Update: Nitrite-Free Processed Meats

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Final Report

Nitrite-Free Processed Meats Committee of the American Meat Science Association

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Report Summary

Although nitrite and its precursor nitrate have been involved in the curing of meat for hundreds of years, its continued use in meat products has come under question because of recent health concerns surrounding this additive. The incorporation of nitrite (or nitrate) to a meat product fixes the lean color in a stable pink state, imparts a distinctive flavor to the product, functions as an antioxidant, and enhances the product's storage life and safety through its antimicrobial action. Elimination of an ingredient which performs these multiple functions would be expected to have profound effects upon the resulting meat products. The objective of this committee has been to review information which relates to the production of meat products prepared without nitrite.

Safety Aspects of Nitrite-Free Processed Meats

Although discontinuing the use of nitrite may affect product shelf life and increase the risk of food-borne illness caused by a number of microorganisms, this report has focused on the threat of growth and toxin production by *Clostridium botulinum* in nitrite-free processed meats. Because of the high fatality rate associated with the disease of botulism, it must be regarded as the most serious safety hazard to consumers.

The potential of botulism from nitrite-free processed meats is a very complex issue, and a consideration of the factors related to the growth of *C. botulinum* in such products does not easily lead to a definitive answer about their safety. Proponents of nitrite-free processed meats might point to the following factors as some assurance of botulinal safety:

1) The incidence of the causative organism, *C. botulinum*, is low and sporadic in meat products, usually regarded as on the order of 1 viable spore per 1-7 pounds of meat.
2) Even in the absence of nitrite, a formidable hurdle to botulinal growth through the synergistic interaction of factors such as a salt, acidity, water activity and heat treatment can exist in most processed meat products.
3) Botulinal growth is unlikely below 50°F, and the great majority of refrigerated storage conditions encountered by processed meats throughout distribution satisfy this requirement.
4) In inoculated tests with *C. botulinum* in nitrite-free meat products, two or more days of storage at moderate tem-

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Reciprocal Meat Conference Proceedings, Volume 33, 1980

peratures (70-80°F) are required for toxin formation. Under normal commercial conditions, toxin production might not occur for several days under abusive storage conditions.

5) Botulinal toxin production is usually accompanied by putrefaction or gas formation, warning consumers that the product is toxic.
6) Botulinal toxin is heat labile, and the pre-consumption heating of processed meats will help insure destruction of the toxin.
7) The good safety record of the limited production of nitrite-free products in the U.S. and Norway demonstrates that these products present no botulinal hazard.

On the other hand, those who question the safety of nitrite-free products can point to the following concerns:

1) Although the reported incidence of *C. botulinum* in meat products is low, the possibility of sporadic pockets of very high concentrations exists. Furthermore, there is reason to believe that as detection techniques improve and sample sizes increase, higher contamination levels will be observed.
2) Although other factors in the chemical and physical environment of meat products present hurdles to botulinal growth, the elimination of nitrite removes one of the most effective obstacles to the growth of this organism, and greatly reduces the assurance of botulinal safety in temperature abused products.
3) Meat is an excellent medium to support the growth of *C. botulinum*, and historical records point to meat products as the causative food in numerous botulism outbreaks. The great majority of these outbreaks resulted from home-processed meat products, many of which were produced without nitrite or nitrate, and without proper processing or storage controls. On the other hand commercial meat products manufactured with nitrite have enjoyed an excellent safety record.
4) Although wide-spread temperature abuse does not appear to exist in meat product storage and handling channels, surveys have shown that temperature conditions which can support botulinal growth (above 50°F) can be found at retail and in home refrigerators.
5) Temperature abuse of processed meats due to human error or carelessness, or equipment failures, is impossible to predict or avoid. A processor, although liable for product safety, loses control of its storage and handling conditions once it leaves his plant.
6) Although botulinal toxin production is usually accompanied by putrefaction or gas formation, occasionally toxin is produced in meat products with no obvious evidence of spoilage.
7) Heat can destroy botulinal toxin, but it is questionable if the mild heat treatment received by many products during manufacture or before consumption would be adequate. Heat inactivation of toxin is, of course, no help to processed meats which are not heated before consumption.
8) Commercially produced nitrite-free products have created no apparent safety problems in the U.S. and Norway. However, these products represent only a very small proportion of the total processed meats produced. Larger scale manufacture of nitrite-free products would increase the botulism risk.

The above points demonstrate the extreme difficulty in reaching a firm conclusion about the botulinal safety of nitrite-free processed meats. Almost every consideration can be interpreted in a number of ways. Because many of the factors which must be considered in making a decision are very uncertain, the determination of a clear-cut answer becomes almost impossible.

The relative dangers to human health from processed meats prepared with nitrite, and processed meats prepared without nitrite, represent two theoretical problems which are not easily solved. It is unlikely that consumption of nitrite (or nitrosamines) from cured meats can be directly linked with human cancer. Likewise, it can not be entirely assured that nitrite-free processed meats will not, at some point in time, under a given set of conditions, cause an outbreak of botulism. It would seem that the best opportunity for resolution of the questions surrounding the use (and non-use) of nitrite in meat products lies in continued research, with greatest emphasis directed at the following areas:

1) Defining the true human risk from the consumption of nitrite (and nitrosamines) found in cured meat products.
2) Finding suitable alternatives to the use of nitrite to assure the safety of nitrite-free products.
3) Establishing the botulinal risk associated with the commercial production of nitrite-free processed meats.

Organoleptic Acceptability of Nitrite-Free Processed Meats

Numerous research studies have demonstrated that nitrite has a definite effect on the flavor of cured meats. The exact mechanism by which nitrite modifies meat product flavor is not clearly understood. Nitrite also aids in preventing deterioration of meat product flavor by reducing oxidative changes in unsaturated fatty acids.

From the little information currently available, it appears that consumer preference for products made with or without nitrite is varied, and depends somewhat on the class of the product. In some tests, panelists have preferred the product containing nitrite. In other studies, tasters had equal preferences for the meat products prepared with or without nitrite.

There are no meaningful profiles that define cured meat flavor for any product, or the flavor notes provided by nitrite. Chemical and instrumental analysis of flavor composition have not provided information that would clarify the role of nitrite in flavor development. More research is needed on both the sensory response of the consumer and the chemical reactions involved when nitrite is used in curing meat products in order to evaluate the need for nitrite in the development of cured meat flavor.

The experiences of Norway indicate that consumers prefer the traditional pink color of nitrite-cured products, but they will accept gray nitrite-free products if that's all that is available.

Labeling of Nitrite-Free Meat Products

Because of the uncertainties surrounding the safety of nitrite-free meat products and their reported flavor differences, it is recommended that unique descriptive names be established for new products of this type to sufficiently differentiate them from traditional cured look-alike products. This would not necessarily have to apply to non-cured products where "common and usual" names and/or standards of identity already exist, (as in the case of some liver sausages). Nitrite-free products should likewise carry suitable precautionary labels recommending appropriate storage conditions. Further research should be conducted to better determine consumers handling practices with respect to processed meats, and the extent to which label warnings are perceived and heeded.

