meats from a technological point of view. In other words, does the type of cooking in water that they are actually subjected to affect their quality? If you try home methods aside from the can, and you tend to overcook just a little bit, you probably end up with the same mushy, soft texture. My point is this: Has any work been done or been contemplated, using good cuts of beef such as we like to get in the can, properly sterilized, to see if you can really get an improved product in a can if you just relieve the amount of heat—or is it almost an impossibility because of the conditions under which that product is cooked?

TISCHER

I can make one comment on that although I am afraid I am in the same boat as Dr. Halvorson: We are still in the process of attempting to provide such information. We work with canned beef without addition of anything, except time and temperature. What we are hoping to do is expand upon the evaluation of attributes, whether they are subjectively evaluated or otherwise, which have something to do with the final acceptability of the product. What we hope to do in particular is to use a setup similar to the one Dr. Ayres described, and I described later, in mapping out the changes which take place at various processing temperatures and what may be considered the requisite length of time to accomplish a fraction of, all of, or more than the

necessary amount of sterilization. Until we get through with that, I can't give you any answer, but at least, I can say there is some work going on at the moment, our own work, which we hope will throw some light on that subject—for just plain beef, of course, not for mixed products.

GARDNER

Mr. Chairman, part of the answer to the question lies in the economic feasibility of using higher grades of beef. There is another closely related aspect. That is, are we really on the right track when we think overprocessing and overcooking contribute to lesser acceptability?

WINSTON S. OGILVY (Armour & Company)

The thing we want to do first is to try to get some idea of the relationship of acceptability of the product, that is, flavor and texture, to the processing that it gets. In order to do this, cooperating industrial organizations are going to make up a product using several processing levels and subject it to taste panel evaluation.

CHAIRMAN ROBINSON

I have thought for quite some time about this problem of more acceptable canned meats. From the industry's viewpoint, you are aware it is not a very satisfactory business. Acceptability is so low that the volume of product purchased by the American public does not represent a very suitable financial return on the basis of necessary investment. It would be most pleasant for the Armed Forces if you could give everybody a nice piece of roast beef similar to a piece of roast beef they would have left over and prepared as so-called fancy cold cuts, or roast pork, or baked ham. These items taste exactly like the articles as they come out of the kitchen. When you can give them that, you have given them the things they want most, and, of course, we are coming closer and closer to achieving that ideal. Within 2 years we are going to see some of those kinds of products because of the advances made possible by the fundamental knowledge that has been supported by the Quartermaster group and others. We are learning what to do about these spoilage organisms, what different types of heat treatment mean—the sort of thing we heard today. But that isn't the only answer—not everybody can afford to eat cold roast beef, cold roast pork, and cold baked ham. I don't know that the Armed Forces can afford to feed that exclusively; so you have to come back to these so-called comminuted products. I believe there is a great future for them simply by their having a better taste and regardless of whether they have a particularly better texture.

All of us all of our lives have used from the best on down the scale—the things that aren't quite as good, but don't cost us as much. We eat them because we can afford them; we eat them for that lunch-

eon, for that supper, for that night, for that not quite so fancy meal. My answer is that out of this work for the Armed Forces civilians are going to get 2 new types of products; one, the aseptically canned, first-grade items that are not available today in any sense, and the other, improvement on the sort of thing that we have which won't be equal to them, no matter what you do, but which will be a lot tastier as a secondary type of meat.

GARDNER

I might add that the Quartermaster has been supporting research, to be reported tomorrow, on the use of dielectrics, and we are at exactly that point. We have determined the microbiological aspects, and the next question is: Using controlled subjective methods of evaluation, will the improvement be worth while? I think Dr. Doty will answer that question tomorrow.

ROY E. MORSE (Wm. J. Stange Co.)

When you discuss canned meats, you inevitably make the comparison with a nice piece of fresh roast beef. This seems to me to be starting off on the wrong foot. When we purchase a can of peaches or pears, which we have accepted through the years, we no longer expect to compare those with fresh pears or fresh peaches. Why, necessarily, do we expect to compare canned meats with fresh meats? They have the additional advantages, which the fresh meats do not have, of being storable in some areas, and at the same time we pay for the quality degradation. I think we should introduce that thinking a little bit into this whole symposium.

GARDNER

Speaking for our program, that has been taken into consideration. Fresh peaches are not available to the consumer for a large part of the year, and for a long, long time they have been sold in the form of canned peaches. The consumer has therefore developed a liking for canned peaches. But meat is available to the consumer the year around in the form of fresh meats or a sausage product or a cured and smoked product. The consumer is therefore less content with a canned product. That's our reason for having a fresh-tasting piece of properly cooked meat as our canned meats goal.

F. WARREN TAUBER (The Visking Corporation)

I would like to raise this question in relation to these canned products: Why do the Armed Forces invariably pick the inconvenient sizes and shapes? It seems that frequently they want to cook up something in an odd shaped can. Basically, we run into experiences on the farm where you select the proper size and shape of can and get a fairly decent product out of it, yet it seems that in canning for the Army and frequently for commercial use, they are after a can with a

small amount of tin. which seems to be the primary concern. Our experience has been that, in many of the things they want, there is no attempt to consider the problem of size or shape. I was wondering whether that was being given any consideration in the program at the present time.

CHAIRMAN ROBINSON

I don't know whether Dr. Gross or Mr. Brissey or some of these other gentlemen here agree with you on your original premise that they may not be putting luncheon meats up in the right size can. Let's ask them if they have given any thought as to the best can sizes both commercially and for the Army.

TAUBER

Both commercially and for the Army—invariably they seem to pick a size because it is better adapted to the tin they are using, not necessarily the right size and shape for the product to be processed. One thing I had in mind, specifically, was canned meat and sausage. For some of these products the commercial grades utilize a little 4-ounce container. The product in this can is in much better condition than would be a comparable product in a 1½-pound can or greater for the Army. It seems to me the Army specifications call for a much higher quality of material, but in the process of preparing it. it is pretty well chewed up.

GROSS

I think the Army people will have to answer from their angle.

COLONEL WILLIAM JACKSON (OQMG)

I have been listening to this discussion with much interest. I was particularly interested in Dr. Robinson's comment—that the civilian thinks of canned meat as an occasional meal. He spoke of it in that sense—that you might have it occasionally as a substitute for a cold supper or dinner. In the Army that is not the purpose of canned meats. When we buy canned meats we buy large quantities as assurance that we can feed the soldier in the field under extreme combat conditions where you cannot get refrigerated products. We try to get fresh food there whenever possible, but to do that, we do have to carry large reserves of canned meats, and we do have to eat them. I was in charge of the food program in Japan which supported the Korean operation. Initially, we tried to ship perishable items to Korea, that is, in September 1950. Due to combat conditions and shortages of shipping and the sudden build-up of troops, we were unable to furnish troops with fresh food, and clear through December 1950 they subsisted for about 3 months on canned items entirely. The morale of the Army at that time was not good. I don't know how much the food contributed to this, but I know it had a definite effect. Beginning in January, due to the insistence of General Ridgway, we put fresh

food up there. It was quickly a rejuvenated Army. However, at the time we did that, food shipments were made at the expense of other items because we had to get something in there to help revitalize the Army.

If we can get a good canned meat that you can feed, you can reduce the expense to the taxpayer. You can reduce the spoilage losses that the Army has to sustain in the field.

We made another test quite recently of the small cans of meats which are in the C Ration. Most of them are mixtures with vegetables, but even there, when we placed troops on a test for 30 days and gave them nothing else to eat, under controlled conditions, where they couldn't get any other items except what we might give them, they got to the point—after 10 days—where they didn't want to eat at all. Their acceptance of food dwindled to the extent that it impaired their health. They couldn't work; they didn't care. That is basically why we are interested in getting a good meat item in the can for the Army or for the Air Force or Navy. It is perhaps an emergency item, but it is an extremely important one. It is also the only item you can ship when you have an immediate mobilization of the Army in the field. You haven't refrigeration. You are busy with all the other factors in combat, and you must have an item that the troops will eat and enjoy. Meat is still about 50% of the ration; frankly, the canned beef, canned pork, and the various substitutes or mixtures that we have all seen taste the same after you eat them about 5 days, and if you don't believe it, any one of you put yourself on that diet for 5 to 10 days and see what you think. The old items we had—hash and meat and vegetable stew and some of those items—all taste the same. You can't tell whether you are eating a piece of potato or a piece of meat, actually, after it is stored for about a year, and most of the items that we issue are 2 years old when we issue them. They are not fresh because we have to buy them and keep enormous reserves at various strategic locations. Unfortunately, they often just sit there. If the items were acceptable, or had greater acceptability than at present, we could inject more of them into the daily ration and our turnover would be much more rapid. We do feed it to all troops in the Army, Air Force, and Navy at the present time by direction. I think in the Far East Command they eat about 7 meals of canned meats a month, but it doesn't set very well with the soldier. He doesn't know why he has to eat it because he doesn't like it. In many cases he just kind of half skips that meal. We have to find something, when we are using soldiers in the field. We have to keep them full of pep and energy, and the only way you can do it is to give them food.

Canned meat is an extremely important problem to the Armed Services. If you ever develop canned meats that are really highly acceptable to the soldier, he will change the tastes of the civilian market because he has done it in other wars when he came back. He changes

the habits of the American people because he likes certain items, and when he comes back he demands those items. Canned meats are not a highly profitable item, I have been told, by the various canners, but I think that is the problem that we have to solve—not to make profits but to get a better product.

CHAIRMAN ROBINSON

Colonel Jackson, we are in perfect accord with what you have said. I actually went on a fishing trip 2 years ago and bought all kinds of canned meats I could get. It took me only 2 days to find out they all tasted alike. In the meat industry we are absolutely non-complacent about our canned meats. They are not good; we recognize the fact that if we could give you in the Armed Forces an acceptable product that the soldier could, when essential, eat day after day, on that day we would have *arrived* also in the civilian market. Today we are spending millions of dollars in the industry on all these processes that you will hear about tomorrow.

COLONEL JACKSON

I know you are, and that's the purpose of this discussion. I didn't imply the industry wasn't doing a great deal. You are, and the universities are doing a great deal, and we are doing, actually, a very small portion in the total over-all picture. We hope to expand our activity in this field; it is a very large problem for the Armed Services. It is a problem, I think, which is going to be with the Armed Services indefinitely. It isn't anything you are ever going to whip immediately. I think the effort spent on canned meats is well spent. It is a good investment for the American taxpayer and the American public.

GARDNER

Mr. Chairman, I might get back to the original question on containers for the purpose of illustrating how the information brought out in this symposium and the one that meets tomorrow is going to be of benefit to us. Mr. Smith is going to tell us something about what he and Dr. Ball have done. The process they have worked out would, if it bears out its promise, save the taxpayers of the United States $160,000 on containers alone.

CHAIRMAN ROBINSON

We have time for 1 or 2 more questions.

CARL S. PEDERSON (New York State Agr. Exp. Station)

Dr. Dack, Dr. Sugiyama, Dr. Williams, and, I believe, Dr. Halvorson have been studying the relationship of the various factors of spore germination and spore formation and heat resistance of spores. I am wondering if they have given any thought as to whether some of these same factors may be effective in these new types of processing.

That is, in regard to electron bombardment and radiation and so forth, whether any thought has been given to whether the same factors will hold true in those new methods of processing. It is entirely theoretical, I suppose.

SUGIYAMA

Actually, we are trying to run a concurrent set of tests with cobalt 60 radiation, to see if the factors increase or decrease the heat resistance of the spores or in some way affect the susceptibility of the spores to that radiation.

WILLIAMS

I have thought about it a little, but not long enough. I haven't formed an approach to the problem yet. I certainly believe that it very much deserves attention.

DACK

One thing is true—it takes more reps to kill the very heat-resistant organisms than it does some of the vegetative cells; and another thing, the amount of heat it takes to kill such organisms deteriorates the quality of the product, very often leaves you an inferior product. Flavor and color are anything but acceptable. I think that's in line with your experience, too, isn't it, Dr. Robinson?

CHAIRMAN ROBINSON

That's correct.

BALL

This is not so much a question as a comment. Colonel Jackson's remarks on canned meat acceptance made me wonder whether or not there would be a question of nutritional quality involved. His remarks seemed to me to indicate that the soldiers will eat until they reach the point of disinterest or not caring. I always associate such an attitude with improper nutrition. Should we be considering the nutritional qualities of these products as well as the organoleptic quality? Possibly after they live on these particular types of foods for a while, they do lack some of the nutritive elements they ought to have had.

COLONEL JACKSON

The Surgeon General has been conducting some tests on that in conjunction with the Quartermaster Corps; they have been a little shocked at the loss of nutritional quality of these meats. In the experiments I made we ran only a couple of actual controlled experiments with troops. The meats were quite old, and the nutritional loss was quite substantial. They are going to make a much more thorough study of the problem now because nutrition is definitely involved; the loss of nutrition is quite great.

CHAIRMAN ROBINSON

Thank you all for coming. It has been a very nice meeting.

IV. Canned Meats of Today

WEDNESDAY MORNING SESSION

April 1, 1953

The meeting convened at 9:15 with Dr. Clarence Wiesman, presiding.

CHAIRMAN CLARENCE WIESMAN

Yesterday we had a very interesting session concerned with the microbiology of canned meats; later, the discussion turned to heat-transfer problems connected with processing of canned meats.

Today we will discuss first of all something about the canned meat situation as it is today, something about what the Army would like in canned meats; the papers will be concerned with new methods of processing designed to get away from some of these problems that have caused the symposium to be called. Actually, in looking over the program and in listening yesterday, it occurred to me that perhaps the word *symposium* isn't really a good description of the kind of program we have had here. To me it is really a short course in canning. I know I have gotten a lot out of it so far, and I am sure every one here will have learned much about canned meats before this is over.

This is an unique type of symposium in that we haven't invited any one here to be a listener. Every one here is invited to be a participant. Later on this afternoon we are going to have a round-table discussion, and we would like everyone in the audience to participate in this discussion, not only from the standpoint of asking questions, but also from the standpoint of contributing information that might be helpful to the problem.

The next speaker, Major William B. Levin, assistant chief, Military Operations Office, Quartermaster Food and Container Institute, formerly was an infantry officer and served in the European, Pacific, and Korean theaters. He is well qualified, obviously, to explain "Why We Need Better Canned Meat Products." Major Levin.

Why We Need Better Canned Meat Products

MAJOR WILLIAM LEVIN

The obvious reasons why any ration item should be improved are: (1) to increase the acceptability, nutritional qualities, and stability; (2) to add interest to the diet of the soldier; (3) to improve the lot of the fighting soldier. These reasons are generally known and accepted. It is my hope to furnish you with a picture of *how* our troops are supplied with food in Korea, *how* they are disposed on the ground to form

a typical fighting unit, and *how* they are fed under combat conditions. You will then be able to see the part that foods play in combat operations—and why, among many other subsistence items, it is vital to have the ultimate in the canned meat items.

The ration distribution pattern in Korea. With regard to how food is distributed down to the front line elements of an infantry division, let us consider in broad outline the arrangement of the troops on the ground. A normal infantry division consists of approximately 18,700 men and officers. However, in Korea an infantry division usually has several attached units, and therefore its strength generally exceeds this number. A division in combat usually is spread out into 4 operating echelons. The echelon closest to the enemy—where the heat is on—is called the *outpost* or the *Operational Line of Resistance.* This echelon is there to intercept a surprise attack on the main forces which are located on the *Main Line of Resistance* and to divert the attack or break it up. You can readily see that these units must be on the alert 24 hours each day. Since this echelon is in direct contact with the enemy, to get the food to them takes planning and maneuvering. The problem is complicated by the fact that it is Army policy to serve hot meals to the soldiers whenever possible. In Korea, where we have endeavored to supply at least one hot kitchen-prepared meal to the soldiers on this Operational Line of Resistance each day, it must be brought to the troops during the hours of darkness. The other 2 meals consisting of packaged operational rations, containing canned meat items, are less difficult to supply and can be carried, in some instances, on the soldier's person.

The bulk of the soldiers of a division are found on the Main Line of Resistance. In Korea, it has generally been possible to serve at least 2 hot meals each day to troops on the main line. However, as in the case of the Operational Line of Resistance, we are again confronted with the problem of preparing the food, transporting it, and seeing that it reaches the soldier in a hot, palatable condition. Food for the main line is prepared at unit level in infantry company kitchens. It is possible here to use field ranges and to distribute the food directly from the kitchen to the individual soldier. Meals are fairly well regularized at this point and no need ordinarily exists for delivering the meal under darkness or other unusual circumstances. The soldier on the Main Line of Resistance usually gets 2 hot meals a day; the soldier on the Operational Line of Resistance gets a maximum of one hot meal a day. The operational C Ration is used for the other meals. It is an interesting fact, sometimes overlooked, that soldiers on the Operational Line of Resistance, who must maintain a 24-hour alert, require more than the usual 3 meals a day. Their expenditure of energy is greater and food, of course, under some circumstances, can relieve tension. It has therefore been found necessary to supplement Operational Line Resistance feeding with an additional meal, usually during the evening or during the night. The Individual Assault Pack, which is not a complete ration in itself, has been used for this purpose. This ration centers around canned meats and it might be said that regardless of the soldier's location, whether on the Operational Line of Resistance or the Main Line of Resistance, whether his food is served hot or cold, the food he eats is processed food, usually in the form of canned foods. It is therefore essential that it be appetizing, continuously acceptable if possible, and nutritious. Canned meats fulfill these requirements rather well, but there is certainly room for further improvement if we are to meet these requirements adequately.

Behind the troops on the Main Line of Resistance, there are other division echelons extending in some cases as far back as 30 miles. With standard Army policy to serve hot meals to the soldiers whenever possible in mind—here we find the ideal situation. It is possible under present tactical situations in Korea to serve 3 hot meals a day to the service elements of an infantry division. These elements include the engineers, ordnance, and signal troops which have head-

quarters back of the Main Line of Resistance. The normal, field-type kitchen is used here. The food served does not differ markedly from domestic garrison feeding.

The fourth operating echelon of an infantry division in Korea, the very rear of the division, usually is spread over several miles, and its soldiers are fed in a *consolidated mess.* This has been found to be necessary since replacement soldiers and numerous other soldiers are constantly being processed through this area, both to and from the front elements of the division. The consolidated messes usually serve 500 to 1,000 soldiers cafeteria style. These messes are established on a semipermanent basis and often have dishwashing equipment and more elaborate serving facilities than is possible closer to the front.

From this brief review, it can readily be seen that the difficulties in feeding an infantry division increase as one approaches the front elements of the division. Troops up to the Main Line of Resistance are served from the field kitchens with 3 hot meals daily. Troops on the Main Line of Resistance usually have been able to receive 2 hot meals daily and must use a packaged operational ration for the other meal. The troops on the Operational Line of Resistance sometimes receive more than one hot meal per day, usually receive one, but in many instances must use a packaged operational ration for all 3 meals.

To win battles, the soldiers in any army must be properly supplied. Food is the fuel that powers the soldier and as such it needs a high "octane"—or fuel value—just as does a motor fuel. It behooves all of us, whether we are in the Military Service or in civilian occupations, to do all that we can to see that the food we supply our soldiers on the firing lines is the very highest in quality and better, if possible, than that eaten under happier circumstances. It can never be said too often that if rations are not appealing, they may not be eaten, and if they aren't eaten, their nutritional value is *nil.* Moreover, wastage of food means that time, effort, and the money expended in manufacture and supply have been nullified. Add to these factors the further one that rejected rations are a source of disgruntlement and low morale, and few will dispute the generalization that if soldiers don't eat their rations, their effectiveness in battle is lowered.

Canned meats in relation to morale. Canned meat products are of prime importance in combat rations. These products are central to the ration, and upon them the effectiveness of the ration as a whole depends. If it were possible to achieve the ultimate—a canned meat that even after prolonged storage tasted like fresh, it is likely that all other items in the ration would have added appeal. You, as scientists, often use that expensive word—*synergism*—which means the conjunction of 2 qualities that, added together, more than exceed the effect of the mere sum of the 2. Thus, when we arrive at the ideal canned meat we can perhaps consider that this one basic improvement will produce an over-all acceptability for rations greater than would normally be expected by this improvement of only one item. With canned bread now a reality we may be able to supply—when we attain the perfect canned hamburger—the perfect hamburger sandwich! You will realize, of course, that I am using this example only by way of enforcing a point. We seek the ideal but realize that we must be content with the improved—that is, with a way point toward perfection.

During World War II and during the Korean conflict, many new and highly satisfactory canned products were developed and proved to be suitable for ration use. Field reports still emphasize, however,

that continued use of even the present improved canned meats leads to monotony, with an accompanying reduction in acceptance. The search for methods of eliminating these deficiencies is still necessary, and we must turn to your group for real improvement in canned meat items in future military rations. Perhaps, by furnishing you with a brief glimpse of combat feeding, I have indicated the great value of your past efforts and the continued need for further advances.

V. Potentialities of New Methods of Manufacturing

CHAIRMAN WIESMAN

Thank you very much, Major Levin. I am sure that your paper has helped give us all a better understanding of the problems of feeding the Armed Forces.

The next paper will be presented by Mr. Horace L. Smith, Jr., consulting engineer and co-author of the famous Smith-Ball process. Mr. Smith is going to describe the potentialities of pressurized manufacturing facilities for producing canned meat products. Mr. Smith.

Potentialities of Pressurized Manufacturing Facilities for Producing Canned Meat Products

HORACE L. SMITH, JR.

In this discussion on sterilization of canned meat products the destruction of pathogenic and spoilage organisms by heat alone will be considered. There are other processes under investigation that are directed toward sterilization methods that do not involve appreciable increase in temperature of the product, but this line of work is being left to other investigators. It is assumed that high-temperature, short-time processing provides the means for producing the most desirable method of sterilizing meat products. In order to reduce the time of processing to minimum practical values it is necessary to consider temperatures much higher than the boiling point of water at atmospheric pressure. In the past, this requirement has necessitated sealing the product in pressure-tight containers before sterilization, and then subjecting the sealed containers to the conventional high-pressure steam retort procedure. The disadvantages of this process are obvious and need not be elaborated.

A specification for the ideal process would require all of the product to be heated uniformly in the shortest possible time. In considering canned meat products we are dealing with discrete particles as distinct from homogeneous or liquid products. In considering the means of securing rapid and uniform heating of these discrete particles, the physical dimensions of the particles or pieces of meat play an important role, and also the environment in which the products

are heated is equally important. If it is necessary to heat the product to temperatures in excess of 212°F., it is essential, since all of these products contain moisture, that the heating process be carried out under pressures greater than atmospheric, otherwise the higher temperatures could not be reached.

In considering available means to secure rapid heating of the product, 3 basic methods offer possibilities. If the largest discrete particle is of small dimensions, it is possible to secure satisfactory heat transfer by simple conduction from a heated surface. A product of the consistency of hash or chili con carne could be heated at a satisfactory rate if spread out in a very thin layer or film on a heated surface. As the size of the particles increase in dimension, heating by conduction from one surface is not fast enough to satisfy the criteria specified. An increase in the rate of heating can be provided by surrounding each separate particle by an atmosphere of steam at a temperature higher than the temperature required at the center of each particle. This method also relies on conduction from the surface to the center of the particle; therefore, as the dimensions of the particle increase the time also increases. A 3rd and very promising method of heating immediately suggests itself, and that is by means of internal molecular friction within the product itself. This method is sometimes termed *diathermy, electrostatic heating, micro-wave heating,* etc.

The basic concept of the methods previously outlined require conditions that will permit heating of low-acid food products to temperatures of from 240° to 260°F.; and the filling of products at these temperatures in open containers. To achieve this requirement, the so-called Smith-Ball pressure canning process was developed. It is based on the physical law of vapor pressure. We know that water boils at 212°F. at sea level under normal barometric pressure, and that on the top of a high mountain the boiling point is lower. Conversely, as the pressure over the water increases, its boiling point increases. At 20 pounds gauge pressure water will not boil until it reaches 260°F. The Smith-Ball process consists of a room or building of steel plate designed to withstand internal pressures in excess of the highest pressure expected to be used. In this room is located all of the equipment needed for the processing or heat sterilization of the product, conventional filling and closing equipment and means provided for at least partially cooling the containers in the pressurized space. The normal complement of operating personnel would work in this space, performing the same duties required in a more conventional canning plant.

With the suggestion that people work at an elevated pressure, the question immediately arises as to the effect of the higher pressure on the human body. Fortunately, there is a great amount of data available on this point. All of the railway and vehicular tunnels built under the Hudson and the East River in the New York area were con-

structed by means of the compressed-air shield method of tunneling. "Sand hogs" worked under compressed air for long hours and engaged in strenuous physical effort. The Bureau of Mines has collected statistical data on this subject and the record shows that of a total of 809,838 decompressions from pressures up to 22 pounds gauge, only 16 cases of compressed air sickness resulted, and all of these were trivial. This 22-pound pressure corresponds to approximately 263°F. Several high-pressure wind tunnels are in operation in this country. The marine diver is normally subjected to pressures much greater than 22 pounds—to pressures, in fact, as great as 265 pounds gauge pressure. This is equal to an open sea dive of 561 feet. The latest U. S. Navy Diving Manual issued by the Navy Department, Bureau of Ships, July 1, 1952, specifies from 4 to 6 minutes decompression time for a diver working approximately 4 hours at a depth of 50 feet, which corresponds to a pressure of 22.3 pounds gauge. It can be definitely stated that with exercise of reasonable care there is no industrial hazard involved in working at pressures of the order of 20 pounds gauge.

The application of the Smith-Ball process to meat products such as hash, vienna sausage, frankfurters, luncheon meats, hamburgers, and any other type of meat products that are of relatively small dimensions in at least one direction, can be quickly heated to acceptable temperature values by means of heat exchangers designed to the physical requirements of the products, by surrounding the product with steam, by cooking in water or high-boiling liquids such as cooking oils, etc. The heating of the product can be carried out either exterior to the pressurized chamber or within the chamber. The containers and ends can be pre-sterilized by means of steam. When steam from a high-pressure source is allowed to flow into a compartment or enclosure within the pressurized space, the temperature of the steam corresponds to the pressure maintained within the chamber, therefore with 20-pounds pressure the temperature of steam available for sterilizing the containers and ends would be 260°F.

High frequency heating. In dealing with meat products of larger dimensions, such as shoulders, hams, fowl, or any other large piece of meat, heating by conduction from the surface to the most remote point may require a time greater than is compatible with maintenance of product quality; therefore the use of heating by means of molecular vibration appeared to hold great promise. Considerable commercial success has been achieved by a number of manufacturers supplying electrostatic heating equipment used in heating non-electrical conducting materials such as wood, paper, pre-forms for the molded plastic industry, synthetic fibers, and a long list of other products. Special applications of this basic process have also been used to cook foods, especially meat products. The early work done in the use of high-frequency heating was in the relatively long wave-length band, in the range from 2 to 20 megacycles. As this art developed, it became apparent that better results were obtained with the shorter wave lengths, which meant higher frequency. With the rapid development in the entire field of electronics, equipment has become available that operates at much higher frequencies. In the patent literature on this subject it is stated that the best results are obtained by using a frequency corresponding to a wave length that approaches at least one

physical dimension of the article being heated. If we assume that 10 cm. (approximately 4 inches) is a desirable wave length, this corresponds to a frequency of 3,000,000,000 cycles per second. Electronic heating could be on a batch basis or a continuously moving conveyor carrying the material through the high-frequency field. The details of high-frequency heating would have to be worked out to fit the requirements of a specific product or group of products.

Pressure chambers. Pressure chambers suitable for use with the Smith-Ball process would be built to satisfy local codes and to fit in available space. One method of constructing an inexpensive pressure chamber is to build the chamber in the shape of a horizontal tank. Taking an arbitrary size, 22 feet in diameter and 70 feet long, the chamber could have 2 work decks or floors and would provide approximately 2,400 square feet of usable floor area at a cost of between $6.00 and $8.00 per square foot. This cost is comparable to the cost of a plain first-class multi-story plant. The pressure chamber could be located outside of existing buildings, possibly parallel to a wall of the building, with an airlock and communicating means through the side of the tank or through one end. The upper deck could be used for product heating, pre-sterilization of containers and ends, filling and closing equipment; the lower deck could be used for can-cooling equipment. A cylinder is inherently stable for internal pressure; therefore, relatively light construction could be used with the usual factor of safety complying with the American Society of Mechanical Engineers' code for unfired pressure vessels. As floor drains are necessary in practically all canning operations, the space between the bottom of the cylindrical shell and the underside of the lower deck could be used as a sump or catch basin to accumulate and store floor drainage run-off. This accumulation of waste water could be continuously discharged by means of a float-control drainage valve or the water could be accumulated batch-wise and a manually-operated valve used to discharge the water after the pressure in the chamber had been relieved. Where physical plant arrangement permits the addition of the pressure chamber outside of present buildings, it is the equivalent of adding additional floor space in the form of the pressurized chamber but at a cost comparable to regular plant cost on a per square foot basis.

Operating procedures. Empty containers can be continuously valved into the pressure chamber by means of rotary pocketed valves similar to those used on continuous pressure cookers. The cans would be conveyed through an enclosed space filled with live steam, thereby pre-sterilizing the cans before they reached the product-filling equipment. The can ends can be pre-sterilized by providing a simple additional device on the closing machines to space the ends in order that steam may reach all surfaces and to provide a short time delay for the ends in this steam-filled chamber.

After the cans are filled and closed, there should be a short holding time at the filling temperature. If an occasional viable microorganic spore is present in the head space, the holding time will insure its destruction. Although the air supplied to the interior of the pressure chamber is presumed to be sterile, there is always the possibility of viable microorganic spores being released from the person of the operator, from the surface of can covers before they enter the sterilizer, or from the surface of the can valves. After the short holding time at filling temperature, the cans are cooled to a degree that reduces the internal pressure to a value that would not cause undue stress in the containers when passed out to atmospheric pressure. If there is any head space in the container, and if cold water is sprayed on the

can, condensation of the water vapor within the head space immediately occurs, thereby reducing the pressure within the container. This, in turn, causes boiling or evaporation of additional moisture. As the only source of latent heat to provide evaporation of additional moisture is obtained from the sensible heat of the product, rapid cooling occurs throughout the product so long as condensation occurs in the head space. In using glass containers it may be desirable to carry out the cooling within the pressurized chamber to a much greater degree than would be necessary for tin containers. It is entirely practical to do all of the cooling within the pressure chamber. The cooled or partially cooled containers are passed out of the pressure chamber by means of rotary pocketed valves similar to those used in passing the empty containers into the pressure chamber.

In any canning operation involving filling of a hot product there is always considerable water vapor or loose steam being liberated around the equipment. In the pressure chamber the most practical way to remove this steam is by means of well-designed hoods connected by suitable ducts to a suction fan whereby the steam can be condensed by means of cold water spray. The air is then passed through a steam or hot water reheat coil to reduce the relative humidity and increase the dry-bulb temperature to optimum comfort level. Fresh air is continuously introduced in quantities sufficient for ventilation purposes and the air supply is passed through a sterile filter before being discharged into the pressure chamber. The excess air is continuously valved out of the pressure chamber by means of simple control instruments that can be set to maintain any predetermined pressure within the chamber.

In order to sterilize the pressure chamber and all of the equipment contained therein it is very simple to locate all electric motors on the outside of the chamber and provide packing glands or stuffing boxes for the several shafts where they pass through the wall of the pressure chamber. All electrical controls for the several motor drives are located within the chamber and a simple method of protecting the electrical equipment is to have pressure-tight boxes or cabinets in which are located all push-button starter switches, telephone connections, etc. Prior to steam sterilizing the chamber, the cover of these boxes is secured by means of wing nuts, the cover being made watertight by means of a simple rubber gasket, thereby protecting all of the electric control equipment.

Visibility within the chamber is easily provided by means of plate glass portholes, usually circular and from 8 inches to 10 inches in diameter. The usual construction is to have 2 separate pieces of glass, each separately gasketed. If from any accidental cause one of the glassses is cracked or broken, the remaining glass will be adequate to withstand the pressure and prevent sudden release of the air from the chamber. These portholes provide excellent visibility either from without or from within the chamber.

Personnel entering the airlock or entrance vestibule can be brought up to operating pressure in a very short time, the only limitation being a slight discomfort if the Eustachian tubes are abnormally small or inflamed or irritated by a head cold. If the pressure changes too rapidly for equilibrium to be established in the inner ear through the Eustachian tubes it is simply a matter of personal comfort to decrease the rate of pressure change. Going from atmospheric pressure to 20 pounds pressure can be easily accomplished in 2 minutes. Decompression can be regulated manually or by a simple control instrument having a preset schedule to provide any rate of decompression desired. The standard Navy diving procedure is to make rapid pressure changes to a lower value, then hold the pressure at this value for a definite time, then again a rapid decrease in pressure. The time required for decompression is a function of the higher pressure and the length of time that the operator is exposed to the higher pressure, but in no case would decompression require more than 6 minutes from a 20-pound chamber pressure.