Introduction

For hundreds, and probably thousands of years, nitrate and nitrite have been added to cured meats, either as an intentional ingredient or as a naturally occurring contaminant (saltpeter - potassium nitrate) of the curing salts (Binkerd and Kolari, 1975). The beneficial effects of these compounds in cured meats have been long recognized. Meat products cured with nitrate and nitrite retain a pink, heat-stable color, have a distinct flavor (partly due to nitrite's ability to suppress oxidative rancidity) and are more resistant to deterioration by spoilage microorganisms. In particular, these agents, when added to meat products in the proper concentrations, have been shown to delay or suppress the growth of *Clostridium botulinum,* the microorganism which secretes the potent neurotoxin responsible for disease of botulism (Christiansen et al., 1973, 1974, 1975; Hustad et al., 1973). Nitrite is the active ingredient responsible for these effects. Nitrate, when used, merely serves as a reservoir of substrate which can be converted to nitrite by biological systems.

During the decade of the 1970's, the continued addition of nitrite to processed meat products has been seriously questioned. This concern was initiated by the finding that carcinogenic nitrosamines were consistently produced during the frying of bacon through the reaction of added nitrite with secondary amines (Fazio et al., 1973). The attacks were intensified in 1978 with the release of the Newberne Report (MIT) which suggested that nitrite itself might be a cause of lymphatic tumors in laboratory rats (Newberne, 1979). Although the validity of both of these nitrite-related concerns is far from clear at this time, they have prompted some government regulators and consumers to call for the production of nitrite-free meat products. This would give consumers concerned about nitrite consumption an alternative choice at the retail meat case. (Note: The following is an exerpt from a statement issued jointly on August 19, 1980, by Dr. Jere E. Goyan, Commissioner of the FDA, and Carol Tucker Foreman, Assistant Secretary for Food and Consumer Services of the USDA: "A group of independent pathologists has completed an extensive review of the study conducted at the Massachusetts Institute of Technology (MIT) that led us in 1978 to consider the need to phase out nitrite as a preservative in cured meats and poultry. . . . A committee of scientists from several government agencies has evaluated the pathologists' review and has concluded that insufficient evidence exists to support a conclusion that nitrite induced cancer in the rats, based upon the MIT study."

Because of nitrite's prominent role in maintaining the safety and sensory properties of cured meats, a shift toward a greater production of nitrite-free processed meats should not be undertaken without a thorough assessment of the possible consequences. The purpose of this committee has been to review information which relates to and reflects on cured meats manufactured without nitrite. This report does not attempt to give definitive answers to the questions of absolute safety and consumer acceptability of nitrite-free processed meats, but it does raise some issues which need to be considered.

The major areas reviewed in this report are:

a) safety aspects of nitrite-free processed meats
b) sensory properties and acceptability of nitrite-free processed meats
c) labeling of nitrite-free processed meats

Safety Aspects of Nitrite-Free Processed Meats

Although cured meats can serve as a vehicle for a number of microbiological food-borne hazards, the threat of most serious consequence appears to be from the often fatal disease of botulism. Commercial cured meats in the United States have enjoyed an exceptional safety record with regard to this dreaded disease (Lechowich, 1978; Sofos and Busta, 1980). This record is believed to be the result of the synergistic interaction of factors such as nitrite, salt, pH, heat and water activity (A_w) within the meat product (Leistner et al., in press) combined with a reasonably good national refrigeration system and normally low levels of contamination of this organism within the meat product.

Nitrite is regarded as a key element in the defense against the growth of *C. botulinum* in cured meats. Although nitrite is not an absolute or perfect inhibitor of this organism under all sets of conditions, its effectiveness in suppressing and delaying botulinal growth in temperature abused meat products has been well established (Christiansen et al., 1973, 1974, 1975; Hustad et al., 1973).

Although the safety-related consequences of widespread removal of nitrite from cured meats is not definitely known, some information is available about botulism and its causative organism, as well as the properties and handling conditions of meat products. A consideration of these factors may be useful in assessing the safety of nitrite-free products.

Incidence of Clostridium Botulinum in Meat

Soil is the primary reservoir of *C. botulinum.* Therefore, all foods coming in contact with soil or airborne dust carry the potential for contamination with this organism. *Clostridium botulinum* thrives in rich organic media, including meat and other animal tissues (Riemann, 1973).

Only a relatively small amount of research has been directed at determining the extent of contamination of *C. botulinum* in meat products. Lechowich et al. (1978) and Tompkin (1980) have reviewed the studies conducted in this area. Findings were erratic and ranged from a high of 36 positives in 397 bacon samples tested in the United Kingdom

(Robert and Smart, 1976), to a low of 0 positives out of 1,279 raw pork and beef samples from the U.S. and Canada (Greenberg et al., 1966). In summarizing the results from these studies, it is often reported that the incidence of *C. botulinum* in meat and meat products is on the order of one viable cell per 1 to 7 pounds of product (CAST, 1978).

The limited number of studies reported in the literature suggest that *C. botulinum* is a very infrequent contaminant of meat. This may truly be the case, but several additional points should be considered. Most of the surveys used sample sizes of less than 50 grams. Thus, although some of the studies reported large numbers of samples tested, the total amount of product tested may have been quite small. For example, in one phase of the work of Greenberg et al. (1966), the 1,279 raw pork and beef samples tested represented less than 9 pounds (4 Kg) of total product. As methodology improves and as analytical sample size increases, it is likely that an increase in the incidence of *C. botulinum* will be found in meat (Lechowich et al., 1978). This is supported by the fact that the incidence of this organism in meat products increases with the chronological order of the investigations, reflecting improvements in methodology (Roberts and Smart, 1976).

Estimates such as 1 cell per 1 pound of product infer that this organism would be uniformly distributed throughout the meat. However, meat is notorious for its lack of uniformity. If we accept the estimate of 1 cell per 1 pound of product, then it seems reasonable to assume that in some instances, we may find 99 pounds of product containing no cells, and 1 pound containing 100 cells. The possibility of localized high concentrations or colonies of *C. botulinum* deserves consideration. Botulinal levels in the tens of thousands have been found in mushrooms and soil samples, suggesting that great variation may also occur in meat. An example of this variation was the unexpectedly high incidence of *C. botulinum* in the abused non-inoculated bacon from 1 of the 4 plants in the recent USDA study on sorbate (USDA, 1979a). The low incidence of *C. botulinum* in meat may justifiably be viewed in a similar vein to the occurrence of *Trichinella spiralis* in pork. A 1976 study reported only one finding of trichina among 513 sow diaphrams examined (Pullen et al., 1976). However, even with an expected infection rate of only 2 pigs per 1000, all pork must be handled as if it were infected, to insure safety when the rare, true trichina-carrying pig comes along. Similarly, it may be prudent to consider all cured meats to be contaminated with viable botulinal cells, to protect against those infrequent packages which actually are carrying this organism.