Additional advantages. It should be clearly understood that although the Smith-Ball process has been built in commercial size, it has not been used in combination with high frequency product heating. The combination certainly offers interesting possibilities, and the technical problems involved at the moment do not appear to be insurmountable. Additional advantages of the process are:

a. The entire processing equipment can be kept in practically sterile condition because at the end of a day's operation the entire pressurized room can be flooded with live steam, thereby sterilizing not only all of the equipment but the ceiling, floors, and everything within the enclosure.
b. The air continuously introduced for ventilation purposes is sterile.
c. Conventional closing and filling equipment can be used, and as this equipment is further refined and developed, improved machines can be installed whenever desirable.
d. By means of pre-sterilizing and filling at sterilization temperature, dry packs can be obtained because the process does not require a liquid-filled can in order to secure heat conduction within the container.
e. With the use of high-frequency equipment within the pressurized space it may be possible to use higher voltages between the treater electrodes due to the greater insulating effect of the denser atmosphere.
f. The process does not rely on aseptic filling, as the product is filled at sterilization temperatures; furthermore investigations during the past 10 years have conclusively proved that with a decrease in the number of organisms present the severity of the process can be decreased.

CHAIRMAN WIESMAN

Thank you very much, Mr. Smith. I am sure your paper will provide many questions for the panel discussion this afternoon.

Our next speaker will be John P. Bolanowski, who is manager of the pilot plant of the Girdler Corporation of Louisville, Kentucky. Mr. Bolanowski.

Potentialities of Utilizing a Continuous Type of Process in Conjunction with Aseptic Canning for Production of Canned Meat Products

JOHN P. BOLANOWSKI

Although the approaches to a discussion such as this are numerous, it is felt that the potentialities of this method of canning some types of meat products can best be illustrated by attempting to bring to light the prerequisites of the process and the problems involved in fulfilling these prerequisites. This will be done by presenting in brief: the definition of the combined process; the equipment required; heat transfer and flash sterilization; the advantages of flash sterilization and aseptic canning.

Definition of the process. Simply stated, the continuous, high-temperature, short-time food sterilization in conjunction with aseptic canning is a process which enables the separate and independent but synchronized and concurrent sterilization of the product, the container and cover, aseptic filling and sealing. The work reported by Ball gives a lucid demonstration of the merits obtained with high-temperature, short-time sterilization and aseptic canning.

The flash sterilization and aseptic canning process differs from the conventional retort operations in that the product is rapidly but separately sterilized and cooled before being sealed in the container. Sterilization of the food material is attained by pumping it successively through heating, holding, and cooling sections of a closed, continuous-heat-exchanger system under pressure.*

In summary, the procedure for high-temperature, short-time sterilization consists of 4 continuous but separate operations executed concurrently in a closed system, as follows:

a. The product is continuously sterilized under pressure at a high temperature (280°-290° F.) by pumping a high-velocity stream through a heat-exchange system consisting of heating, holding, and cooling sections.

b. The containers and covers are sterilized by exposure to superheated steam or other hot gases at a temperature of 400°-600° F. for a time sufficient to sterilize.

c. The cold (50°-90° F.) product is filled continuously into the sterile containers in an atmosphere kept sterile by 400°-600° F. superheated steam.

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* One type of heat exchanger which has proved very satisfactory for the sterilization operation is manufactured by the Girdler Corporation of Louisville, Kentucky, and sold under the trade mark, "Votator." Depending on the product, the operating pressure will be 100 to 200 p.s.i.g. in a Votator heat-exchanger system. Pressures of over 2,000 p.s.i.g. have been recorded when using coil-type or tubular-heat exchangers on products such as purees, dog food, potted meats, cream-style corn, concentrated soups, etc. Although pressure is required to prevent flashing, this pressure need not exceed 200 p.s.i.g.

This, in the case of meat products, eliminates oiling off or fatting off in the can.

d. The container filled with cold sterile product is sealed with a sterile cover in an atmosphere continually kept sterile by superheated steam.

Equipment required for flash sterilization and aseptic canning. Sufficient research and process development has been accomplished to permit definite specification of the equipment required. To accomplish flash sterilization and aseptic canning, 5 important equipment requirements must be fulfilled:

a. A pumping system capable of pumping a wide variety of products through the heat-exchanger system at a constant flow against a pressure sufficient to prevent flashing. In addition, this pumping system must not damage the product or cause the discrete particles to lose their identity as, for example, creamed beef or cream-style corn.

b. A continuous heat-exchanger system capable of very rapid heating and cooling under non-flashing pressure only. In addition, the heat-exchanger system must not alter the identity of the product by mechanical and physical breakdown of the product. The heat exchanger must be so constructed as to operate with a minimum of burn-on, bake-on, and caramelization.

c. A holding section to insure each singular portion or particle equal, controlled exposure to the sterilization temperature, so designed that it will not impose excessive pressures across the heat-exchange system. The holding section must also be capable of maintaining the sterilization temperature, preferably by insulation or jacketing.

d. A means of maintaining a sufficient back pressure in the heat-exchange system to prevent flashing. The pressure-maintenance means must operate under sterile conditions without pulverizing or comminuting the product—such products, for example, as dog food, creamed chipped beef, cream-style corn, or chili without beans.

e. And last, but certainly not the least, an apparatus which is capable of continuously sterilizing the cans and the covers, and is also capable of filling and closing under sterile conditions.

Heat transfer and flash sterilization. It must be thoroughly understood that all the equipment discussed is equally important and equally essential to make flash sterilization with aseptic canning a possibility. Individual perfection of any one item is meaningless without an equally perfect functioning of the other items of equipment. Nevertheless, as in all processes, although no one item is most important, there is invariably one part that must be capable of compensating for variables in the process. In this case, due to the numerous types of food products that are adaptable to aseptic canning, it is the heat-exchanger system. To put it another way; in most of the work done, our experience has been that the cans and lids with proper liners and compounds can be readily sterilized, the product can be pumped, and a suitable holding section and means of applying back pressure can be attained. The important question is: Can the product be sterilized without deleterious effects?

Advantages of the Votator type of heat exchanger. Several years ago the development work on the high-temperature sterilization of food products was undertaken by the Votator Division of the Girdler Corporation because it was felt that due to the design and the principles of the Votator scraped-surface heat exchanger, the proper type of flash sterilization could be attained for a wide variety of foods. There are several characteristics of this type of heat exchange which indicated that it would be effective in flash sterilization. These characteristics were well known, for a considerable amount of

work with products ranging from the very fluid, such as dairy products, to the very viscous, such as dog food, potted meat, and creamed beef, has been done in the past. From this work it has been established that the heat-exchange system for high-temperature, short-time sterilization of food products must have several definite requisites. The heat exchanger under discussion provides these requisites and in many cases affords some unique advantages, as follows:

a. The high ratio of heat-transfer surface to the volume of material treated fulfills the requirement for a very high heating rate.
b. The constant and rapid cleaning of the heat-transfer surface (1000 to 1400 times per minute) prevents scorching and localized overcooking, in the case of heating, or frozen film formation in the case of chilling and freezing.
c. Turbulence is created by the revolving shaft and blades rather than by forcing the product at a high velocity through small-diameter tube exchangers, thus eliminating the necessity of building the heat exchanger to withstand high pressures. As a matter of fact, the pressure drop across this exchanger is so low that additional pressure has to be imposed by a back-pressure valve in order to operate at a process pressure more suitable to the product.
d. The low-pressure drop across the system eliminates the need for high-pressure pumps.
e. Because of the spinning shaft and blades and the flexibility of pressure adjustment across the heat-exchanger system, the equipment lends itself to the processing of a wide variety of food products irrespective of a wide range of viscosity and consistency.
f. By proper design of the shaft and control of the annular space, products containing discrete particles have been successfully processed, as for example, cream-style corn, dog food, creamed chipped beef, cream of mushroom soup, etc.
g. In respect to sanitation, the heads and shaft are readily accessible. All surfaces coming in contact with the product can be visually inspected.

In short, this type of heat exchanger has been proved to be ideally suited for application where the material is heat sensitive, very viscous, or undergoes a change of state during heating or cooling. Examples may be found in starch cooking and cooling, gelatin cooling, freezing of concentrates, chilling and plasticizing of fats and oils.

The commercial size of the equipment referred to has been employed in pilot-plant and semi-commercial operations in conjunction with 2 types of aseptic canning and closing devices. The pilot-plant tests were conducted with:

a. The HCF unit developed by the American Can Co., Maywood, Illinois, and

b. The Martin aseptic-canning unit developed by the James Dole Engineering Co., Redwood City, Calif.

Both of these companies collaborated on the test projects with beneficial and useful results.

At this time we come to the point where it is appropriate to ask: What are the potentialities of utilizing a continuous type of process in conjunction with aseptic canning for the production of canned meat products?

Over the past 3 years a number of meat products have been flash sterilized and aseptically canned at Louisville, Kentucky. The process consisted of heating from approximately 160° to 285°-290°F., cooling to 90°-100°F., filling and closing aseptically, using a combination of Votator heat exchangers and the Martin aseptic-canning system. The products were: potted meat, dog food, creamed beef (hamburger meat), creamed chipped beef, and liver soup (baby food).

The work on various other types of meat products is now being carried out at the Votator pilot plant in Louisville. Development at this time is being concentrated on products such as Braunschweiger, deviled ham, pureed liver, beef, etc. Because these products do not include a carrier such as starch, in the case of dog food, creamed beef or gelatin bearers, as well as in the case of potted meat, the heat-sterilization problem is more complex.

In conclusion, a report on the potentialities of high-temperature, short-time sterilization would not be complete without a statement and review of the system's advantages. The most important of these are:

a. A better flavor, texture, and color are produced with the flash-sterilization method.

b. The flash-sterilization method, with aseptic filling and closing, provides a very wide range between scorching of the product and sufficiently safe sterilization, thus permitting a large factor of safety without sacrificing quality.

c. Regardless of container size, the quality of the finished product is the same.

d. Product sterilization in a continuous heat exchanger or a continuous pressure cooker allows very accurate control and measurement of the product temperature during the processing.

CHAIRMAN WIESMAN

Thank you very much, Mr. Bolanowski.

Our next paper relates to dielectric methods of heating for the production of canned meat products; it will be presented by Dr. D. M. Doty of the American Meat Institute Foundation.

Effectiveness and Potentialities of Dielectric Methods of Heating for the Production of Canned Meat Products

D. M. DOTY

Conventional steam-retort methods of heating for processing canned meat products tend to overheat the material near the outside of the container before the meat near the center of the container has been heated enough for effective preservation. This results in the typical overcooked flavor and poor texture of many canned meat products, particularly those processed in large size containers.

To overcome these disadvantages, several new techniques have been proposed and are being investigated in several laboratories. These include processing with intermittent heat treatment, continuous-type processing used in conjunction with aseptic canning, "cold" sterilization using β or γ radiation from fission products or electron bombardment, and high-frequency dielectric-type heating. This paper will present the results of experimental studies on the last-named method.

Although dielectric heating has not been applied widely for heat processing food products, the method has been used experimentally for blanching sweet corn (*1*). Basic patents covering the application of high-frequency dielectric heating to processing canned meat products were obtained by Bowman (*2*) and Beadle and Bowman (*3*) of our laboratories. Satchell and Doty (*4*) reported the experimental application of the method for thawing frozen pork bellies.

Although meat, and probably other food products as well, have a high dielectric constant and therefore should heat readily in a high-frequency dielectric field, the method of heating offers certain difficulties because of the high conductivity and non-homogeneity of the product. However, with proper design of processing equipment it is possible to heat meat products to uniform processing temperatures in a very short time. The technique has an advantage over present steam-retort methods in that the product is heated uniformly, and overcooking near the outside of the container is avoided.

Equipment used. As a source of high-frequency energy we have used an industrial model 15 KW oscillator capable of operating at frequencies of 2-10 megacycles. All of our processing studies have been made at frequencies of approximately 9 megacycles.

Basically, the experimental design for processing equipment is illustrated in Figure 1. The dimensions of the processing cell are limited by the properties of

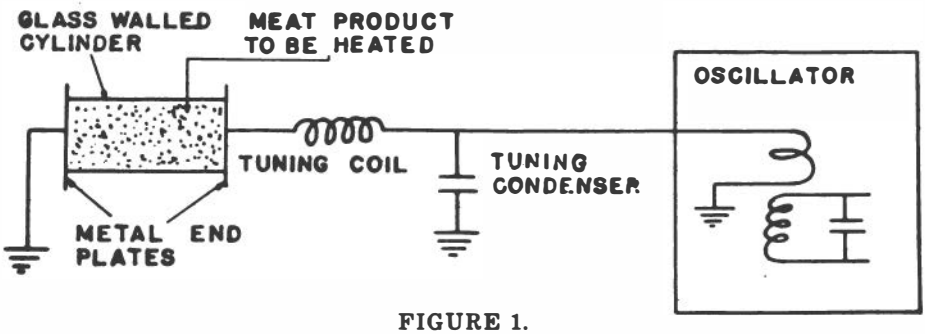

FIGURE 1.

SCHEMATIC DIAGRAM OF EXPERIMENTAL EQUIPMENT USED FOR PROCESSING MEAT PRODUCTS.

the product to be heated and the characteristics of the oscillator used. For our oscillator, which has an internal resistance of 80 ohms, we have been able to use cells 4 inches or 6 inches in diameter and 6 inches to 24 inches long. The longer length is desirable because the total resistance of the meat more nearly balances the internal resistance of the oscillator.

Materials used. We have processed the following meat products in the equipment described: pork luncheon meat (cure in); fresh pork luncheon meat; boned cured hams; and ground beef at 12% and 25% fat content.

Temperature uniformity in products processed. If high-frequency heating is to be used for processing meat products for canning, the temperatures attained in a definite time must be uniform throughout the body of the meat. We have been able to attain reasonably uniform temperatures in pork luncheon meat along the entire axis of the meat cylinder (Table 1). The temperatures at right angles to the axis of the meat cylinder were also quite uniform except for areas immediately adjacent to the wall of the processor (Figure 2). If the heat lost to

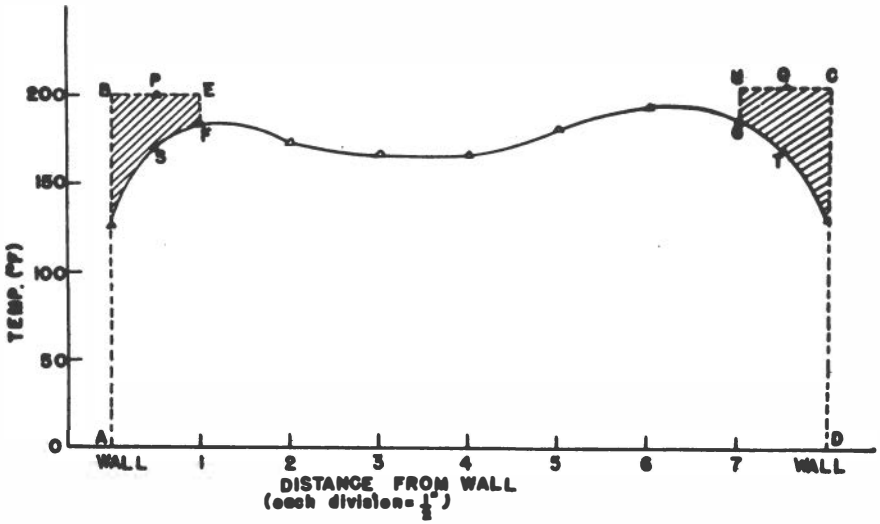

FIGURE 2.

TEMPERATURE DISTRIBUTION ALONG THE DIAMETER OF A CYLINDER OF PORK LUNCHEON MEAT. SHADED AREAS INDICATE HEAT LOST TO PROCESSING CELL WALLS.

TABLE 1

TEMPERATURE DISTRIBUTION ALONG THE AXIS OF PORK LUNCHEON MEAT CYLINDER

(9 KV; 1.5 amperes at 10 megacycles)

Run No.	Wt. of Meat (lbs.)	Time of Heating (min.)	2"	6"	10"	14"	18"	22"	Avg. Temp. °F.
			Distance from End of Processor						
			Temperature—°F.						
4	10.25	3.20	172	196	185	185	206	196	188
5	13.00	5.33	226	241	235	255	249	—	242
6	13.00	4.83	250	255	256	241	254	260	251

the walls of the processing cell is taken into account (see shaded areas, Figure 2), the variations in temperature throughout the body of the meat cylinder were not great.

The temperature distribution in boned hams heated by this process has not been quite so satisfactory (Table 2). As for luncheon meat, the lowest temperatures were near the walls of the processing cell, and refined experimental techniques and improvements in the processing cell should lead to more uniform heating.

Sterility of products processed. To determine whether or not meat products could be effectively processed from a sterility standpoint, pork luncheon meat, ground fresh pork, and ground beef were inoculated with spores of the culture of putrefactive anaerobe designated as P.A. 3679, and processed at different times and temperatures. The inoculated sample for bacteriological study was packed in a small "wiener" enclosed in a cellulose casing which was placed in the center of the processor full of meat. After heating and cooling, the inoculated wiener was emulsified in a mechanical blender and then subcultured in a pea broth at 30° C. For some of the heating trials the wiener was placed in a sterile tube and incubated without subculturing. If growth occurred, further bacteriological examination was made to establish definitely that it was actually P.A. 3679 and not other organisms that may have entered as contaminants after processing. The sterilization efficiency for each separate processing run was determined by calculating the F_o—value (z=18) using the graphical method described by Shultz and Olson *(5)*.