Conditions for Growth of Clostridium Botulinum

It was mentioned earlier that meat is an excellent medium to support the growth of *C. botulinum*. However, this growth will not occur if environmental conditions within the meat product are restrictive to this organism. What conditions then are necessary to guarantee complete inhibition of botulinal growth?

Clostridium botulinum is a strict anaerobe and oxygen is strongly toxic to it (Riemann, 1973). Vacuum packaged products would, therefore, seem to present a most favorable environment for botulinal growth. However, even exposure of the product to air does not guarantee suppression of growth and toxin production. Oxidation-reduction potentials sufficiently low to permit the growth of *C. botulinum* can exist in food masses exposed to air (Kautter, 1964). Christiansen and Foster (1965) found no difference in the rate of botulinal toxin production between inoculated sliced bologna samples packaged in plastic film wrap with or without a vacuum.

A number of environmental factors are capable of suppressing botulinal growth and toxin production in meat products. Riemann (1973) pointed out that salt (sodium chloride) addition corresponding to a brine concentration of 10% is inhibitory to all types of *C. botulinum*. Pivnick et al. (1969), working with heat pasteurized canned luncheon meats found a brine concentration of 6.1% in these products to be adequate to suppress botulinal growth in the absence of nitrite. The 6.1% brine concentration was achieved through the addition of 3.5 to 4.0% salt to these products. Likewise, a reduction in water activity (A_w) below .93 through dehydration or large additions of salt and sugar assure control of botulinal growth (Ohye and Christian, 1967; Marshall et al., 1971; Riemann, 1973). Acidic conditions of pH 4.5 (Riemann, 1973) or pH 4.6 (Ohye and Christian, 1967) are also inhibitory to this organism.

The spores of *C. botulinum* are not easily destroyed by heat. The relatively mild heat treatments which most processed meats receive (130-170°F) are not adequate to kill these spores (CAST, 1978). Such temperatures may kill the vegetative forms of *C. botulinum*. A theoretical process necessary to render a 1.5 pound nitrite-free canned ham commercially sterile would require 205 minutes of heating at 230°F (Lechowich et al., 1978).

Proper refrigeration is an effective means of stopping botulinal growth and toxin formation. Types A and B *C. botulinum* are the usual contaminants of meat products, and these strains will not grow below 50°F (10°C) (Ohye and Scott, 1953). Although type E *C. botulinum* and a non-proteolytic type B strain have been shown to grow and produce toxin at temperatures as low as 38°F (3.3°C) (Schmidt et al., 1961; Eklund et al., 1967), these types have not been considered of significance in meat products in the U.S.

The above discussion points out that in the absence of temperature control and nitrite, only limited numbers of processed meat products have any one factor which would insure control of *C. botulinum*. Products which are heavily salted, dried, pickled, highly fermented or severely heat treated could be regarded as absolutely safe from botulinal growth if temperature abused. However, products with these sorts of extreme characteristics make up only a small part of total cured meat production.

In reality, meat products which do not fully achieve any of the above individual requirements for botulinal control may not be quite as vulnerable as they might appear. The synergistic interaction of microbial inhibitors such as salt, acid, A_w and heat will provide some degree of inhibition (Leistner et al., in press). Because of the diverse nature of the many types of processed meats produced, different products may represent varying degrees of botulinal hazard. High-moisture, mildly salted, non-acidic products are more susceptible to outgrowth of spores than the intermediate or low moisture, heavily salted, fermented products. Unfortunately, a thorough understanding of the synergism among inhibitors has not yet been achieved.

Botulism Outbreaks Attributed to Meat Products

The excellent review prepared by Tompkin (1980) of botulism outbreaks attributed to meat and poultry demonstrates that such products are capable of serving as a vehicle for botulism. Of the 66 outbreaks (71 deaths) reported in the United States and Canada since 1899, 51 outbreaks (55 deaths) were caused by home processed products. It is not known how many of the implicated meat products contained nitrite. Homemade meat products would seem to be inherently at greater risk since many are not cured with nitrite or nitrate. Those which are cured have almost exclusively been done so with nitrate, which reduces control over the nitrite content of the products. Seven of the 15 commercially manufactured products causing botulism outbreaks were products which normally are cured with nitrite. Although nitrite is an effective inhibitor of *C. botulinum*, its effect can be overridden under a variety of conditions of product abuse.

Tompkin's survey also calls attention to 1,154 botulism outbreaks attributed to meat and poultry which were reported outside the United States and Canada since 1793. Certain European countries have experienced much higher incidences of meat and poultry related outbreaks than the U.S. In France and Poland, meat products are the major source of botulism outbreaks. Part of the explanation for this is the fact that people in these countries carry out more home curing and home canning of meats. Refrigeration and freezer storage is also less readily available in some of these areas. Although European countries have a far greater incidence of botulism outbreaks and cases than the U.S., their fatality rate is much lower. This discrepancy may be due to a predominance of outbreaks caused by a less toxic strain in Europe, or it may be a reflection of the major differences in the types of meat products causing botulism in the two regions.

This historical information clearly points out that meat and poultry products manufactured and stored without the proper controls can represent a significant botulism hazard.

Temperatures Encountered by Meat Products During Distribution and Storage

As mentioned above, even though most processed meat products do not have environmental characteristics which on their own would guarantee inhibition of *C. botulinum*, adequate refrigeration would hold this organism in check. In considering the safety of nitrite-free products, it becomes important to know the temperatures encountered by meat products from the time they are produced until they are consumed. It can probably be safely assumed that processed meats will remain under fairly good temperature control from time of their manufacture until they leave the processing plant or distribution center. Up to that point, these products are under the control of meat industry personnel who have the expertise for and a vested interest in maintaining the products in excellent condition. Beyond that point, however, control of the product is turned over to people often less skilled in the proper handling of processed meats, and whose close attention to this task is diluted by a responsibility to manage a wide range of food products. Therefore, temperature encountered at the retail sales outlet and in the home refrigerator are of particular interest.

During the months of August and September of 1979, various members of the American Meat Science Association participated in a survey to help establish some definitive data on temperatures to which processed meat products are exposed in retail stores across America. This study was coordinated by Dr. Robert Rogers (Rogers and Althen, 1980). A total of 120 stores were surveyed in this study. The stores surveyed were located in 13 states, of which seven could be classified as cooler northern states, and six warmer southern states.

Of the total of 120 stores, 57 were chain supermarkets, 30 were independent supermarkets, 7 were "Mom and Pop" type stores, 24 were quick-stop markets and 2 were locker plants. No attempt has been made to summarize the data in this report according to store type.

Only 22 (18%) of the 120 stores had nitrite-free processed meats (i.e., bacon, franks, bratwurst, etc.) for sale. Eighteen of the stores that had these type of products for sale had them displayed in vacuum packages. However, 7 of the stores that had these types of products kept them frozen.

The data concerning case, shelf and pegboard temperatures as measured by the scientists are presented in Table 1. It should be noted that these values represent the thermometer reading when it was resting on the top package in each of these various types of display cases. This should represent the maximum temperature of product in each display case evaluated in this study. The major purpose of this study was to determine the frequency that processed meat products are held above 40°F, since this was the maximum temperature recommended by the USDA for storing nitrite-free products

Table 1. Air Temperature Adjacent to Top Package

	Case type		
Item	*Chest*	*Shelf*	*Pegboard*
N	107	110	86
Range, °F	25-68	24-60	28-63
Mean, °F	40	40	41
S. deviation, °F	8	8	8
Coef. of variation, %	21	21	19
% temps over 40°F	36	37	38

Table 2. Case Thermometer Readings

Item	*Case type*		
	Chest	*Shelf*	*Pegboard*
N	88	78	59
Range, °F	1-48	20-60	20-58
Mean, °F	31	33	33
S. deviation, °F	7	7	6
Coef. of variation, %	24	21	19
% temps over 40°F	7	5	5

which carry conventional cured meat names such as bacon, franks, etc. (USDA, 1979b).

Due to the fact that over 35% of all display case temperatures recorded exceeded the 40°F minimum, and all case temperatures ranged from 24 to 68°F, it appears as if it would be potentially hazardous to merchandise these types of products without some very stringent temperature controls being imposed and enforced. It should also be noted that the federal government has no regulatory authority over retail stores, except in the District of Columbia. Most states have regulations concerning food handling and storage temperatures at the retail level, but these data indicate they are not being uniformly enforced in all cases.

The data in Tables 1 and 2 reveal that of the 107 chest cases checked, only 88 had a monitoring thermometer present. Likewise, monitoring thermometers were only found in 78 of 110 shelf-type cases and 59 of 86 pegboard cases.

Another important point to consider about display case thermometer values as compared to air temperature values is that they averaged about 8 or 9°F lower than air temperature on the surface of the top package of each case. The rather large standard deviations and wide range of temperatures again point out the potential problems associated with shelf life of all products as well as for the nitrite-free products previously discussed. It should also be noted that most meat case thermometers are located directly in front of the cold air outlet and don't really measure the true temperature of the area where most of the meat is actually displayed.

The holding cooler temperature data are summarized in Table 3. These values are similar to those presented in Table 2 for case temperatures and also indicate a potentially hazardous situation if nitrite-free products are stored for long periods of time under some of these conditions.

Table 3. Holding Cooler Temperatures

Item	*Value*
N	106
Range, °F	20-58
Mean, °F	35
S. deviation, °F	5
Coef. of variation, %	14
% temps over 40°F	6

All of the temperature data recorded were considered, disregarding location in store, and the highest recorded value for each store was summarized according to a range of temperatures. This summary is presented in Table 4. Only 47.5% of the stores surveyed had all product below 40°F, 35.8% had some product over 45°F and 20% of the stores had product stored at temperatures greater than 50°F.

Table 4. Distribution of Highest Temperatures Recorded for each Store

Temp range, °F	>40	41-45	46-50	51-55	55
% in range	47.5	16.7	15.8	10.0	10.0

Although the data were not separated by state or region of the U.S., more of the higher temperatures were from the southern states (Texas, New Mexico, Mississippi, Alabama, Arkansas and Kentucky). However, every state represented had temperatures above 40°F and some of the highest values were from the northern states.

Only 24% of the meat market managers said that they return a product that exceeds 40°F when it is delivered to their store. The seriousness of high product temperatures (over 40°F) during delivery is indicated by the small number of managers returning product that exceeds this limit. Probably even more serious is the fact that 76% (91 of 120) of the managers did not determine product temperature or think that it was an important factor to consider.

The survey of meat market managers revealed that 41.7% (50 of 120) of them did think that processed meat shelf life was significantly shorter in the summertime as compared to the other seasons of the year. This suggests that there may be some significant temperature control problems in the distribution and sale of processed meat products in the United States. Several market managers also mentioned the fact that the current requirement of keeping store temperatures at 78°F has reduced their ability to keep meat case temperatures as low as they desire.

Fifty-five percent of the stores had processed meats offered for sale that were beyond the expiration date. The range of days past expiration was from 1 to 132. The average value was 20 days, but the coefficient of variation was 139%. It was also noted that several market managers reduced the price for expired merchandise. Others noted that it appeared to be a regular practice to cover with a price sticker the expiration date on outdated merchandise.

Six stores, 5%, had product that required refrigeration displayed at room temperature. Most of these items were canned hams. This has already been a source of confusion with the rather commonplace sterile canned ham products that require no refrigeration being readily available. In some cases, similar products (i.e., canned hams requiring refrigeration) were side by side at room temperature.

The data obtained in this survey complements the data presented in a USDA survey of home refrigerators (USDA, 1977). This report stated that of 2,503 householders surveyed in 1974, 32% of the homemakers kept their household refrigerators at or above 45°F, temperatures not cool enough to significantly retard bacterial growth.

Time Requirements for Production of Botulinal Toxin

Although the cured meat storage temperatures reported above do not indicate widespread temperature abuse, a significant number of storage conditions were found which would support the slow growth of *C. botulinum*. This fact, coupled with the documented occasional long storage periods found at retail (as indicated by code dates) and potential additional long storage in high temperature home refrigerators, suggests that some product may attain the appropriate time-temperature conditions necessary for toxin formation by *C. botulinum* if this organism is present in sufficiently high numbers. However, even more dangerous than the products held for long periods of time at low botulinal growth temperatures are those products which accidentally receive shorter periods of moderate temperature abuse (60-80°F). This may occur sporadically and unpredictably due to human error, equipment failure, or during recreational trips or picnics.

At such elevated temperatures, how much time would be required for outgrowth and toxin formation by *C. botulinum* in nitrite-free meat products? The answer to this question is not precisely predictable because of the inherent biological variation in the organism and the fact that it's growing in a wide range of meat products presenting many different physical and chemical environments. However, examination of some inoculated pack studies sheds some light on this question. Table 5 summarizes a number of studies in which meat products inoculated with *C. botulinum* were exposed to moderate holding temperatures. A great deal of variation exists in the storage times required to bring about toxin production. From the evidence presented, it appears that nitrite-free meat products which are suitably contaminated with *C. botulinum* and exposed to moderate temperatures might be expected to become toxic after 2-14 days of moderate temperature abuse. Some of the studies reported were limited by infrequent sampling periods which may have caused overestimation of the time required for toxin production.