The results (Table 3) show that these heat-resistant spores were killed at F_o—values comparable to those reported for conventional steam sterilization. For pork luncheon meat (cure in), processing to F_o—values of about 1.0 or less appears to yield a product in which P.A. 3679 spores will not grow out unless subcultured. For uncured pork and ground beef the need for processing to F_o—values near 7.0 is indicated for the spore load employed.

TABLE 2

THE TEMPERATURE OF 11-POUND BONED HAMS PROCESSED IN A CELL 6 INCHES IN DIAMETER AND 12 INCHES LONG

Current (amperes)	Heating time (min.)	(9 KV; 10 megacycles) Temperature °F.			
		Mean	Max.	Min.	Avg. Dev.
1.3	7.52	224	246	150	16
1.3	7.35	222	254	166	21
1.8	4.55	232	258	161	19

TABLE 3

EFFECTIVENESS OF HIGH FREQUENCY STERILIZATION OF COMMINUTED MEAT INOCULATED WITH P.A. 3679 SPORES

(100 spores per gram in a 25-gram sample)

Type of Meat	Temp. Range at Max. (°F.)	Time in Max. range (min.)	Cooling Time (min.)	Approx. F_o Value	P.A. 3679 Growth
Luncheon Meat	248-252	2.5	3.5	4.7	
Luncheon Meat	250-252	0.25	3.5	2.1	+
Luncheon Meat [a]	228-237	6.5	11.0	0.8	
Fresh Pork	246-255	4.5	4.5	7.8	
Fresh Pork [a]	246-254	3.5	5.5	5.9	+
Fresh Pork [a]	238-246	2.5	4.5	2.0	+
Ground Beef [a] (25% fat)	248-256	4.5	3.5	7.0	
Ground Beef [a] (25% fat)	250-255	2.0	3.0	2.6	+

[a] Meat incubated without subculturing.

Palatability characteristics. **Boned ham heated by high frequency to an F_o—value of 2.76 scored 7.85 *(very good)* by an acceptance panel which scored ham chunks from a regular Army canned ration item 6.90 at the same time.**

In a critical taste panel evaluation of pork luncheon meat in a regular 6-pound Army pack as compared to dielectrically-processed luncheon meat from the same mix, 6 panel members out of 10 preferred the high-frequency processed sample. The dielectrically-heated sample was of firmer texture with no overcooked flavor, but was not as juicy as the product processed by conventional steam heating.

In a consumer-type preference test involving 44 representatives of the meat-canning industry, 32 (73%) preferred the dielectrically-processed meat (served cold) over the regularly steam-processed meat. An acceptance panel consisting of 81 testers at the QM Food and Container Institute laboratories expressed a significant preference for the dielectrically-processed luncheon meat over meat processed by standard methods when the meat was served cold. When the meat was served hot, the preference was not as pronounced.

These preliminary taste panel evaluation studies indicate that ham and pork luncheon meat heated by high frequency is somewhat superior in texture and flavor to comparable meat heat processed by conventional methods. As yet we have no information on the stability of dielectrically-processed meats.

Practical evaluation and application of high frequency heating for canned meat products

The results reported indicate that high-frequency heating can be applied for the processing of canned meat products if only the quality of the processed meat and sterilization effectiveness are considered. From a practical and technological standpoint, however, there are some very important problems to be solved.

Efficiency calculations with several processing runs with our experimental equipment indicate that 55%-58% of the electrical energy input to the oscillator is recovered as heat in the meat and processing cell. With this efficiency the actual heat cost for processing meat would be approximately 0.3 cents per pound with present electrical rates in the Chicago area. Amortization and maintenance costs on the high-frequency oscillator would probably cost approximately the same

amount. Thus, the total heating cost for processing would amount to less than one cent per pound of meat. While comparable figures are not readily available for processing by the present steam-retort method it is likely that the actual total heating cost, including maintenance and amortization of equipment, is 0.2 to 0.3 cents per pound. Thus, the comparative cost of high-frequency heating is not excessive if a superior, high-quality product is obtained.

There are 2 important drawbacks to the technological adoption of the high-frequency heating of meat products for canning. First, the initial equipment cost is high and the capacity is limited. With a 15 KW oscillator costing approximately $10,000 it would be possible to heat process only about 200 pounds of meat per hour. Secondly, it would be necessary to use a continuous processor followed by aseptic packing in sterile containers, or to use a container with metal ends and insulating walls for processing. Although we are attempting to develop materials and techniques that may overcome this 2nd disadvantage, the solution of the problem is not yet in sight.

Summary

Pork luncheon meat and boned hams may be heat processed by means of high-frequency, dielectric-type heating. The heated product has usually been judged to be of as good or better quality than comparable meat processed by the conventional steam-heating method. The meat can be effectively sterilized without developing the typical overcooked flavor and odor exhibited by most meat items sterilized by the methods now in commercial use.

The heating costs for the high-frequency process probably would be somewhat higher than those for steam processing but would be fully justified if a product of superior quality could be consistently obtained.

The high original cost for equipment, the limited capacity of the equipment, and the development of a suitable continuous processor or processing containers are disadvantages of the process that must be considered before technological application of the processing method can be recommended.

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CHAIRMAN WIESMAN

Thank you very much, Dr. Doty. There are certainly many interesting implications in connection with the possibility of using dielectric heating. I am sure there will be a lot of questions on this subject this afternoon.

WEDNESDAY AFTERNOON SESSION

April 1, 1953

CHAIRMAN WIESMAN

The next paper will be presented by Mr. Joseph Stukis of the Quartermaster Food and Container Institute.

Technological Information Obtained from Storage Studies on Canned Whole Hams Processed by Intermittent Heat Treatment

J. M. STUKIS

In recent years, several avenues of approach have been contemplated in the attempt to secure a mild-flavored ham. One approach has been based upon the lard-packing of properly cured and smoked hams. A second method has been the use of intermittent heat treatment as applied to canned whole boneless hams. More recent developments include the application of dielectrics to the sterilization of whole hams. Work currently under way concerns the application of electron bombardment and the use of nuclear fission byproducts as a means of securing a sterile product. This discussion will be concerned with the second method, intermittent heat treatment.

A canned meat product, intended for Armed Forces use, must possess a minimum stability equal to 6 months at 100°F. or 2 years at 72° F. These standards are predicted on needs established by the extended supply channels—virtually world-wide in scope—now being used by our Armed Forces.

The canned ham product, as seen and consumed by the serviceman, must be equal in acceptance to the product with which the consumer is familiar. That is to say, the color, odor, flavor, and texture must be closely similar to those of a canned perishable ham of commerce. The yield of edible meat per can must be high and the product easy to slice and prepare for serving.

Late in 1951, a member of the Research and Development Associates, Food and Container Institute, Inc., aware of the need for a sterile whole ham, offered his assistance in solving the problem. The process suggested was that described in U. S. Patent 2,305,480, dated December 15, 1952, entitled "Production of Canned Meats for Storage." Purpose of the procedures specified in the patent was: "to subject canned meat to a temperature which assures incubation of thermophilic and hence other bacteria and then to heat the canned meat under conditions to assure killing the thermophilic and other bacteria . . . ," "to effect, in process, a flavoring development of amino acids," and "to effect sterilization by steam generated within the can, of the can walls and ham surfaces."

The following sentences extracted from the above-mentioned patent best describe the reasoning employed: "By the present invention, conditions are imposed which will assure that dormant life awaken and enter the active phase, whereby it can then be killed by lower temperatures while the meat is cooking under conditions to limit purging. One essential of this treatment is to avoid too long an exposure for awakening the dormant life, so that spoilage in the can is not effected." The patent described intermittent heat treatment[a] as applied to raw meat, incompletely cooked meat, and cooked meat when canned. Details of the patent as applied to raw cured ham are quite similar to those described in this paper.

Experimental Procedures

In December of 1951, production of 182 hams by the method described in the patent, "Production of Canned Meats for Storage," was completed. Production of the hams took place in a plant maintained under the regulations of the U. S. Department of Agriculture, Bureau of Animal Industry, Meat Inspection Division. The production of the hams was observed by food technologists from the QMFCI and the patent holders. Forty-five of the hams so produced were utilized by the QMFCI for test purposes.

The production of the test hams began with the selection of the raw material. The hams utilized were in the 15-pound weight range, plus or minus one pound. The hams, 2 days old when production was initiated, were of good conformation, light in color, and of smooth-textured flesh. The hams were obtained from hogs of various breeds and were said to be from midwestern and southern farms.

The skinning of the hams was followed by the curing operation. An artery pump was used, with a weight increase of 10%. The pumping pickle used was prepared according to the following formula: 50 gallons of water, 120 pounds of salt, and 13¾ pounds of a commercial curing agent composed of sodium chloride, sodium nitrite, sodium nitrate, and dextrose. The temperature of the ham at the time of pumping was 30°-36° F., and the temperature of the pickle was 36°-40° F. After a short draining period, the pumped hams were rubbed with 3 pounds of the following mixture for each 100 pounds of ham: 25 pounds of salt and 5 pounds of the commercial curing mixture described above.

The rubbed hams were then placed in the curing cellar on racks in 3 layers starting at floor level. The curing cellar was maintained at a temperature of 38°-40° F. The dry-cure period was 6 days long.

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[a]It should be pointed out that sterilization through intermittent heat treatment is known by such names as fractional sterilization, intermittent sterilization, or Tyndallization. The process dates back to 1877, when the English physicist, Tyndall, discovered that one hour of exposure to boiling temperature might not kill every microbe in a nutrient infusion, but that boiling for one minute on 5 successive occasions with intervals of several hours at room temperature would succeed in sterilizing. Based on those experiments, Tyndall concluded that bacteria exist in 2 forms, one thermolabile and one thermostable. In our day, the process is commonly employed to reduce the likelihood of chemical breakdown during sterilization of certain bacteriological media which would decompose more rapidly at higher temperatures and prolonged processing times.

After the hams were cured, they were scrubbed and washed under showers, skinning was completed, and the product defatted to the proper level. Boning was accomplished in the usual commercial manner. At the time of boning, it was found that the hams had gained 6% in weight over their original weight (that is, the weight of the boneless cured ham at the time of canning, plus the weight of the skin, bones, fat, and trimmings did not exceed 106% of the weight of the fresh uncured ham). No smoking was employed in this process.

It should be noted that all of the equipment with which the ham came into contact during the above described curing and boning procedure had been thoroughly cleaned prior to use with a commercial cleaning compound, dissolved in a specified amount of water, and used as a liquid cleaner. Active ingredients were sodium carbonate, trisodium phosphate, a quaternary ammonium salt, and a sodium alkyl aryl sulphonate.

After boning, the hams were moved by means of a conveyor to a workman performing the weighing operation. At the weighing point, a chute delivered washed pear-shaped cans to the scaleman. The hams were placed into the cans and a workman marked them with the proper weight and a "T," designating "test product." At the end of the conveyor line the ham was removed from the can, the shank end tucked into the bone cavity and returned to the can with the fat side up and the shank end toward the smaller dimension of the pear-shaped can. The hams were then conveyed to a meat press, a hydraulic device with a pear-shaped compression foot. Pressure was applied and the product made to conform to the shape of the can. The compressed product was next moved to a crimping machine where a lid was crimped into place. The packaged product was next moved to the soldering pot and the crimped side of the can fluxed and dipped into molten solder.

When the can was sealed (with the exception of the steam vent) it was ready for its first heat treatment. The cans, with the longest dimension in the vertical position, and with the steam vent on top, passed by means of a conveyor through an oil bath (lard maintained at 340° F.) for an exposure time of 8 minutes. The vent end, that is, the smaller end of the pear-shaped can, was approximately 3 to 4 inches out of the hot lard. As the cans passed through the hot lard, strong steam and air pressures were generated; these pressures were forcefully released through the steam vent. As the cans emerged from the hot lard bath and the steam and air pressures were subsiding, the vent was capped with solder. It was observed that in some instances pressures created during the hot bath were great enough to buckle the end plates of the can at the time of sealing. In severe cases, the hams were repacked. As the cans began to cool, sufficient vacuum was obtained to collapse or panel the can in several places along the body of the can and to draw in the can ends firmly.

The cans of ham were then placed in a cooking tank (a retort) and were held at 127° F. (temperature of the water) (see Figure 1) for 4½ hours, the temperature was then raised to 135° F. and held at this level for 2 hours, or until the internal temperature of the can at the center of the product reached 129° F. The cans were then transferred to the chilling room at 54° F. and kept there overnight. On the second day of processing, the canned hams were again placed in the cooking tank and given the following process:

2¾ hours at 127° F. (water temp.)—reaching an internal temperature of approximately 98° F.

2¾ hours at 180° F. (water temp.)—reaching an internal temperature of approximately 146° F.

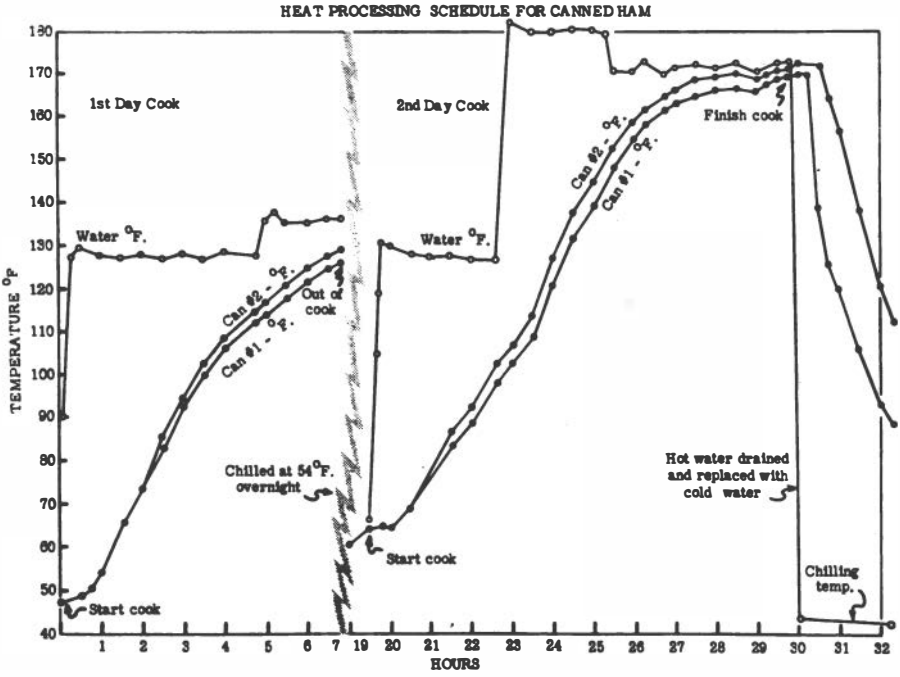

FIGURE 1

PROCESSING SCHEDULE FOR CANNED WHOLE HAMS—INTERMITTENT HEAT TREATMENT

4½ hours at 170° F. (water temp.)—reaching an internal temperature of approximately 165° F.

2 hours of cooling at approximately 42° F.—reaching an average internal temperature of 100° F.

The product was then transferred to the chilling room for a 24-hour holding period at approximately 50° F.[b]

While a representative number of canned hams were undergoing incubation, plans were being formulated as to the methods to be employed in testing the product. During this period, the National Research Council, Committee on Foods, Subcommittee on Animal Products, at the request of the QMFCI, solicited opinions on the procedures, as outlined in the covering patent, from 25 leading academic and industrial bacteriologists, with results as follows:

None suggested the adoption of the procedure without further testing; one had no opinion; 10 recommended further testing; 4 recommended fur-

[b] It is interesting to note that a 10-pound canned ham can be rendered sterile by conventional heat processing in approximately 6 hours at a temperature of 230° F. However, this severe treatment makes it unacceptable to the consumer, particularly with regard to texture and flavor. Canned perishable ham for commercial use receives a 170° F. hot-water cook for 4 to 6½ hours, depending upon the size of the ham. More recent experiments, using dielectric treatment, have shown that a 10-pound ham can be sterilized to an F_o—value of 10 in 8 minutes and 40 seconds.