Several studies have included high temperature incubation of nitrite-free products which were not intentionally inoculated with *C. botulinum*. Sofos et al. (1980) reported no toxin production in 60 samples of nitrite-free bacon held 60 days at 27°C. Hustad et al. (1973), detected no toxin production in nitrite-free wiener samples held for 56 days at 27°C. A very recent Canadian study (Hauschild and Hilsheimer, 1980) cultured four 75 gram samples from each of 104 packages of commercial bacon for botulinal spores and vegetative cells. After seven days of incubation at 35°C, only one of the 416 total samples exhibited toxin production. Thus, one out of 104 consumer packages of bacon contained *C. botulinum*, for

Table 5. Toxin Production by *Clostridium botulinum* in Inoculated Nitrite-Free Meat Products Stored at High Temperatures

Product	*Spores/gm Inoculation*	*Storage Temperature, °C*	*Days to Produce Toxin**	*Source*
Canned comminuted ham	90	27°	7	Christiansen et al., 1973
Frankfurters	620	27°	14	Hustad et al., 1973
Cooked, sliced ham (2.1% salt)	10,000	30°	2	Pivnick and Barnett, 1967
"	"	25°	5	"
"	"	20°	10	"
Summer Style Sausage				
–high acid	~500	27°	56	Christiansen et al., 1975
–low acid	~500	27°	14	"
Bacon	52	27°	7	Christiansen et al., 1974
"	1,000	27°	4	USDA, 1979a

*or visible signs of botulinal spoilage.

an incidence of close to 1%. Their MPN estimate of *C. botulinum* in the 104 packages of bacon was 0.064 spores per Kg.

Evidence of Spoilage Accompany Botulinal Toxin Production

Growth and toxin production by *C. botulinum* are frequently accompanied by putrefaction, gas formation and other visible indicators of spoilage. Does such evidence of spoilage always coincide with toxin formation, and would it be adequate to dissuade consumers from eating a toxic product? The apparent answer to this question is no.

Although some studies have reported a close association between toxin production and visible product spoilage (Christiansen et al., 1973, 1974, 1975), others have reported the presence of toxin with no or very little hint of spoilage. Pivnick and Barnett (1967) found inoculated, temperature-abused bologna samples (6 days at 30°C—all toxic) to be often acceptable if stored in air-impermeable packaging, but were almost totally rejected if stored in air-permeable packaging. In an evaluation of toxic samples in air-impermeable packaging by an expert meat industry panel, 24 of 30 samples were scored acceptable for appearance and 13 of 30 were regarded as acceptable in odor. Results of the four plant bacon study (USDA, 1979a) indicated a lack of or low gas production from many toxic samples. Similar observations were also made by Sofos et al., (1980) on toxic bacon samples. Lechowich (1979) reported that he found toxin could be present as much as two days before gas production was observed. These findings indicate that visible spoilage will not always be sufficient to warn consumers of the presence of *C. botulinum* toxin in meat products.

Heat Inactivation of Botulinal Toxin

Botulinal toxin can be effectively inactivated by adequate heat treatment. Is the usual cooking of meat products a viable method of protecting consumers from toxic samples which evidence little or no signs of spoilage? This question is complicated by a number of factors. Different strains of *C. botulinum* produce toxin of varying thermal stability (Bradshaw et al., 1979). The pH and type of substrate in which the toxin is found also influence its destruction by heat. Bradshaw et al. (1979) confirmed that botulinal toxins are more thermostable at lower pH values (pH 5.0), and are significantly more resistant to heat destruction in beef and mushroom patties than in a phosphate buffer system of the same pH. Thermal inactivation of the toxins follows a two phase pattern in which the majority of toxin is initially rapidly inactivacted, followed by a period of slower inactivation of the remaining toxin (Woodford et al., 1978 and Woodburn et al., 1979). Toxicity of Type A botulinal toxin has been shown to be unaffected by up to 180 days of frozen storage (Woodford et al., 1978).

Differences in toxin concentration and type, as well as chemical differences in products, make it difficult to recommend any one heat treatment which would be satisfactory for a wide range of foods. A general rule in the past has been to boil the food for 10 minutes. Woodburn et al. (1979) suggested as a guide 20 minutes at an internal temperature of 79°C, or 5 minutes at 85°C. Similarly, Bradshaw et al. (1979) suggested 54 minutes at 71°C, or 3 minutes at 77°C. These general schedules were offered as being satisfactory to inactivate a wide range of toxin types occurring in a variety of food products, and undoubtedly include a substantial margin of safety.

The recommended conditions seem quite severe for most processed meats, many of which have already been precooked and require only a mild reheating before serving. Products heated in a microwave oven often exhibit "hot" and "cold" spots, and this could affect toxin inactivation. There is also the possibility that pre-formed toxin could be transferred by the food handler from the affected product to other foods which are consumed without heating. In addition, a wide range of meat products (such as luncheon meats) are usually not heated before consumption. Although heat inactivation of botulinal toxin may play a role in assuring the safety of some nitrite-free processed meats which have been temperature abused, it would not provide an over-riding safety factor in the case of all nitrite-free products.

Current Production of Nitrite-Free Processed Meats

In considering the safety of processed meats manufactured without nitrite, it is of interest to evaluate the experiences of commercial meat processors who have already marketed nitrite-free products. Such circumstances exist in Norway and among certain meat processors within the United States.

Nitrite-Free Processed Meats in Norway. During the 1970's Norway initiated a course of action to eliminate the use of nitrate and reduce the use of nitrite in meat products (Braathen, 1979; Hoyem, 1976). In 1974, the use of nitrite was restricted according to class of product. Its addition was discontinued in dinner sausages such as frankfurters, knackwurst and Vienna sausage. It was also banned from heavily salted meat products which were cooked before eating, and fully preserved meat products. Nitrite may be added to slicing sausages, bacon and some hams, but at reduced levels (60 ppm) for development of cured flavor and color. In certain special and fermented products which would be eaten raw, as well as canned meats, nitrite was to be added for preservative purposes (200 ppm). The use of nitrate in meat products was totally banned in 1975.

Norway's regulations removing nitrite from some types of meat products were not met without resistance from its meat industry, particularly smaller sized processors. Numerous ways were developed to produce pink or reddish coloration in products (at least on their surface) without direct addition of nitrite. These included heating nitrite-containing and nitrite-free products in the same chamber, soaking sausage casings in nitrite brine, combining nitrite salts with the sawdust used for smoking, and other procedures. In addition, normal environmental sources of nitrate were often sufficient to produce a mild cured color. These incidental methods of achieving the cured color created a regulatory dilemma. This problem was somewhat resolved by establishing 5 ppm residual nitrite as the limit allowable for environmental contamination of products which are to contain no nitrite. In reality, many of Norway's no-nitrite products might better be characterized as low-nitrite.

The introduction of gray-colored, nitrite-free products into the market place initially resulted in a decline in consumption of the affected types of products. However, with time, consumption levels returned to normal. Given the choice, consumers prefer the red-colored sausages. Companies actively promoting the idea of gray, nitrite-free products found their efforts unsuccessful when red-colored products were also available. However, when only the gray products were available, consumers would purchase them.

During the past several years in which nitrite-free and low-nitrite meat products have been produced in Norway, there have been no reports of botulism outbreaks caused by them. It has not been reported if shelf life is shortened in products in which nitrite has been reduced or eliminated, but adequate shelf stability has not been reported to be a problem. There have been some reports of reduced flavor in the nitrite-free products (Braathen, 1979).