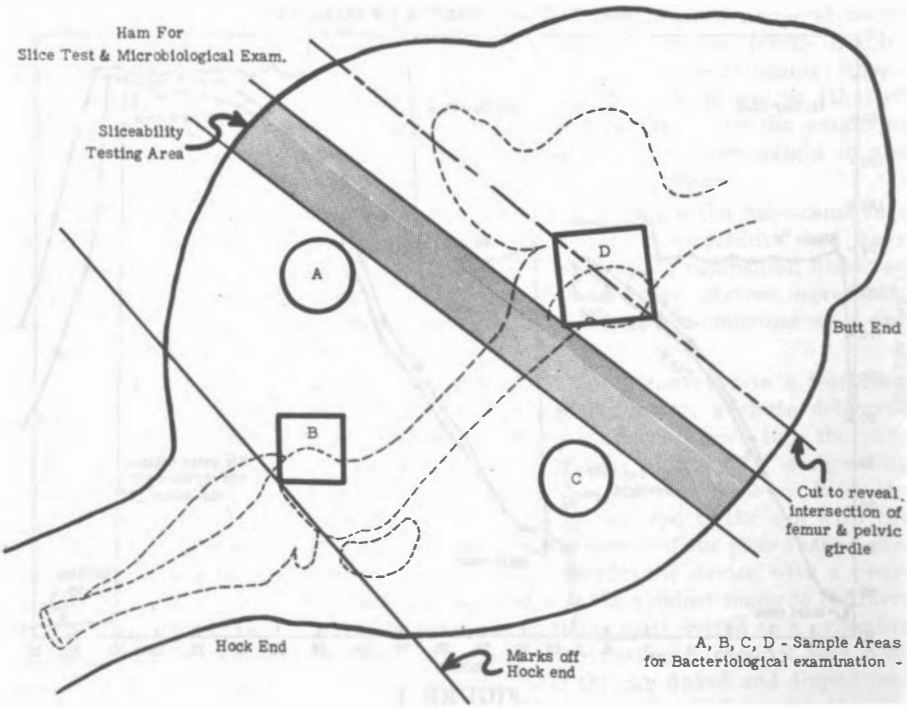

FIGURE 2

CROSS SECTION OF HAM PRIOR TO BONING

ther testing but were dubious as to the success of such a test; and 10 stated that the process was without merit and recommended that further testing not be considered.

However, it was decided that further tests should be conducted in order that the merits of the process be completely appraised.

It was decided that in addition to initial examinations, the canned hams would be subjected to storage for periods up to one year at temperatures of 40° F. (the control), 72° F., and 100° F. Three hams were to be withdrawn from each of the 3 temperatures at the end of approximately every 3 months, bringing the total to 9 hams per evaluation period. Therefore, 5 evaluation periods were established, initial, 3, 6, 10, and 12 months. It was further decided that bacteriological, chemical, and technological tests would be conducted. Consumer acceptance tests were excluded from the plan since doubt was expressed among those whose opinions were surveyed as to the soundness of the process from the public health standpoint.

At the beginning of the bacteriological examinations, vacuum readings were made on each can after sterilizing the surface of the narrow end of the can and the tip of the gauge. After taking the vacuum reading, the gas in the head space was collected in a gas analyzer apparatus. Each can was then opened under aseptic conditions and the ham transferred to a sterile tray. Sampling procedures were performed in a sterile room equipped with an ultraviolet sterilizing lamp and positive air pressure. Samples were taken from areas A, B, C, and D (see Figure 2)

as well as from the juice and gelatin liquid surrounding the ham. Area B was in the center of the ham at the hock end where the bone joint had been removed, and area D was in the center section at the butt end from where the acetabulum had been removed. It was felt that the cavities left in these areas by removal of the ham bones might afford particularly favorable conditions for the survival of organisms during processing. Areas A and C were cross sections through the thick muscle portions of the hams.

Approximately 100 g. of meat were taken from each area, using sterile stainless steel borers and boning knives. Each weighed sample removed for bacteriological culturing was blended for 10 minutes in a Waring blender with distilled water to make a 1:5 dilution of meat (or juice). Fifty ml. volumetric pipettes with enlarged tips were used to transfer 50 ml. amounts of this 1:5 dilution (10 g.) to bottles and flasks of media. The importance of using large enough meat samples has been emphasized by the work done on the incidence of anaerobic spores in meat. Harriman *et al.* reported *(2)* an average load of 2-4 anaerobic spores per g. in fresh and cured pork trimmings, while Burke *et al. (1)* found an incidence of less than one spore per g. in fresh, cured, and processed pork trimmings. One ml. amounts of this 1:5 dilution, as well as higher dilutions, were transferred to Petri plates and mixed with TGE agar medium for standard plate counts and isolation of aerobic organisms. The TGE agar plates were incubated at 32° C. for 48 hours in order to make standard plate counts of aerobic organisms. Also, direct smears were made of this 1:5 sample dilution and examined microscopically. All materials and equipment used in the preparation and inoculation of samples were sterile. The 50 ml. amounts containing 10 g. of meat or juice were separately inoculated into capped bottles containing 150 ml. of beef-heart infusion or thioglycollate broth, and into cotton-stoppered flasks containing 150 ml. of TGE broth. The formulae of the media used were varied to some extent during the course of this study in an attempt to establish the optimal growth conditions for isolation of the ham flora. After inoculation, the anaerobic cultures in tubes and bottles were sealed with paraffin and heated at 80° C. for 10 minutes, making the come-up and come-down times as brief as possible. All aerobic and anaerobic broth cultures were divided into 2 sets for incubation at both 32° C. and 55° C. After 2 weeks incubation, the cultures were examined microscopically and for such visual changes as gas evolution, darkening of meat, or digestion of meat. Subcultures were made where necessary for identifying types of organisms. All cultures were held for 30 days and examined again at the end of this period before being reported as negative.

Chemical analyses included determinations for moisture, ash, fat, protein, chlorides as NaCl, sodium nitrite, and sodium nitrate, reducing sugars and total sugars as dextrose. The peroxide value and free fatty acid development were measured. The pH of all samples was determined. An attempt was made to measure protein degradation through the measurement of free ammonia, water-soluble amino nitrogen, total reducing capacity, non-protein reducing capacity, total salt-soluble nitrogen, total salt-soluble non-protein nitrogen, and total salt-soluble protein nitrogen. Ham juices were analyzed for free ammonia, water-soluble amino nitrogen, sodium nitrate, sodium nitrite, and pH. The density of the juice was also calculated. Gas analysis was made on the head-space gas of all hams.

Technological examination of the samples included an evaluation of the color, odor, sliceability, and yield on a drained weight basis. The sliceability test, developed by the QMFCI to determine the ease with which a product slices, was used

as a measurement of the firmness of the product. The slicing is performed in an area just to the rear of the butt section (see Figure 2). The ability to obtain a well-defined slice, which is the mirror image of the mass from which it was obtained, is directly related to the texture of the product. The thinner the cut at which a well-defined slice can be obtained, the better quality texture a product possesses. A Hobart electric slicing machine, which is equipped with a ¼-hp motor delivering a speed of 1750 r.p.m., was used for slicing. The cutting blade had a diameter of 10½ inches, ⅞ of an inch of which comes into contact with the product. Numerical values on sliceability were obtained by a direct reading of the control knob. Correlations were sought between chemical changes as reflected by analysis, and physical changes as reflected by gross technological examinations and sliceability.

Results and Discussion

The findings of the 12-month storage study were reviewed and conclusions drawn with the minimum military stability standard of 6 months at 100°F. and the desired stability standard of 12 months at 100°F. kept well in mind.

Vacuum data are inconclusive, except it might be noted that this process produced a maximum vacuum of 5 inches in this test. Bacteriological examination showed both aerobic vegetative types and anaerobic spore-forming organisms in the canned hams at the beginning of storage. Thus, it was concluded that the product was not sterilized by the intermittent heat process used. In addition, one ham which showed evidence of swelling after 2 weeks incubation at 72°F., was examined bacteriologically and showed the presence of small numbers of gram-positive sporulating bacilli, mainly aerobic and mesophilic. These organisms were also found in the 3 hams examined initially. In addition, gram-positive staphylococci were isolated from section D (intersection of the femur and the pelvic girdle) and the juice. Storage at 72° and 100°F. showed that bacteria not only survive for months but actually multiply in these hams and build up sizable bacterial populations. Aerobic counts in these hams rose sharply during the early part of the storage and then began dropping off. At 100°F. storage, the plate counts had fallen from 15,000 g. at 3 months to 500 at 10 months, while at 72°F. storage, the plate counts dropped from 700 to less than 10 over the same period. Although quantitative counts were not made of the sporulating anaerobes, their presence was noted in all hams examined during this study, except in the 100°F. hams stored for 10 months. This may be interpreted as practically complete germination of spores within 10 months at the elevated temperature and, consequently, a dangerous situation if *Clostridium botulinum* were present, and a putrefactive condition if putrefactive anaerobes were present. In most cases, smears made of the 1:5 dilution of meat or juice samples did not reveal the definite presence of organisms. Direct microscopic examination of products such as canned ham is not a reliable indication of the bacterial load.

No definite correlation could be drawn between the incidence of organisms and the particular section of ham examined. There was some indication that the juice contained less bacteria than the tissue sections.

Evaluation of the data obtained from chemical analyses[c], which included proximate analysis, free ammonia, water-soluble amino nitrogen, reducing sugars, total reducing capacity, non-protein reducing capacity, salt-soluble nitrogen, salt-soluble, non-protein nitrogen, salt-soluble protein, peroxide value, free fatty acid, and pH, leads to the conclusion that the chemical changes, as measured in this study, were slight in nature. It was believed that certain chemical changes took place which resulted in a product of reduced acceptability, however, these changes were not measurable by the methods of analyses used. It was further concluded that the extent and nature of the chemical changes were in keeping with the temperatures and lengths of storage. It should be noted, however, that the peroxide value and free fatty acid content showed a significant increase. Analyses of head-space gases showed the presence of CO_2 in a range from 14.9% to 43.4%. It was concluded that these values were in keeping with the findings of the microbiological examinations except for samples stored at 40°F. where CO_2 in quantities as high as 25% was found with no apparent microbiological changes.

With the exception of 2 cans, it was found that from 20% to 33% of the product was cooked-out juices. From this it was concluded that the yields, with regard to range, did not vary greatly regardless of the time or temperature of the storage. It was further concluded that by comparison to the requirements of the current Federal specification for canned whole ham (limitation of 12½% gelatinous material in the can) the yields found in this study are considered to be low. With regard to product color, it was concluded that the color was satisfactory for 12 months at 40°F., 6 months at 72°F., and *3 months at 100°F.* It was concluded that the odor of the product remained satisfactory for 12 months at 40°F., until 10 months at 72°F., and until the 6th month at 100°F., whereupon it became unsatisfactory. The texture as determined by the sliceability test was satisfactory until the 10th month at 40°F., with some evidence of deterioration of texture after the 10-month level. The texture was unsatisfactory afer 10 months at 72°F., and *3 months at 100°F.* The flavor of the product was found to be satisfactory upon initial examination, but the product was not tasted afterwards because of potential microbiological hazards.

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[c] Detailed results of all aspects of the technological, bacteriological, and chemical tests reported herein are available upon request to the Quartermaster Food and Container Institute for the Armed Forces, 1819 W. Pershing Road, Chicago 9, Illinois.

Examination of the cans after storage indicated that tin plate deterioration commenced after 6 months at 100°F. and progressed noticeably through the 12th month at 100°F. Analysis of head-space gases showed hydrogen to be present in amounts as high as 16.7% after storage at 100°F. for 10 months. It was concluded that the high percentage of hydrogen present in the head-space gas was chiefly the result of the reaction between the product and the container. Through the course of study it was noted that there occurred a progressive loss of can paneling.

On the basis of the findings reported above, it has been determined that the application of intermittent heat treatment to whole canned hams is not at this time a satisfactory solution to the quest of the Armed Forces for a stable whole ham that will keep without refrigeration.

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CHAIRMAN WIESMAN

Thank you very much, Mr. Stukis.

Up until now we have talked about processing canned meats using some form of heat or another. We heard papers describing the normal type of heat processing. We have heard about strata cook. We have heard about the continuous cooking, using aseptic filling. This morning we heard about the pressurized system for heat treatment, intermittent heat, and now we are going to have a couple of papers which are going to consider the processing of canned meat items using what might be termed *cold sterilization.*

The first of these papers is by Dr. L. E. Brownell, who is head of the Fission Products Laboratory at the University of Michigan.

Potentialities of Utilizing Radiation from Fission Materials for the Production of Canned Meat Products

L. E. BROWNELL

Research by a number of investigators has shown that a variety of types of ionizing radiation can be used to destroy microorganisms. This has led to consideration of using ionizing radiation to sterilize food and thereby prevent food spoilage resulting from the action of microorganisms. One such application would be the substitution of radiation sterilization for thermal sterilization in the processing of canned meats and other foods. An advantage of the use of radiation

in the processing of canned foods is the elimination of the requirement of processing at elevated temperatures. Another advantage lies in the instant penetration of radiation as compared to the slow penetration of heat. However, the use of radiation has numerous disadvantages and presents some new problems.

The early studies were made with X-radiation (*3*). X-rays have never been considered seriously as a means of sterilizing foods because of the high cost of using X-ray machines for this purpose. Electron accelerating machines, such as the Van de Graff machine and the Capacitron, have been developed and improved during the past several years, and their use in sterilizing foods and other products has been demonstrated (*1, 5*). Current interest has developed in the use of gamma radiation as a means of sterilizing foods because of the possible availability of large amounts of radioactive wastes produced as byproducts in the operation of nuclear reactors. Gamma radiation has the advantage of appreciably greater penetration than either electrons from accelerating machines or X-rays from conventional 200 KV machines. Gamma radiation obtained from radioactive wastes could be much cheaper than X-radiation from machines; however, as yet only limited cost information on these wastes is available.

The Atomic Energy Commission has contracted with the Engineering Research Institute of the University of Michigan and other universities to investigate the possible industrial uses of radioactive wastes. The Michigan Memorial Phoenix Project[a] supports research on the uses of atomic energy which will benefit mankind. This project is separate from the contracted research conducted by the Engineering Research Institute and has no connection with the Atomic Energy Commission. Both of these projects at the University of Michigan have conducted experiments on the uses of gamma radiation. This research was begun in the summer of 1951 when the Fission Products Laboratory of the Engineering Research Institute received a one-kilocurie cobalt-60 source of the type described by Manowitz (*4*).

Sterilization by gamma radiation. One of the first of the questions investigated was the dosage required to destroy various microorganisms. The Michigan Memorial Phoenix Projects 20 and 41 have supported a study of the effects of

[a] The Michigan Memorial Phoenix Project is a memorial to the Michigan dead of World War II. The Regents of the University at their meeting on May 1, 1948, on recommendation of their War Memorial Committee, voted to "create a War Memorial Center to explore the ways and means by which the potentialities of atomic energy may become a beneficent influence in the life of man, to be known as the Phoenix Project of the University of Michigan." In taking this action the Regents recognized that the release of the energy of the atom through fission is destined to alter almost all aspects of our civilization and culture for many years to come and stated their intention to establish a center to support researches and studies on all phases of the impact of nuclear energy on our life.

gamma radiation on microorganisms. A wide variety of bacteria, molds, yeasts, and viruses were tested and spore-forming bacteria were found to be the most resistant organism tested. *Bacillus subtilis* and *Clostridium botulinum* require a dose of approximately 2.0 to 2.5 million rep (measured in air) to destroy all the spores and bring about complete sterility. Table 1 gives typical data obtained with *Bacillus subtilis*.

TABLE 1

EFFECT OF DOSAGE OF GAMMA RADIATION ON COUNT OF *Bacillus Subtilis*

Radiation Dose, Million Rep (in air)	Count of *Bacillus subtilis*	Per Cent Reduction
0	18,000,000	0
0.34	960,000	94.6+
0.68	202,000	98.8+
1.02	20,500	99.9+
1.35	14,450	99.9+
1.70	75	99.9+
2.04	0	100.0

Much smaller dosages were required to destroy the non-spore-forming types of bacteria. For example, a dose only about 1/6th as large was sufficient to destroy the microorganisms *Eschericha coli*, *Proteus vulgaris*, and *Lactobacillus arabinosus*. A similar small dose (less than 400,000 rep in air) destroyed the yeast *Saccharomyces cerevisiae*, and the molds *Penicillium notatum* and *Aspergillus niger*.

Tests were also made on the flora of raw and pasteurized milk. A dose of 2.04 million rep (in air) gave a count of zero in both raw and pasteurized milk. A gram-positive sporulating bacillus isolated from canned evaporated milk was found to have about the same resistance as *Bacillus subtilis*. A dose of 2.04 million rep (in air) gave a count of zero.

It might be added that 2 pathogenic viruses, psittacosis virus and mouse pneumonitis, have been treated with gamma radiation. Both viruses were inactivated and rendered noninfective by relatively small dosages of greater than 0.085 and less than 0.26 million rep (in air). These experiments yielded the interesting finding that these pathogens are much more susceptible to radiation than sporulating bacteria.