From the information available to date, it appears that nitrite-free or reduced-nitrite products have not created any safety or shelf-life problems in Norway. This country has a generally colder climate than the U.S. and being smaller in size, has a shorter and less complex distribution system. These factors would lessen problems of instability with their products. Hoyem (1978) estimated that 20% of all Norwegian cured meats were now sold in the frozen state. This is not entirely the result of the reduced use of nitrite, but it rather represents a long-term trend toward greater use of frozen meat in that country. It may also be significant that the sausages in which nitrite has been eliminated are dinner sausages which are usually cooked prior to consumption. Adequate cooking could help inactivate the heat-labile botulinal toxin and represents another defense against botulism. Bear in mind that the production of low-nitrite and nitrite-free products in Norway represents a relatively small scale and short term experience (about 5 years), and complete toxicological assessment of this change must await the further test of time. No other European countries are considering restricting the use of nitrite at this time. However, many countries are closely watching the actions of the U.S. regulatory agencies in their handling of the nitrite question.

Nitrite-Free Processed Meats in the United States. Although the great majority of salted meat products in the U.S. are produced with added nitrite, there is none-the-less a substantial production of processed meats which contain no nitrite or nitrate. For the purpose of this discussion, these nitrite-free products will be separated into the following three categories:

1) Fresh sausages
2) Traditional cooked sausages prepared without nitrite
3) Nitrite-free products arising out of the nitrite controversy

Fresh sausage has been estimated to make up approximately 20% of our total sausage production (Terrell, 1979). These sausages are uncooked and contain no added nitrite. The primary sausages in this category are fresh pork sausage, fresh Italian sausage and fresh bratwurst. There seems to be much less concern about the safety of fresh sausages than the safety of nitrite-free, pre-cooked products. Most consumers realize the greater perishability of fresh sausages and treat them accordingly. Some fresh products are marketed and stored in the frozen state. Since fresh sausages are not heated during processing, they still contain the full complement of contaminating bacteria, and should readily demonstrate obvious spoilage if temperature abused (Lechowich, 1979). The requirements to cook them thoroughly before eating presents an added measure of protection against botulinal toxin.

The second category listed represents nitrite-free cooked meat products which have a rather long history of existence. This group would include such products as pre-cooked bratwurst and pre-cooked pork sausage, white hots, some liver sausages, etc. Products of this type make up a very small portion of the total manufactured meat production in the United States. Although these nitrite-free products would seem to be at some risk from botulism if temperature abused, no apparent problem is evident.

One type of pre-cooked nitrite-free product which deserves further mention is the "white hot," which is indigenous to certain areas of New York State. This product is basically a non-smoked, nitrite-free hot dog which is marketed in the same manner as traditional hot dogs containing nitrite. Production of white hots is believed to date back more than 100 years. In areas of high popularity, one white hot is supposedly consumed for every 5 cured hot dogs which are eaten. Shelf life is adequate for the usual sales period.

At least 13 federally inspected commercial producers of dry-cured or country hams use no nitrate or nitrite in their products (Kemp, 1979). Most of these are relatively small producers. Their product should be stable against botulinal growth due to its high salt and low moisture content.

The final category of nitrite-free meat products refers to those which have entered the market primarily as a response to those consumers who want to avoid the consumption of nitrite. These products are usually imitations of existing cured productions, and are frequently marketed in the frozen state. Despite all the negative publicity which nitrite has received over the last ten years, production of these nitrite-free products still appears to be very limited. The proposed USDA regulation permitting nitrite-free products to be labeled with traditional cured meat names (USDA, 1979b) may have led to increased production of these types of products. However, that labeling proposal was blocked by court action. Future growth of these nitrite-free products probably is dependent on future research findings regarding the safety of nitrite.

A 1979 interview with a Wisconsin processor who markets several recently introduced nitrite-free products (summer sausage, beef wieners, smoked brats, Polish sausage) provides some insight into this situation. This processor initiated production of nitrite-free products in response to an apparent demand from questioning customers. He has found the demand to be less than he anticipated (even though he has advertised), and nitrite-free products currently make up a very small part of his total production. He describes the nitrite-free products as "totally different" from the traditional cured products. The color is gray and the flavor is much more bland than the same formulations containing nitrite. All nitrite-free products are marketed vacuum packaged in the frozen state, and limited freezer storage has not appeared to affect flavor. No shelf-life tests have been conducted on his nitrite-free products stored in the non-frozen state.

In conclusion, some nitrite-free products are currently commercially produced in the U.S. Although most of these represent fresh sausages, some are precooked products which are believed to be at greater risk to botulinal growth if seriously temperature abused. However, no obvious safety problem has resulted from these products to date. Pre-cooked nitrite-free processed meats truly represent only a small fraction of total manufactured meat products produced in the United States, and it is uncertain if this botulinal safety record could be maintained if a much larger proportion of U.S. meat products were produced without nitrite.

Alternatives to The Use of Nitrite in Processed Meats

If future research and/or regulatory action mandates the elimination of nitrites from processed meats, what courses of action might be available to the meat industry? One extreme option might be to avoid producing potential high risk products such as pre-cooked sausages and semi-perishable canned meats. However, the large volume of meat sold in these forms and their high demand by consumers does not make this a very attractive alternative.

Another option might be to simply remove nitrite from the formulations and continue to produce current products in nitrite-free form. By following this route, a processor would be placing his confidence in the safety record achieved by already existing nitrite-free products in Norway and the United States. It would be assumed that the apparent infrequent occurrence of *C. botulinum* in meat products along with the physical and chemical microbiological barriers already built into such product would delay the development of botulinal toxin in the occasionally temperature abused product.

A third alternative might be to assure the safety of nitrite-free products by modifying processing or handling conditions. This might involve increasing the use of salt, acid, heat or dehydration to insure the stability of these products. They could be marketed frozen or labeled with strong warnings calling consumer's attention to their strict refrigeration requirements. This course of action presents several problems. One is that there are limitations to how much a product's physical or chemical nature can be altered without entirely changing its identity or making it much less acceptable to consumers. For example, high salt levels are objectionable to many people, and are criticized by some health authorities. Another problem stems from the fact that many of the modifications in processing or handling are energy intensive, such as increased heating or greater use of freezing.

A fourth alternative in the production of meat products without nitrite is to continue to search for a satisfactory alternative. However, since nitrite performs three important functions in meat products (bacteriostasis, color fixation and flavor formation and protection), it is not an easy compound to replace. It has been reported that more than 700 compounds have been tested for their suitability in meat curing, with little success (CAST, 1978). One additive studied to date has been potassium sorbate, which when used at levels of about .26% in meat products has demonstrated anti-botulinal activity approaching or equal to nitrite. The effect of sorbate in inhibiting *C. botulinum* in a variety of meat products has been reviewed by Sofos and Busta (1980). Although this additive can increase the safety of nitrite-free meat products, it does not impart cured meat color and flavor. A compromise in the use of nitrite which has received strong consideration is the addition of sorbate (.26%) and low levels of nitrite (40 ppm). This would bring about a three to four fold decrease in the use of nitrite, while retaining the color, flavor and antibotulinal characteristics of the products. Although research on the use of sorbates in processed meats has been promising, its future use has been clouded by the report that throat and skin irritations were experienced by 8 individuals involved in taste panel evaluation of bacon containing sorbate (USDA, 1979a). It is not clearly known if sorbate was involved in these reactions.