Animal feeding experiments. A few months after receiving the one-kilocurie gamma source some preliminary animal feeding experiments *(2)* with food exposed to gamma radiation were conducted by F. H. Bethell, M. D. The results showed no difference in health, growth, etc., between the animals fed irradiated whole milk and those fed the controls. All milk samples were irradiated in polyethylene bags in the one-kilocurie cobalt-60 source, receiving a dose of slightly over 2,000,000 rep (in air). The milk was reconstituted Klim prepared as a 4-times concentrate and diluted just before feeding by the addition of a salt solution. This milk constituted the entire diet with the exception of one leaf of lettuce added each week which was not irradiated. It was emphasized that this experiment was only exploratory and that any conclusions from the data were preliminary and contingent upon further testing, both with feeding experiments and more refined methods of assay for individual components of the diet. This

would require microbiological assay for amino acids and the setting up of long-term feeding and breeding experiments.[b]

In the experiment proposed, the main calorific intake should consist of a suitable mixture of carbohydrates, fats and proteins. In addition a portion of the water intake should be in the irradiated food. Some of the effects of irradiation are believed to result from the formation of hydrogen peroxide from water; therefore, it is important that the food to be irradiated not be in the anhydrous state. Also, the suggestion has been made that meat would be a more suitable and convenient food than reconstituted milk because of the difficulties of obtaining normal feeding with a complete liquid diet.

The feeding experiment to establish the wholesomeness of irradiated food should be independent and not combined with an experiment which might involve the dosage of radiation required for sterility. If the animals are given food in which the wholesomeness of the food is independent of the requirements of sterilization by radiation, using food such as canned milk or canned meat which is sterilized thermally, the variable of radiation dosage required to sterilize the foods will not influence the experiment. This precaution will prevent the possible loss of animals from food spoilage which would destroy the experiment to investigate the wholesomeness of irradiated food. Experiments to further investigate the dose of gamma radiation necessary to produce sterility in canned foods may be conducted simultaneously and separately and at less cost by suitable microbiological studies rather than by animal feeding experiments.

With these different considerations it was decided that the animal feeding experiment should involve the feeding of 4 generations of rats. A diet should consist of irradiated food supplemented with vitamins and minerals. The irradiated food may consist of 50 parts of canned meat such as Swift's Chopped Beef for Babies, 25 parts of carbohydrates such as cornstarch, 10 parts of fat, 10 parts of dry casein and the remaining 5 parts be used to provide a supplement of mineral and non-irradiated vitamins. This diet has been suggested because it is believed that it will be necessary to supplement the ground meat with carbohydrates, fat, inorganic salts, vitamins, and probably proteins for a completely satisfactory diet.

Tests with irradiated foods. In the Fission Products Laboratory food has been packaged in plastic containers and in glass tubes and preserved from spoilage by microorganisms for many months. Green vegetables such as peas, spinach, asparagus, broccoli, carrots, etc., seem to be most satisfactory foods for preservation by irradiation. In the studies made in the Fission Products Laboratory it was found that these foods undergo very little flavor change; in fact, the peas and carrots seem to be slightly sweeter and are definitely more tender as a result of irradiation. There is a tendency to bleach, which is a disadvantage in the case of green peas but may not be a disadvantage in the case of asparagus and carrots. There also seems to be a softening of the foods with a certain amount of cell destruction, as evidenced by an increase in tenderness, a decrease in crispness, and the loss of some fluid from the cell. For example, irradiated peas cooked for 3 minutes have the same tenderness as the control cooked for 6 minutes.

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[b] The proposed long-term animal feeding experiments have been discussed with the personnel of other laboratories that have conducted similar experiments using food sterilized by electronic bombardment from accelerating machines. There has been some discussion of the proposed experiments in correspondence with representatives of the Food and Drug Administration.

Flavor tests made in the Fission Products Laboratory indicated that protein foods of animal origin are not as satisfactory as fresh vegetables when treated by irradiation. In general, protein foods of animal origin undergo 2 types of flavor change; the proteins develop a strong animal-like odor and taste and the fats develop a tallowy or rancid odor and taste. These off-odors and off-flavors are quite volatile and in many instances disappear upon cooking. However, there seems to be little promise at present of irradiating foods such as milk, cottage cheese, and eggs without developing off-flavors that would be objectionable to a large percentage of the public, although some individuals are unable to detect these off-flavors except when very great doses of radiation have been used. Rats fed irradiated milk accept it as readily as the control.

It was discovered that irradiated bacon, ham, and corned beef were relatively free of any off-flavors after these products were irradiated and then cooked. Representatives of a major packing company tasted samples of our irradiated bacon, corned beef, and ham and stated that the bacon had flavor which would be quite acceptable and that the corned beef was very good. The ham which was tested seemed to have a slight off-flavor of irradiation. However, other hams have been tested which were found to have no off-flavors after irradiation and cooking. It was believed that sodium nitrite and nitrate used in processing these meats protected the flavor molecules during irradiation. Other tests have been made using sodium nitrite with raw ground beef, and a noticeable improvement in flavor was observed. Concentrations of sodium nitrite as low as 100 parts per million appear to be effective in preventing flavor change. The Food and Drug Administration permits up to 200 p.p.m. of sodium nitrite in meats cured using sodium nitrite and/or sodium nitrate. One hundred parts per million of sodium nitrite does not affect the flavor of raw meat when cooked but does have a tendency to give cooked meat a reddish color rather than a greyish color.

10-kilocurie gamma source. The original one-kilocurie source received by the Fission Products Laboratory has been useful in exploratory studies but has limited use because of the small size of the opening. No commercial size tin can would fit into this source and all experiments with irradiated food were conducted with glass test tubes or plastic bags as containers. Therefore, to provide better facilities for the irradiation experiments a new source consisting of 10-kilocuries of cobalt-60 in the form of 100 cobalt rods ¼-inch in diameter by 10 inches long with aluminum jackets has been irradiated in the NRX reactor at Chalk River, Canada, selected because of its high flux and the availability of radiation time at this installation.

This new 10-kilocurie source is housed in a radiation room with 4 feet of concrete shielding in all walls. The source is "shut off" by lowering it into a pit of water 16 feet deep located in the center of the radiation room. The radiation room has a floor area of 8 feet by 11 feet and a height of 8 feet, which permits ample space for setting up a variety of experiments which may be run simultaneously.

The point of highest flux will receive a radiation dose of about 200,000 rep/hr in air throughout a cylindrical volume of 6 inches in diameter and 10 inches long. A flux of about half this intensity will be available immediately outside the double ring of cobalt rods. At further distances the flux will be decreased by the inverse square law and by absorption of radiation by the experimental samples and equipment.

The Fission Products Laboratory now is one of the best equipped laboratories to handle gamma irradiation experiments as a result of its radiation chamber and

the one- and 10-kilocurie sources of gamma radiation. With the new source it is possible to irradiate a No. 10 size tin container, whole hams and sufficient volumes of food to conduct appropriate animal feeding experiments. It has been estimated that the new 10-kilocurie cobalt-60 source in the Fission Products Laboratory has increased the irradiation facilities at this laboratory perhaps more than 30-fold. The research performed at the University of Michigan on the uses of gamma radiation is at present limited by the number of research personnel employed. In the field of the irradiation of food, the Michigan Memorial Phoenix Project will support the animal feeding experiment in which 4 or more generations of animals will be given food treated with a sterilizing dose of gamma radiation. The studies of the effect of gamma radiation on trichina in pork and pork products will also be continued by the Phoenix Project. At present, the Engineering Research Institute has limited its studies with gamma radiation to the investigation of chemical reactions promoted by gamma rays. New research projects will be brought into the laboratory in an attempt to attain maximum use of the radiation facilities. The chemical industry and the oil industry has shown more interest in making use of these facilities than has the food industry. The authors have some concern over possible loss by default of what is considered to be the most powerful and versatile gamma source for the studying of irradiation of foods.

Sterilizing canned meat. At the writing of this manuscript no meat canned in tin containers has been irradiated in the Fission Products Laboratory. A western model can-closing machine has been supplied to the laboratory by the American Can Company and has been put into operating condition. A variety of foods will be canned and irradiated this spring. However, with present support, these tests will be rather limited.

The possible future of the process of gamma ray sterilization of canned meat is very promising in spite of the hurdles yet to be crossed. The penetration of gamma radiation gives it a great advantage over other types of radiation. For example, if a radiation dose of 2,000,000 rep is required for sterilization, the average radiation by electron bombardment may be 4,000,000 rep (8,000,000 or more near the surface and the minimum of 2,000,000 in the center) as compared to an almost uniform 2,000,000 rep with gamma radiation. Where irradiation results in flavor change, this difference in uniformity of dosage is an important consideration. Of course, there are disadvantages of using gamma radiation such as the longer time required to sterilize with gamma rays, the inability to stop gamma radiation except by shielding, and the present unavailability of cheap gamma sources. However, at present gamma radiation appears to be the only type of ionizing radiation which may prove to be feasible for sterilizing large size containers (No. 10 or 12) of canned foods.

Summary

Three important steps must be taken before food can be preserved by gamma radiation on a commercial basis: (1) food sterilized by gamma radiation must be proved acceptable to the Food and Drug Administration's requirements and to consumers' tastes; (2) industry

must show an interest by supporting research work to develop the process in terms of commercial feasibility; and (3) the Atomic Energy Commission must make suitable fission product gamma-ray sources available in sufficient quantities and at reasonable costs.

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CHAIRMAN WIESMAN

Thank you, Dr. Brownell. That was a very interesting paper.

There is no question but that it behooves the canning industry to follow the results of this work very closely in order to be in a position to take advantage of anything worth-while that might develop from it. There are a lot of interesting implications.

The next paper will be concerned with sterilization by use of ionization radiation. There has been a lot of work going on for a number of years at the Food Technology Department of M.I.T. The paper, prepared by Dr. S. A. Goldblith, associate professor of food technology at M.I.T., will be given by Dr. Nickerson.

Potentialities of Utilizing an Electron Bombardment Treatment for the Production of Canned Meat Products

SAMUEL A. GOLDBLITH

Over the past few years, it has been demonstrated that destruction of microorganisms in any organic or inorganic medium can be achieved by bombardment with ionizing radiations, irrespective of whether the container holding the medium is of metal, glass, or fiber. For most of the research in this field, cathode rays or beta particles produced in particle accelerators of various types have been used, and canned meat products are among those foods that have received considerable attention to date.

In a consideration of the sterilization of meat products by cathode rays a number of factors must be taken into account. The answers to some problems are already at hand, but a number of others remain yet to be solved.

The purpose of this paper is to outline the present-day status of the sterilization of canned meat products by high-energy cathode rays and the requirements and methods to meet the objectives in such sterilization.

Equipment. The early experiments on cathode ray sterilization were conducted with particle accelerators, which were designed primarily for nuclear studies. Consequently, such equipment was of relatively low-power output (500 watts or less) and produced ionizing radiation of moderate energy levels (1 to 3 m.e.v.).

More recent developments in particle-accelerator equipment have led to greater power outputs (up to 12,000 watts) but not to greater energy levels (voltage). It has been shown *(1)* that the potential difference (voltage) through which electrons are accelerated determines the penetration of these electrons in matter, according to the equation:

$$R_{max} = \frac{0.542E - 0.133}{P}$$

where R_{max} is the maximum penetration of electrons (cm.) of energy E (m.e.v.) and P is the density of the absorber (gm./cc.).

Electron accelerators more suitable for sterilization purposes have been built and are now available with a sufficient electron "flux" for rapid sterilization at

TABLE 1

GENERAL FACTORS OF IMPORTANCE IN ELECTRON ACCELERATORS USED FOR STERILIZATION PURPOSES

Factor	Remarks
Voltage (m.e.v.)	Determine penetration
Electron beam current (ma.)	Determines number of electrons per unit of time bombarding sample, hence rate of sterilization of material of thickness determined by voltage
Total power (watts)	Combination of voltage and current that determines total quantity of material that can be sterilized.
Efficiency of utilization (%)	Based on inherent variation of ionization in depth of cathode rays in matter
Reliability of operation	Determines how much material needs to be reprocessed; at present appears to be limited, in general, by tube performance; dictates number of spare machines required
Cost of sterilization (cents per lb.)	Determined by original capital investment, over-all performance of sterilization units, number of units required, cost and frequency of replacement of certain components

energy levels up to 3 m.e.v. Particle accelerators have been built to accelerate electrons to higher energy levels. However, these have not yet been built for sterilization purposes.

It would be well to define and illustrate the general factors of importance in any electron accelerators, regardless of make, for sterilization purposes. These factors are listed in Table 1 and are discussed below.

Voltage. The accelerating voltage required is dictated by the sizes of the conventional containers that are used today. At the present time an upper limit of 3 m.e.v. has been achieved. The degree of reliability of maintaining this voltage with present accelerators at high beam currents appears to be fair. Higher voltages should be obtainable (up to 5 to 8 m.e.v.) with modifications of present equipment and with power outputs high enough for sterilization purposes. However, this situation will require considerable development and cost.

Present voltages available in such types of equipment provide facilities for surface sterilization of a number of products and for sterilization of products in containers one inch in thickness or less. This will be discussed later in this paper.

Current. The electron beam current is a measure of the total number of electrons accelerated down the tube and available to impinge on the material being irradiated. This current determines the quantity of material—of a thickness limited by the voltage—that can be irradiated per unit of time. The requirement for steadiness of the beam current is obvious. At the present day, 3 m.e.v. beam currents of 4 milliamperes and slightly higher have been produced.

Power output. The product of voltage and current, that is, the power output, dictates the total quantity of material that can be treated per unit of time. The manner of presentation of the material of the beam and the efficiency of utilization of the power are also controlling factors. These factors will be discussed separately. A power output of 12 kilowatts (as represented by an accelerating voltage of 3 m.e.v. and a tube current of 4 ma.) represents a power equivalent of 12,000 joules per second. On the assumption that a dose of 2×10^6 rep has been determined experimentally to be the sterilizing dose, and as 1×10^6 rep is equivalent to an energy absorption of 8.3 joules per gram,

$$2 \times 10^6 \text{ rep} = 16.6 \text{ joules/g.}$$

and

$$\frac{12{,}000 \text{ joules per second}}{16.6 \text{ joules per gram}} = 723 \text{ g./sec.}$$

The value of 723 g. represents the amount of material that can be processed per second with a power output of 12,000 watts, if 100% efficiency is assumed.

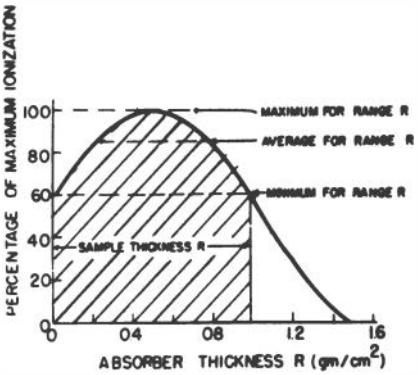

FIGURE 1

IONIZATION IN DEPTH FOR MAXIMUM, MINIMUM, AND AVERAGE DOSES OF IONIZING RADIATIONS.

Efficiency. In the preceding paragraph, the efficiency of utilization of the electron beam energy was assumed to be 100%. Such an efficiency cannot be achieved, however, because of the inherent scattering of electrons in matter. Figure 1 represents the well-known ionization-in-depth curve of cathode rays in matter. As has been shown by (*4*), utilization of the beam is dependent on the thickness of the sample chosen. For example, if a sample of 3/5 R_{max} (at 3 m.e.v., R_{max}=1.5 cm. and 3/5 R_{max}=0.9 cm.) is chosen, the ionization curve shows a minimum dose of 60% at entrance and exit levels of the radiations with the maximum or 100% dose at 1/3 R_{max}. In other words, a variation in dose of from 60% to 100% to 60% is present from top to bottom of the sample. In addition, the "tailing" of the ionization-in-depth curve is not utilized. This represents an energy loss of 15% of the total available energy not utilized at all. Of the available 85% of the total energy that is used, the efficiency of utilization is 75%, because of the variation in dose through the sample (*2*).

The 15% of the total energy that is not utilized by the one-direction bombardment can be utilized by "crossfiring" or bombarding through two portals of entry, e.g., the top and bottom of a can, when a sample thicker than R_{max} is treated. This is advantageous from the viewpoint of product thickness. This can be done by splitting the electron beam and bending it with magnets or by making 2 passes with the cans filled with solid materials, turning the cans over before the second exposure.

The efficiency of penetration of the electron beam energy when conventional sardine cans are crossfired is illustrated in Figure 2. It is to be noted that the can cover absorbs a great deal of the energy available as pointed out by (*4*). With 3 m.e.v. electrons, a steel sardine

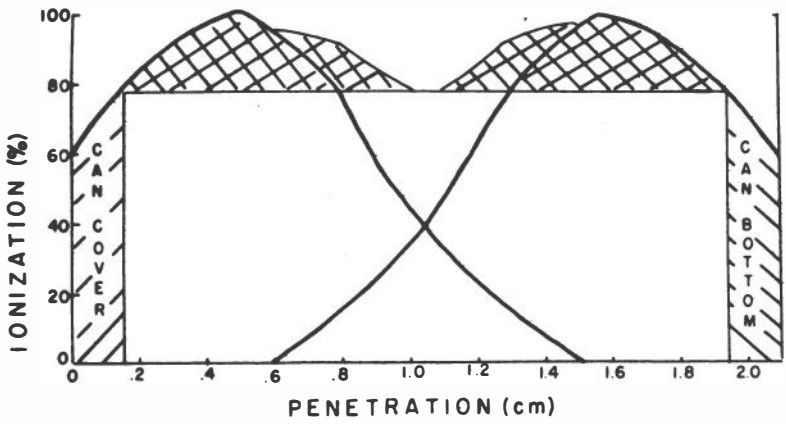

FIGURE 2

IONIZATION IN DEPTH IN STEEL SARDINE CANS FILLED WITH MATERIAL OF UNIT DENSITY AND CROSSFIRED BY 3.0 M.E.V. CATHODE RAYS.

can filled with material of unit density can be sterilized by crossfiring, with a variation in dose of from only 78% (entrance dose) to 100% at 1/3 R_{max} (Figure 2) from each surface to the center of the can. The same result can be accomplished with the same efficiency by 2.6 m.e.v. electrons, if aluminum cans are used, for aluminum has a density only one-third that of steel (Figure 3). The lower voltage requirement is a desirable attribute, because it will allow one to use a given accelerator at lower-than-rated voltage and hence should probably increase the reliability of operation of the machine or permit the use of an accelerator of lower voltage.

As higher voltage accelerators for sterilization purposes are difficult to produce without increased costs for development, it is desirable to use as low a voltage as possible. In this connection, further progress may be expected if plastic films are utilized, because their density is almost unity—in contrast to rigid packages of much higher density. However, further investigation is required to ascertain whether the functional qualities of these films offer as nearly perfect protection for the sterilized products as do rigid containers.

Meat packed in conventional cans, e.g., 12 Z oblong cans, would require 6 m.e.v. electrons for crossfiring as shown by (*5*). An efficiency of beam utilization in depth of 75% should be obtained, especially with means of reducing lateral variation in dose by scanning (*6*). For realistic purposes, a utilization efficiency of 50% might well be used.

The design and development of particle accelerators of such energy levels, with a sufficient flux of electrons, are necessary for containers of greater thickness. The linear electron accelerator may offer a means of achieving such voltages in the near future, if further de-

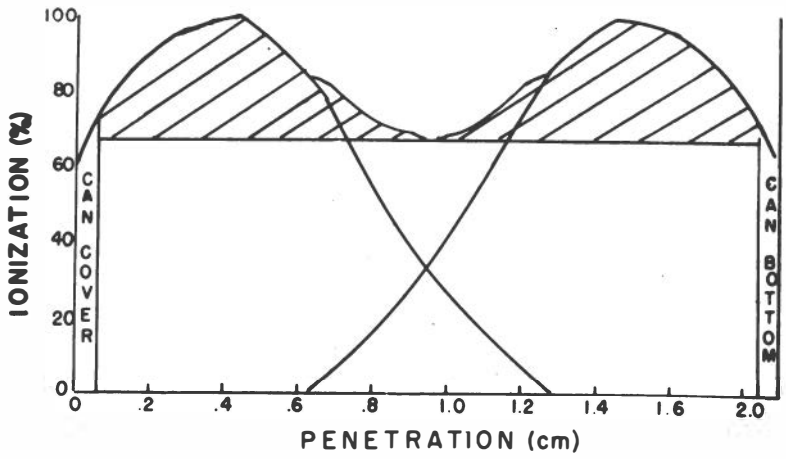

FIGURE 3

IONIZATION IN DEPTH IN ALUMINUM SARDINE CANS FILLED WITH MATERIAL OF UNIT DENSITY AND CROSSFIRED BY 2.6 M.E.V. CATHODE RAYS.

velopmental research indicates that larger power outputs than are presently available can be perfected with a good degree of reliability.

Reliability of operation. With any processing system one must ascertain the reliability of the process. In this particular method, the required reliability of maintaining accelerating voltage and current at needed rated levels is of a high order. A variation in 10% of either of these power components for a given unit of time would require reprocessing of the quantity of material treated in that period of time, because a 10% diminution of one or the other components would reduce the dose delivered to the sample by 10% and would result in some unsterile products. This factor of reliability is also of importance from another standpoint. The lower the reliability, the more the material required to be reprocessed; hence the greater the number of machines needed for the sterilization process and, therefore, the greater the initial investment as well as the higher the upkeep costs.

Cost of sterilization. The cost of the sterilization process by any type of radiation is based on the initial investment required plus some other factors in addition to those previously discussed. The initial investment required, as explained before, is partially determined by the reliability of operation. Other factors, which are common to radiation sterilization regardless of the source of the radiation, are as follows:

Shielding costs and building alterations
Personnel costs
Replacement cost of components of relatively short life
Monitoring and safety costs
Total quantity of material that can be processed per unit of time in the given installation

In addition, the obvious factor of dose requirement is also involved in the cost picture. For instance, a dose of 2,000,000 rep for destruction of spore-forming bacteria presents a cost picture much different from that presented by a dose of 100,000 rep for insect destruction. Time does not permit detailed discussion of each of the cost items mentioned above.

Summary of equipment factors to be considered. One may summarize the equipment factors to be taken into consideration in the radiation sterilization of meat as follows:

Particle accelerators for electron acceleration having a range in voltage of from 1 to 3 m.e.v. have been designed and fabricated.

A power output of 12 kilowatts at 3 m.e.v. has been achieved. This represents sufficient power for commercial production rates and, therefore, allows a unit container of material to be processed in a fraction of a second. However, the limitations on depth of penetration are present.

Higher voltages are possible but require considerable developmental research.

Data concerning the reliability of operation of particle accelerators under conditions of commercial production, e. g., 8 to 16 hours of continuous operation per day, have not yet been obtained.

Proper cost studies must await the solving of the reliability problem. Until this is done, the cost figures should be considered only as rough estimates.

The product. Sterilization of canned meat products by cathode rays, insofar as the product is concerned, involved most of the factors that are present in sterilization with isotopic sources of beta- or discussed in detail previously (*4, 5*), are summarized below.

Inoculum. The resistance of a given species of microorganism is of greater importance than the numbers of that species present. For instance, a thousandfold increase in the concentration of bacteria results in only a small percentage increase in sterility dose requirement, whereas a twofold increase in resistance results in a twofold increase (100% increase) in the sterility dose requirement. These facts are independent of the source of radiation and apply to any source.

Side-effects. Since the beginning of our studies in this field in 1943, it has been known that some undesirable side-effects may be produced in meat and meat products treated by sterilizing doses of ionizing radiations, regardless of the source of these radiations. With meat products, these undesirable side-effects are off-color, off-flavor, and undesirable odor production. A process of addition, in food products, of free-radical acceptors prior to irradiation has been developed in these laboratories which has been successful in minimizing some of the undesirable side reactions. However, the results of long storage tests are necessary before any detailed specifications for the process can be set up.

With fresh, chopped meats packaged in cellophane and irradiated, a darkening of color develops on storage at refrigerator temperature. Whether this is related to the radiation process or to the inadequacies of the type of package used remains to be investigated.

Further fundamental research on the addition of other free-radical acceptors for obviating the undesirable side reactions produced by ionizing radiations is under way in these laboratories. Other methods for preventing these side reactions have been reported recently by Huber, Brasch, and Waly (*3*), such as the use of different gases or the addition of spices, herbs, and seeds.

Enzymes. In the preservation of meat (muscle tissue) by ionizing radiations, it is not considered that enzymes are of importance provided they are not involved in color changes in the product or in rancidification of fats.

Animal tests. Tests of a nutritional and toxicological nature must be performed with animals before the process can be accepted by the appropriate governmental agencies. These tests should be performed

in collaboration with the appropriate agency involved and should include a long-term study of reproductivity effects as well.

The package. Those aspects of the package that affect absorption of high-energy radiations have been discussed previously in this paper. There are other aspects that must be considered, however. These are the functional properties of the container and the manner in which these properties are affected by the radiations. The package must not only remain a barrier against microorganisms after irradiation but must also retain its functional properties such as moisture-vapor retention and gas permeability, which must not be adversely affected by the radiations. Under a contract with the Quartermaster Food and Container Institute for the Armed Forces, we are studying the various phases of the effects of high-energy radiations on packaging materials. When one is considering the use of films for the packaging of meat for radiation sterilization, retention of the color of the meat becomes a distinct problem and research is required to solve the problem of color retention.

Meat products that can be treated with ionizing radiations with some degree of success. Promising results indicating some degree of success in meat sterilization by ionizing radiations have been obtained in studies as follows:

Surface sterilization of meats such as frankfurts, to increase the keeping time under refrigeration storage.

Sterilization of chopped, canned meats in cans or packages. (Thickness limited at present to cans one-inch thick or less.)

Pasteurization of fresh, chopped meats.

Destruction of trichina in pork (*4*).

Summary

This paper has been written in accordance with the title that was indicated by the chairman of this symposium. An effort has been made to present factually the pros and cons of cathode ray sterilization in regard to meat at this time.

In summary, it may be said that the sterilization of meat products by ionizing radiations offers a number of problems common to both accelerator and isotopic sources of radiation. It has been clearly indicated that there are numerous problems yet unsolved concerning this process and that, to provide equipment capable of wide utilization, developments not yet undertaken from a machine standpoint are necessary. It might also be said that the same factors apply to all other suggested means of radiation sterilization and the equipment necessary for commercial production of radiation-sterilized foods.

Although greater penetration is available with isotopic sources of gamma radiations, beta-particle accelerators today offer a power availability approximating that required for commercial production rates. The reliability of operation of these accelerators has not yet been established, and until this is done, realistic cost figures for the

sterilization process will be difficult to calculate. Realistic cost figures for isotopic sources should be equally as difficult to calculate at the present time, because of the unknown cost of preparing and packaging these sources in the multimegacurie quantities necessary for handling even small plant outputs.

The present status of radiation sterilization of meat and meat products, insofar as the product is concerned, has been discussed in detail. Although the data presented show that a great deal of research is yet to be done to make this process commercially feasible, a brief glance into the recent past shows that much has been accomplished in the few years that this method has been studied by the relatively small number of investigators in the field.

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CHAIRMAN WIESMAN

Thank you very much, Dr. Nickerson.

Concluding Discussion

CHAIRMAN WIESMAN

I suppose you are all primed with questions. In order to start things off we have a gentleman here who is acknowledged to be an expert in the art of canning. Dr. Ball, will you summarize the highlights of the meeting so far today?

BALL

It gives me great satisfaction to see the interest that has come within recent years in the improved methods of canning foods. If you have followed my interests at all during the period I have been active in this work, you know that through all the years, I have been looking forward to the things which may bring into effect the improvements in quality of canned food that are possible. The frozen food people are going to have to look to their laurels very diligently because there are qualities in canned foods which they are not able to obtain as yet in frozen food. I think particularly of the stability factors and if we can add to those, great improvements in organoleptic quality, we will have something hard to excel.

As we look over the disclosures that we have had today, we can classify the processes in 2 principal categories; those dealing with heat and those that do not deal with heat in the sterilization of food. All of those that use heat are associated, you might say. We can use various methods of applying heat in almost any of the different methods of processing. All we need is to make little modifications of equipment to go from one type of heating to another; the object is to produce as rapid heating as possible because fast operation, fast effect, is of prime importance in heat processing. In the methods in which heat does not play a part, those described in the last 2 papers, for example, time, from the standpoint of its effect on quality, is not important; of course, it is important from an economic standpoint.

We know that we can never think of a commercial operation which would require what Dr. Nickerson showed is required as to the intensity of radiation. It would not meet the requirements of commercial operation because of its not being economically feasible. In those types of treatment we have to think primarily from the standpoint of economics, whereas, in the heat and the heat methods, the economics are of less importance.

To start off with a question, I would like to ask Dr. Doty, in connection with organoleptic qualities of food heated dielectrically and that heated by steam methods, what kinds of steam methods you were referring to—whether they were fast heating or not?

DOTY

In the case of the pork luncheon meat, comparison was made between dielectrically processed meat which we prepared and the pork luncheon meat as processed at the Food and Container Institute using

the standard procedure required for the product. I can't tell you the F_0 value for it, but it was a sterilization sufficient to hold the product without refrigeration. It was a slow retorted sterilization.

CHAIRMAN WIESMAN

Thank you very much, Dr. Ball. We certainly appreciate your comments. May we have some questions from the floor?

A. C. EDGAR (Wilson & Company)

On sterilization of units—what was the largest size that you worked with, and if you had a large unit, for example, a 10-pound ham for commercial use, would chilling of that product be a problem?

DOTY

On our work with hams, we were processing 11-pound boned ham units. Actually, with the oscillator capacity which we have, even larger units per run would be better because of increased resistance offered by a longer capacitance. Actually, since the ham only grows so big you would have to do it in multiple units or use a smaller oscillator to get more efficient processing. We do not have the figures on the cooked capacitance loss, Mr. Edgar. As a matter of observation, and perhaps Mr. Peterson can check me on this, I think we probably have no more loss and perhaps less than you would have under normal pasteurization procedures as carried out at present because of the speed with which the ham is heated.

MANDELS

I wonder whether one can actually take a complex material like meat which contains proteins and all kinds of other constituents and actually store it at 100°F. for a matter of a year or 2 without getting decomposition. Suppose you took a simple protein like gelatin or something like that, would that be stable under such conditions?

CHAIRMAN WIESMAN

Who would like to answer that question?

STUKIS

I presume it was directed at me. I can't answer the second part of that question with regard to gelatin because I haven't conducted such studies. But these comparisons that we did make, you see, were all relative. In other words, how good would a ham processed by this method be stored for one year at 100°F., say, compared to luncheon meat or chopped ham, processed in a conventional manner, stored for a like period of time at the same temperature. We would assume, and we have found, that conventional methods with pork luncheon meat or chopped ham give better results on color, flavor, texture, and sliceability than we obtained on this particular study with this ham.

I don't know whether this answers your question or not. You see, it is all relative. It doesn't stand by itself. It stands by comparison with some other item. In other words, it didn't store quite as well as some of the other items we have looked at and examined.

GARDNER

I suspect that as we are able to lower our process and obtain a better product initially, there will still be certain chemical changes which are not inhibited, which are now inhibited by the severe process.

HARRY SPECTOR (QMFCI)

As a contribution to the over-all nutritional adequacy of the operational ration, canned meats have an important function. But we have observed a loss of thiamine, as high as 70% of the original content, on processing, and we get an additional loss of 50% during high-temperature storage. In rations which are apparently adequate by calculation, we find that when we feed them to laboratory animals they are inadequate and require supplementation with proteins and vitamins to promote normal growth. In listening to these papers, it seemed that Mr. Smith was the most optimistic about the commercial feasibility of his process. I wonder whether any studies have been conducted on the effect of that particular process with regard to retention of nutrients.

SMITH

We hope to have some, but at the moment we do not.

BALL

There have been studies made on foods sterilized in similar fashion, and the results of those studies should apply to foods processed by our methods also. I refer to a comparison between the short-time sterilized foods and the food sterilized by longer heat processes.

CHAIRMAN WIESMAN

I wonder, Dr. Morse, if you could tell us something about the effect of ordinary steam processing on nutritive value of meats.

MORSE

In addition to improvement of texture and taste quality, we should stress very heavily nutritive retention. I think we ought to hit it harder than we are doing at present. One of the reasons we may have difficulty with acceptance is the old business of people being inclined toward food that "does them good." We may be missing that point altogether. They aren't getting the nutritive value in these long-stored meats they should be getting and therefore they are rejecting them and searching for something which will supply the nutritive value. That's not much of an answer, but it is the best I can give.

CHAIRMAN WIESMAN

Dr. Brownell, has any kind of work been done on the effect of the fission product treatment on the wholesomeness of canned meats?

BROWNELL

The wholesomeness of irradiated food is the problem that we are about to investigate under this animal feeding experiment. As I stated earlier, we have only run one short experiment of 6 weeks. We hope to conduct this next experiment for a period of at least 2 years with 4 generations of animals or more; we hope that that will establish the wholesomeness—the ability of irradiated food to support normal growth without any undesirable autotoxic effects. It will probably be at least 2 years before we have an answer.

CHAIRMAN WIESMAN

How do you feel about it, Dr. Nickerson? There has been a lot of work on ionizing radiation and vitamin retention.