Effect of Removing Nitrite on Product Flavor and Acceptability

One of the technological functions attributed to nitrite is the development of the desirable, characteristic flavor of the cured meat product. It is widely assumed, and often stated, that in the absence of nitrite the products taste like salt pork. Published studies, however, on the sensory effects of nitrite in the curing process are not extensive and chemical analysis has shed little light on the problem. Recent developments showing that nitrite reacts with secondary amines in meat to produce potentially carcinogenic nitrosamines in bacon during frying and that nitrite itself may induce mutagenic changes, has resulted in a situation in which the use of nitrite may be either banned or phased out over the next several years. Serious consideration, therefore, must be given to the role of nitrite in the preference of the consumer for cured meat products.

Studies on Bacon

Brooks et al., (1940) concluded that the characteristic flavor of bacon is due to the reaction of nitrite with the meat constituents during curing or cooking, although no sensory evaluation data were given. They claimed that 10 ppm nitrite was sufficient to give satisfactory flavor in the process they used. Mottram and Rhodes (1973), also using Wiltshire cured bacon in which the entire side is pumped and then immersed in cured solution for 5-6 days, found that increasing nitrite content from 0-2000 ppm led to increasing bacon flavor and a corresponding decrease in porky flavor. Maximum bacon flavor was obtained at 1000 ppm. However, the data show that even without nitrite the bacon was scored 2.54 for bacon flavor on a scale of 0 to 10. Maximum flavor intensity was 4.74 with 2000 ppm nitrite. There was a wide divergence in the ability of the panelists to distinguish between pork and bacon flavor and 30% could not correctly identify the odd sample in a triangle test. Preferences of the panelists for the bacon samples made with 0 to 2000 ppm nitrite were not determined.

Pork bellies, pumped with cures containing 0 or 156 ppm nitrite and 0 or 1.6% NaCl (Kimoto et al., 1976a) were cured and the flavor compared with that of a commercial bacon. Panelist indicated the bacon made with both NaCl and nitrite had just a little more bacon flavor than that made with NaCl alone. The flavor of the bacon made without nitrite, however, was judged to be similar to the commercial product. Bellies cured with nitrite alone had very little bacon flavor. Similar results were obtained when panelists rated bacon flavor based on memory only—products made with and without nitrite tasted essentially the same.

A related study (Kimoto et al., 1976b) demonstrated that the lean meat of bacon has a hammy flavor and the characteristic bacon flavor is developed in the adipose tissue on frying.

An anonymous report (1975a) detailed a study of vacuum and non-vacuum packaged bacon made with increasing concentrations of nitrite. On an acceptance scale of 1 (dislike extremely) to 8 (like extremely) non-vacuum packages of bacon made without nitrite were rated 4.47 while those cured with 170 ppm nitrite scored 5.47. Vacuum packed bacon without nitrite scored 5.13 and 170 ppm nitrite bacon scored 5.82. The panel stated there was no cured meat taste at 0 time and an oxidized pork flavor after 7 day storage of bacon made without nitrite.

In another anonymous study (1975b) bacon made with and without nitrite was subjected to triangle tests for flavor and preference. The panel could significantly detect differences between the two preparations. Descriptive remarks indicated the bacon with nitrite was saltier and smokier than that made without nitrite. The difference in flavor was only slight to moderate and the panelists did not express a statistically significant preference for either bacon.

A consumer study of the preferences of 704 people for bacon made with and without nitrite has been reported (Wasserman et al., 1977). On a 9 point Hedonic scale both preparations were liked equally well (6.0 vs 6.1) and factors such as sex, age and frequency of bacon consumption played no significant role. The bacons were evaluated 15 days after processing.

Another study on consumer preference for bacon made with and without nitrite utilized plate waste evaluation in a student dining hall (Williams and Greene, 1979). The presence or absence of nitrite was not a determinant of the quantity of bacon consumed by these institutional food service facility patrons; 13.7 and 13.4% waste was found for bacon processed with and without nitrite respectively.

Irradiation is being recommended as a procedure for eliminating, or reducing, nitrite in bacon without the problem of *Clostridium botulinum* outgrowth (Wierbicki, 1979). Sensory evaluation of bacon made without nitrite indicate high acceptance by consumer panels. The product, however, had a slightly different flavor, as judged by experts. Pre-fried irradiated bacon, without nitrite, was scored as high for flavor as pre-fried bacon with 40 ppm nitrite.

Studies on Ham

A number of studies have investigated the effect of nitrite on ham flavor from both sensory evaluation and chemical composition aspects. Lane (1973) found no differences in cured meat flavor between hams cured with and without nitrite immediately following short-term curing and baking, however following storage at 4°C for 7 days the nitrite-treated hams had a better cured meat flavor. Hams were cured for 3 days with and without nitrite and evaluated for flavor 24 hours after cooking to 65°C (Swain, 1972). Nitrite-treated smoked samples were selected as having more cured meat flavor (3.3) on a 4-point scale than hams made with smoke but without nitrite (2.3). On a Hedonic scale for desirability the difference between the two samples was less.

An anonymous report (1975b) showed moderate, but significant, differences in triangle tests of the flavors of hams cured with and without nitrite. Flavor descriptions of nitrite-treated ham include words such as mild, smoke, sweet; ham without nitrite was described as mild, bland, old ham, rancid. Most panelists preferred ham treated with nitrite.

Judge and Cioch (1979) only evaluated hams prepared without nitrite, and stated that experienced taste panelists rated these hams quite palatable, but noted the flavor and texture were not like hams cured with nitrite. The flavor was described as uncured roast pork.

Stitch-pumped hams cured with 0, 90 and 180 ppm sodium nitrite were evaluated for difference in flavor from a standard ham made with 90 ppm nitrite on a scale of 1 to 7, with 1 = less flavor, 4 = same, and 7 = much more flavor than the standard ham (Brown et al., 1974). Hams made without nitrite had less flavor (2.48) than the standard; both the 90 and 180 ppm nitrite-treated hams were close to the standard at 3.47 and 3.79 respectively. Acceptability was not evaluated. Kemp et al., (1974) evaluated dry cured hams made with salt and sugar (control), and either sodium nitrite or potassium nitrate. The aroma of all hams were similar for all treatments and was rated excellent. Although flavor scores for hams made with nitrite or nitrate were higher than those for the no nitrite-treated ham, the latter were in the acceptable range, indicating it is possible to have good tasting dry-cured hams cured without nitrite or nitrate.