NICKERSON

There has been work done, and there is apparently not a great deal of loss of vitamins, due to irradiation.

EDGAR

I would like to comment on storage of products processed rapidly with agitation cooking or end-over-end cooking. It has been found that although the flavor doesn't seem to change, particularly, the texture does. In other words, when a product like spaghetti and meat is considered the spaghetti gets rather soft after a period of one year or possibly sooner at elevated temperatures; thus, there is some change even though we have an advantage at the start. We do get some change after prolonged storage, and particularly at 100°F., which is a very severe temperature for storage of meat products. I might add that we do not have any nutritive data on the end-over-end material as yet.

T. C. KMIECIAK (QMFCI)

When material is sterilized by gamma radiation, do you have residual radiation from that particular product which in turn is effective in killing? With this cold type of sterilization, you have the possibility of mutant strains being developed as we have in antibiotics —what will the result be?

BROWNELL

In answer to your first question, there has been no evidence of any residual radioactivity using either gamma or beta radiation. To induce residual activity would require bombardment by neutrons.

Regarding the development of mutant strains, Dr. Gaden at Columbia has done some work along these lines and has exposed microorganisms to radiation, the dose sufficient to kill, say 99% of the organisms. He has then cultured the remainder and repeated his experiment until he has developed strains that have greater resistance. You would not expect, however, in the irradiation process as used with food to have conditions suited to propagating resistant strains.

CHARLES NIVEN (American Meat Institute Foundation)

What proportion of the canned hams used in the Institute experiment that were stored at the higher temperatures showed gross evidence of microbial spoilage as judged by gassiness or digestion of gelatin, foul odor, digestion of the meat, or perhaps a large number of bacteria showing up on direct smears?

STUKIS

To the best of my knowledge there was no gross evidence of spoilage such as extremely foul odors or digestion of the meat. Hams stored at 100°F. evidenced an increase in count over the first 3 months. By the time the 10th month had arrived, evidently the growth cycle had been completed, and the counts were greatly reduced. Perhaps Dr. Rayman would care to add something to that.

MORTON M. RAYMAN (QMFCI)

Of all the cans we examined only one was slightly swollen. There was no evidence of spoilage in the can. The bacterial picture has been described.

GEORGE F. STEWART (University of California)

To go back to cold sterilization for a point of clarification—is it true that regardless of whether it is a beta or gamma radiation it requires the same amount of reps to achieve a kill of spores or vegetative cells? Also, what is the relationship with enzyme destruction?

BROWNELL

Our data indicate the same order of magnitude of radiation required using gamma rays in the destruction of microorganisms as that reported by those working with beta rays. As to enzyme destruction —enzymes apparently are much more resistant to radiation than are microorganisms; it takes perhaps 10 times the dosage or more to destroy certain enzymes than it takes to destroy the microorganisms. However, despite this fact, meat sterilized with radiation does not seem to undergo enzyme degradation as shown by the fact that the meat stored for several months is not liquid. It is still in about the original state.

STEWART

There are many enzyme systems not involving liquidation of meat, however, which cannot be overlooked.

NICKERSON

That's true. The only thing I would add to what Dr. Brownell has said is this: If you have your enzymes in pure solution, you can destroy them very readily with ionization radiation, but in food products they appear not to be affected to any great extent.

GARDNER

Would it be in order to ask what the mechanics are, that is, what does the radiation do to the bacteria?

BROWNELL

The process by which microorganisms are killed by radiation is not very well understood. Ionization radiation has the ability of knocking electrons off the molecule and apparently certain molecules or groups of molecules in the organism are sensitive to such an effect; there has been proposed a target theory that if a certain number of these sensitive molecules are bombarded by radiation, the organism will die. Perhaps Dr. Nickerson could add more to that.

NICKERSON

I don't know that I can add much—it is all theory, anyway. It is something similar, perhaps, to Ryan's theory that some protein in the gene is necessary for reproduction. That's just theory, of course.

A. M. SMOLELIS (Armour & Company)

Have you tried cell-free solutions where you have the enzymes in suspension, for example, and tried to irradiate those?

JOHN GRAIKOSKI (University of Michigan)

Enzymes in diluted concentration are not very radio-resistant, but as you increase the concentration they are more resistant. Enzymes in tissue are very radio-resistant. The enzyme is in a bacterial cell. It will not reproduce and produce a colony, but Proctor and Goldblith have shown enzymatic activity in bacterial cells still continues even after exposure to sterilization dosage required to prevent their (the bacteria) forming colonies. The work was done with *E. coli.*

SPECTOR

With reference to the canned meat items in the C Ration, the chart shows some 10 canned meat items, but the menu is so arranged that the C Ration consists of 6 different menus and 3 different meat items in each menu. So we have only 10 meat items to use where we

need 18 meat items; within the existing 6 menus we have some repetition. Also, some of the items that are used in the C Ration are used in the B Ration, the 5-in-1, and perhaps in the In-Flight. We have been asked on occasion to develop new rations, and we have done that, to meet new tactical situations, but the limiting factor in all of this is the number of available canned meat items. The danger that we run is that even though we may have something like 13 or 14 operational rations, from the standpoint of the soldier who is consuming them, no matter whether he is on the B Ration or C Ration or the Assault Pack or In-Flight—he is seeing the same meat item in just a different size can. From the menu-planning standpoint, therefore, there is a great need for a greater variety of meat items. We are very happy to see that there are some 17 or 18 items on the horizon that we can put into the rations, and that work is going on to increase the number even beyond that.

LT. COLONEL GEORGE F. McANENY (QMFCI)

I would like to accentuate one thing, if I may, and that is we can all sit down around the table in the Institute, and I think a lot of the people here have done so, and try these canned rations. We think they are pretty good, but when you have to subsist upon canned meat for days at a time, it can become pretty tiresome. I am sure you members of industry are well aware of the fact, even though your concentration is primarily upon fresh and frozen meats, that fresh meat is what the American people want. I feel, and I think that all the Armed Forces feel, that a soldier, when he puts on the uniform, is still the American people. It doesn't make any difference. He still would like the frozen and fresh meat, but we must remember there are many times when he cannot get it, and what we would like to get from you people is better canned meats. That is the principal reason for asking for that advancement of canned meats.

CHAIRMAN WIESMAN

Thank you, Colonel.

MEYER

I didn't quite appreciate the advantage of the Smith-Ball process over, say, the standard, at least, the agitated retort process. If you have a piece of meat in a can and don't have it in a retort, but heat it in a room which is pressurized, is the rate of heat penetration in any way enhanced?

SMITH

You can heat the product up to sterilization value with any method that achieves the highest rate of heat penetration, and in the smallest particle size which is used in the product; the pressurized chamber raises the boiling point, raises it up to the sterilization point before

you put the product in the can. Then you put it in the can and seal it at that temperature.

MEYER

Would the intention then be, say in the case of meat chunks, to agitate them while they are being cooked so that you get a greater heat penetration? If you had a large vessel full of compact meat, I suspect the rate of heat penetration wouldn't be any more advantageous than it is in a No. 10 can or any large can in a steam retort.

SMITH

You could heat those meat chunks in an atmosphere of steam where the temperature of the surface would always be that of the steam. If you leave them in a can and you have 2 or 3 pieces in there, the inner face temperature would be lower than at the surface or the rate would be lower.

R. A. LARSEN (QMFCI)

It is my understanding that meat and other products deteriorate in storage for 2 reasons—the growth of microorganisms in the meat products and also because of the action of the enzymes which are inherent in the meat. Yet, in recent years, I have been reading some publications which have made me wonder if the enzymes within a meat product really would cause deterioration. I would like to ask whether, if you prepared meat under absolutely aseptic conditions, it would be necessary to store it under refrigeration or could you store it at normal room temperatures without refrigeration?

MORSE

There is some work being done at Ohio State that hasn't been introduced in the meeting—that is, where animals immediately after slaughter are perfused with an antibiotic solution through the venous system, producing in effect a sterile carcass, internally, at any rate. This meat was hung at room temperature for 11 days without spoilage, and the enzymatic processes do go forward. You can take a pretty tough critter and make a fairly reasonable piece of tasty meat out of it. This is not a direct answer to your question, but I think it gives some of the clues that we are seeking.

Incidentally, in conjunction with that work, there was a technique used that I think may be of some value to some of you. They reasoned that if there were to be microorganisms circulating through the animal tissue, a good logical place to be on the lookout would be the nodes of the lymph system. They developed a technique for isolating, under fairly sterile conditions, the nodes from the animal tissue, immersed this in 95% alcohol and set it aflame, and then went back at it again with sterile instruments. They developed what I think is probably a quite reasonable sterile technique for looking for bacteria

within the tissue and found a lot of them. The enzymatic processes do go forward and even under quite sterile conditions. Incidentally, you could take this meat at room temperature, and leave it on the table for a week, and the outside would turn jet black. If you cut it away, it was perfectly sweet smelling and could be eaten; I ate some and I am here to tell about it.

LARSEN

I would like to ask one other question. I was talking with Dr. Wilt Hachuger of Electronized Chemicals. He told me that with the capacitron and very slight penetration into the meat, he could take a thick piece of beef steak and sterilize it, essentially, just the surface, not penetrating the enzyme systems within the tissue, and that meat could be stored indefinitely at room temperature.

Then there is the work they are doing at Notre Dame, growing animals under aseptic conditions. It is my understanding when those animals die, they do not decompose. If you produced meat under strictly aseptic conditions, would you have to worry about storage properties?

CHAIRMAN WIESMAN

Would anyone else like to comment on that?

RAYMAN

I was going to make the same comment that Dr. Larsen did a minute ago about the germ-free animals. I think there is a difference there. The enzyme reactions that Dr. Morse referred to as continuing and the enzyme reaction that Dr. Larsen refers to as not continuing are probably due to the question of the liberation of the enzyme from the tissue in the slaughtering and meat preparation as opposed to the natural death and the intact enzyme in the tissue. In one case you have it released and have a chance for it to work; in the other case, it just doesn't seem to do anything. I don't know if that is the explanation.

BALL

Have they determined anything at Ohio State as to the termination of this enzyme action? How long is it going to continue? Under what conditions will it affect the meat? Do they know anything about that?

MORSE

Direct answer, no. I think what happens, though, is that eventually spoilage begins, and I don't know how long you would have to store it to determine what the enzymatic problem would be—maybe 6 months—in which case you couldn't very well have it sitting around that long.

STEWART

I think there is ample evidence that enzyme systems continue to operate after death and in the absence of bacterial growth. You can go back to 1900 and prove this. You don't have to take this year's data to do that. The important thing is whether the changes that go on are important changes from the standpoint of eating quality. Certainly, we know the glycolytic system comes to a halt in a few days with the establishment of the lactic acid, and so on; there is also evidence that the proteins are broken down, because some of those early studies, where they kept them under conditions where you did not get growth, eventually end up with essentially a very soft or almost a jelly condition in the meat. So I don't think there is any question about the matter of whether the enzymes act or not. The question is whether the time limit imposed there is important. This business of keeping them indefinitely is a little silly because indefinitely is an awfully long time.

MORSE

Fortunately, it looks as if just the right ones keep on growing a little bit.

CHAIRMAN WIESMAN

There is the problem—I heard the Food & Drug is not going to permit the use of antibiotics in food. What we may have here is a lot of good, fundamental information.

MORSE

The rest of that story—they are unable to detect any of the antibiotics within 48 hours after infusion. Whether that validates the use of antibiotics or not, I don't know.

CHAIRMAN WIESMAN

It is a legal problem, I guess.

NIVEN

I wonder if some factors more important than enzymatic or microbial may be concerned here as evidenced by the work of Stukis and co-workers, that is, of the browning reaction that goes on at elevated temperatures at storage, which would markedly affect the flavor as well as the appearance.

STEWART

I think that is an extremely good point. Dr. Ayres and I did some work on chicken meat at one time in which we inhibited bacterial growth quite effectively. One of the first things that showed up was rancid fat flavors which you never get ordinarily in chicken meat. So I think you do run into those things.

GARDNER

It might be interesting to note that the same odor, though to a lesser degree, and the same flavor difficulties we encountered in Mr. Stukis' experiment are being encountered in experimental work on dehydrated meat, indicating that regardless of how the meat is processed, you may have the same problem.

MISS C. WALLIKER (QMFCI)

We were talking about aseptic slaughtering. I was wondering if that doesn't raise a question. How is that going to affect the aging process?

MORSE

That was the basis for this work, actually. It was an effort to do a round tenderizing. I think it will accomplish the same thing as tenderizing. You are able to elevate the temperature of storage and decrease the storage time used for tenderizing meat. Is that what you have in mind? By raising storage temperature, the time required for aging is greatly decreased. Like any other chemical reaction, it proceeds at a more rapid rate. The aging time is greatly decreased.

DOTY

Actually, at least the assumed situation that occurs during aging, as far as tenderizing is concerned, is the result of the enzyme systems, particularly the proteolytic system in the tissue, and not systems which are contained in the bacteria or yeast which contaminate the carcass. If you keep down the contamination and speed up the enzymatic processes by increasing the temperature, then you should get a more rapid and complete aging without the undesirable effects of bacterial and yeast contamination.

MORSE

As to solid chunks of meat, and the interesting part, the heat induced by the electrical resistance of such material—would you say that the same relationship would hold true on material that had fluid in it—for example a beef fluid? Would resistance be an important factor?

DOTY

Actually, the proportions of moisture in fat and in protein influence the proportion of energy which heats by means of the capacitance of the material and resistance in the material, so if one were to increase the moisture content, one should increase the capacitance and decrease the resistance. With an increased moisture content you expect to get a higher proportion of capacitance through dielectric heating, if you please, and less and less resistance heating. If you use meats of different fat content, then because the fat and moisture

content are essentially inversely proportional to each other, you vary the moisture content in the same ratio. In the heating which we have done with ground beef at 2 different fat levels, at 12% and 25%, then, we have essentially used 2 different moisture contents, and we get essentially the same type of heating.

In the process we use we are not able to distinguish in the process itself the difference between the heating due to capacitance and heating due to resistance, so I can't absolutely answer your question. I am giving you what I think theoretically should be the case. But I think you would get essentially effective heating in something like a beef stew where you had a mixture of moisture and particles.

GARDNER

Have you ever done any inoculating tests—actually inoculated P.A. 3679 to determine the recovery?

BOLANOWSKI

Yes, we have. We inoculate but let somebody else do the determination. We are not staffed with that type of personnel. We do make inoculative tests. We go to the level below and above to make sure. We first test to make sure the inoculum is active.

MEYER

There has been a lot of concern about enzymes and the destruction of them by the new methods of sterilization. What's the status of vitamins?

CHAIRMAN WIESMAN

Dr. Nickerson stated, from the standpoint of ionizing radiation, that they were not destroyed, but they have no storage studies. Dr. Brownell, I believe, said that that work is just under way now.

BROWNELL

There is some destruction of vitamins by radiation. Ascorbic acid in weak solution is readily destroyed by radiation. In the presence of other materials in food, it is protected. Ascorbic acid protects niacin. Niacin protects ascorbic acid, so in foods you would not expect to have perhaps serious vitamin loss as a result of radiation, but there will be some. We haven't investigated that phase of it to any extent, but we thought it not advisable to irradiate the vitamin supplement in the diet. Also, there is some formation of peroxides in the unsaturated fats as a result of irradiation, and in some feeding experiments it has been shown that there might be a vitamin E deficiency. Therefore, we decided not to irradiate the fats that were added to the diet.

KMIECIAK

In the chamber used in the Smith-Ball process you duplicate conditions a submarine has gone through; the submarine command has set up a limit of 5 hours work per day. Now are you assuming your people can work a full 8-hour day under those pressures?

SMITH

We didn't mention submarines. We said divers. A submarine is essentially at atmospheric pressure. I think there are 6 states that have laws governing the operation of personnel at elevated pressures, and all of those states will permit a normal 8-hour working day at 20 pounds pressure.

KMIECIAK

In keeping with that, you have odors coming off some of these foods that do diffuse away from your blowers. What is the concentration of that after, say, an 8-hour run? Overpowering?

SMITH

No. We are continually introducing air for ventilation purposes far in excess of normal ventilation. We are introducing about 150 cubic feet per minute in a chamber for 2 people, so I think the continuous introduction of fresh air is far in excess of what would be required for normal ventilation.

GARDNER

Mr. Chairman, on behalf of the Quartermaster Food & Container Institute I would like to thank each of the individuals who prepared and presented papers; particularly, I would like to thank the National Research Council for making it possible for this symposium to be conducted. I would like to thank each one of you who attended for your contribution. The Quartermaster Food & Container Institute will do its utmost to utilize the information and advice that has been given in the last 2 days. Thank you, Mr. Chairman.

CHAIRMAN WIESMAN

Thank you very much, and thank you all for your kind attention.

(The meeting adjourned at 4:15 o'clock.)