Chemically, only minor differences have been reported to date in the composition of ham flavor, and these are quantitative rather than qualitative. The concentration of valeraldehyde and hexanal were greater in headspace vapors from no-nitrite ham than from hams containing nitrite (Cross and Ziegler, 1965). It was postulated that nitrite inhibits oxidation of unsaturated fatty acids, thus preventing formation of a rancid aroma. Swain (1972) also found more isobutanal, isopentanal and higher molecular weight aldehydes in uncured ham.

An extensive study of ham aroma was carried out by Piotrowski et al. (1970) which demonstrated that cured ham flavor was present principally in the non-polar components of meat. Aqueous extracts of cured ham had a characteristic cured ham aroma on heating which non-cured ham did not have. The aroma of the extracts of the latter was more like cooked meat: Analysis of the amino acid composition of hams cured with and without nitrite was not definitive because of the variability between replicate ham preparations.

Studies on Frankfurters

Emulsion products, principally frankfurters, have also been studied with respect to the effect of nitrite on flavor, although the role of nitrite may be more difficult to detect since a variety of spices are used to help give these products their characteristic flavor. A series of beef and pork frankfurters cured with or without nitrite were evaluated on a 1-9 Hedonic scale in which 0 = dislike extremely (Simon et al., 1973). Frankfurters without nitrite scored 2.9-3.0, which increased to

5.8-6.0 with franks containing 156 ppm nitrite. With nitrite concentration increasing from 0 to 156 ppm, the degree of product approval also increased. Incorporation of nitrate in the cure formula did not affect the Hedonic scores of the product. With all beef frankfurters there was no difference in the score (5.9-6.2) and it made no statistical difference whether the product was cured without nitrite or was processed in the usual manner with nitrite. Addition of the antioxidant BHA to franks with no nitrite improved the flavor but the shelf-life was not as great as product with the conventional nitrite cure. An anonymous paper (1975b) reports a slight to moderate degree of difference that a panel could detect between franks made with and without nitrite. Since 25 panelists out of 50 preferred the flavor of franks with nitrite, 18 preferred the flavor of non-treated frank and 7 had no preference, there was no significant preference for one over the other. MacNeil and Nast (1975) made frankfurters with an extract of rosemary and found that those prepared with nitrite had a greater Hedonic score than nitrite-free franks. The extract of rosemary and nitrite inhibit lipid oxidation and TBA values were low.

In triangle tests comparing frankfurters that were cured with and without nitrite and processed with and without smoke, panelists could differentiate significantly among the various treatments (Wasserman and Talley, 1972). Franks made without nitrite could be differentiated from those prepared with 80 or 156 ppm nitrite, but there was no significant difference between franks with the two levels of nitrite. However, in tests in which "frankfurter flavor" was scored, the no-nitrite sample was rated as highly as the cured smoked sample. There was an interaction between smoke and nitrite as shown by an analysis of variance. Thus smoke plays a role in the characteristic flavor of frankfurters.

Studies on Other Meat Products

Pork *longissimus dorsi* muscle was cured in brine with and without nitrite (Cho and Bratzler 1970). Significant differences were detected in flavor by a triangle test panel. Differences could also be detected when the samples were smoked and when NaCl was omitted from the cure. However, on 116 occasions, comprising 288 individual tastings, no differentiation was made between the pork cured with nitrite and that from which nitrite was omitted.

Two minced meat products—smoked meat sausage and meat loaf—prepared with and without nitrite (Skjelkvaale et al., 1973)—were evaluated by triangle testing. The panelists could differentiate between the preparations made with and without nitrite but there was no preference for one over the other in either product. In tests on meat products made with half of the conventional concentration of nitrite there was no significant difference in flavor between the samples made with nitrite.

Pork shoulder emulsion prepared with and without nitrite or salt was evaluated by a triangle test panel (Hadden et al., 1975). Panelists could distinguish between samples made with or without nitrite and the presence of salt increased the ability of the panelists. However, there was a wide variation in the ability of individual members of the panel to differentiate the flavors.

A minimum concentration of 50 ppm sodium nitrite was necessary to achieve reasonably typical thuringer flavor for fresh and baked pizza toppings, while at least 100 ppm added nitrite was necessary to produce these effects in fried thuringer. Fresh, fried or baked thuringer containing no nitrite was judged most rancid and of poorest flavor and appearance (Dethmers et al., 1975).

Work by Rogers (1980) has shown that for a low fat (3-5%) all beef emulsion-type product, 60 ppm $NaNO_2$ is required to get uniform color fixation and to produce a product that cannot be distinguished as being inferior by a trained panel (under normal lighting condition or when blindfolded) from a control product containing 156 ppm $NaNO_2$. Flavor problems with the low-nitrite product were more pronounced when it had not been vacuum packaged, as compared to vacuum packaged product.

Labeling of Nitrite-Free Meat Products

The issuance of a new set of regulations for "uncured" meat products (nitrite-free products) on August 21, 1979 (USDA, 1979b), introduced further confusion into an already complicated situation. These regulations amended 9 CFR parts 317, 318, 319, to allow for labeling of "uncured" meat products with the common and usual name of their cured counterparts, provided that they were designated as uncured; had a precautionary statement as to temperature of storage (less than 40°F); and had the appearance, taste, etc., of their cured counterparts. These regulations went into effect on September 20, 1979, but their implementation has been halted, first by a temporary circuit court injunction (November 14, 1979), and then by a permanent injunction (February 13, 1980). The injunctions were the result of a petition filed by the National Pork Producers Council and three federal Congressmen.

Federal regulation provides that all products be labeled with a "common or usual" name, or be considered to be "false and misleading" in their labels. Currently, there are a number of noncured products with well established "common or usual" names and/or published standards of identity. In many cases, such as various liver sausages, these approximate some of their cured counterparts. Would these labels have had to conform to the proposed standards?

Further, removal of cure from a product may well place it in a category where a "common and usual" name is already established. For example, a cooked bratwurst is simply a frankfurter without cure and probably unsmoked. Certain types of braunschweiger liver sausage can be made with or without cure, leaving all other ingredients and processing procedures the same. Salt pork can be an uncured bacon product.

Consumers do mishandle cured meats. It is reasonable to assume that noncured counterparts of frankfurters, ham, luncheon meats, etc., will likewise be mishandled, regardless of special label or precautions. There is no pervasive evidence that consumers are avid label readers or that label restrictions on meat products, as to storage and handling, will be followed to any extent.

In light of these considerations, the following is recommended:

1. For noncured products where "common and usual" names and/or standards of identity exist, these prescribed names be carried on as in the past.
2. For noncured products where standards of identity and/or "common and usual" names do not exist, descriptive names be established with sufficient differentiation from look-alike products. Further, these labels should carry precautionary temperature statements.
3. Proceed with research into indicator labels that will provide the consumer with visual evidence of temperature abuse and require these types of labels as soon as practical.
4. Conduct appropriate research into consumer handling of meat products and the extent to which precautionary labels are followed. After this research is evaluated, then modification of the foregoing can be considered.

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