CURED MEAT FLAVOR AND THE ROLE OF NITRITE IN ITS DEVELOPMENT*

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The United States Bureau of Animal Industry authorized the use of sodium nitrite in pickling solutions to promote color fixation during the "corning" or curing of meat in 1926 following investigations of Kerr, et al. (1926). Earlier investigations (Auerbach and Riess, 1919) indicated that the presence of sodium nitrite as an impurity in sodium or potassium nitrate was responsible for the curing process. Lewis et al. (1925) also indicated the feasibility of using sodium nitrite in place of sodium nitrate for curing of a variety of meats.

The use of sodium nitrite in foods has been criticized recently as a possible potential health hazard since under certain acidic conditions, sodium nitrite can react with amines to form nitrosamines. Most nitrosamines have been found to be carcinogenic in certain test animals (Magee and Barnes, 1956). Investigations of various cured meat products (Fazio et al., 1971; Fiddler et al., 1971) have not confirmed the presence of nitrosamines to levels greater than 10 ppb. Recently, the presence of as much as 80 ppb N-nitrosodimethylamine has been reported to be found in commercial frankfurters in the United States (Fiddler et al., 1972). The occurrence of the N-nitrosodimethylamine appeared to be random with no adequate explanation for its formation.

The presence of nitrite in cured products also has been found to be important to deter the development of toxin by C. botulinum (Emodi et al., 1969; Johnson et al., 1969; Pivnick et al., 1969; Greenberg, 1972) and growth of other putrifactive organisms (Bulman and Ayres, 1952; Silliker et al., 1958).

The use of sodium nitrite also has been reported to contribute a characteristic flavor to "corned" or cured meats. A limited number of papers have been published relating the organoleptic quality of cured meat to cure ingredients such as salt, sodium nitrite, sodium nitrate, and sugar. A review on the influence of nitrite on meat flavor has been presented by Bailey and Swain (1973).

One of the earliest investigations discussing "cured meat flavor" was by Brooks et al. (1940) who studied the influence of nitrite in the curing of bacon and ham. They reported that the characteristic cured flavor of bacon and ham was due to the interaction of nitrite with the meat and satisfactory ham or bacon could only be made by using sodium nitrite and sodium chloride. No formal taste panel results were presented in the study.

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The effect of nitrite on the flavor of cured pork loin has been investigated by Cho and Bratzler (1970). Paired (left and right) sections of pork longissimus dorsi muscles were processed in pickle containing either 0 or 300 ppm sodium nitrite, various levels of salt and sugar. The effect of smoke was studied by smoking slices of cured roast with hardwood sawdust smoke for 10 minutes in an air conditioned smokehouse. Cooking was done at 170°C to an internal temperature of 85.6°C.

Triangle and 2 sample testing of the roasts cured with nitrite and without nitrite containing various salt levels indicated that the panelists selected correctly the different sample and chose the sample containing nitrite ($P < 0.05$ or 0.01) as having more cured flavor. Even with the samples which were smoked heavily, as shown by phenolic contents, panelists correctly chose the different sample and the sample cured with nitrite as having more cured flavor ($P < 0.01$ or 0.001).

Similar studies were performed by Swain (1972) using hams cured with and without nitrite. Curing was for 3 days followed by cooking to an internal temperature of 65°C and stored for 24 hours prior to evaluation. A taste panel selected smoked and cured ham samples as having a better cured meat flavor ($P < 0.001$) than nonsmoked, uncured ham samples. Unsmoked, cured hams also were selected as having a better cured meat flavor ($P < 0.05$) than unsmoked, uncured samples. The taste panel rated the various ham samples in the order smoked cured ham, unsmoked cured ham, smoked uncured ham, and unsmoked uncured ham on a hedonic scale for cured flavor (figure 1).

The flavor of frankfurters produced either with or without nitrite was investigated by Wasserman and Talley (1972). Batches of frankfurters were produced from beef and pork containing 0, 1/8 or 1/4 oz. sodium nitrite per hundred weight of meat (equivalent to 0, 1/2 and maximum allowed cure levels by the USDA, respectively). The frankfurters were cooked using a 90 minute program of increasing heat and controlled humidity. When smoking was desired, smoke produced using commercial hickory sawdust was led into the smokehouse for the entire 90 minute cooking period. The frankfurters were stored at 5°C overnight prior to evaluation.

Triangle evaluation of frankfurters containing either no nitrite or the maximum allowed level by the USDA (1/4 oz. per 100 lb. meat block) indicated that judges could distinguish at a significant level the uncured frankfurters from the cured frankfurters (table 1). The selection of the different sample was most significant for the cooked unsmoked frankfurters ($P < 0.001$). Smoking did not prevent the correct selection of the different sample although the number of correct responses was lower ($P < 0.05$ to 0.01). Panelists characterized the cooked uncured frankfurters as having an unappetizing cooked pork flavor. Judges also were able to distinguish correctly between cooked smoked frankfurters which contained only 1/2 the permissable level of nitrite and uncured frankfurters ($P < 0.01$); the panelists could not distinguish to a significant level between the 1/2 and fully cured samples.

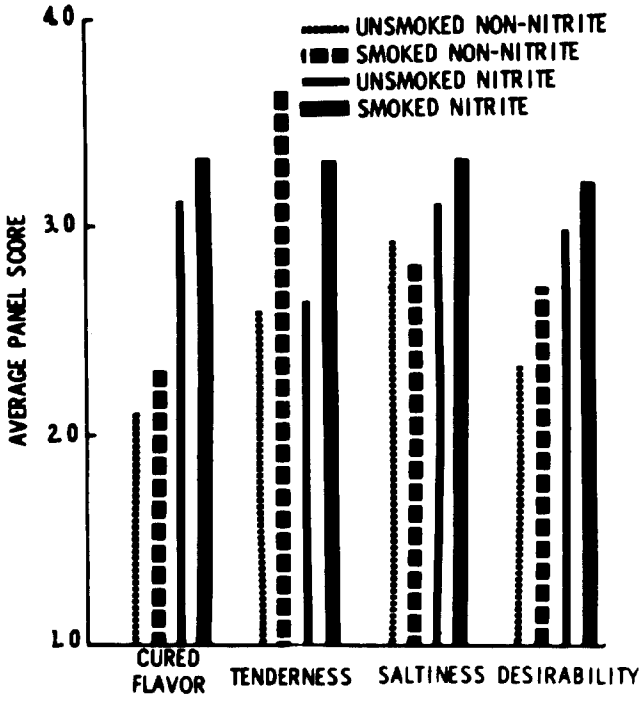

Fig. 1
Influence of curing treatments on sensory attributes of cooked pork (Swain, 1972).

TABLE 1. TRIANGLE TEST EVALUATION OF THE FLAVOR OF FRANKFURTERS PREPARED WITH CURE IN WHICH SODIUM NITRITE WAS EITHER PRESENT OR ABSENT

Experiment	Conditions	No. correct/ No. judges
1	Cooked, no smoke; $+NO_2$ vs. no NO_2	15/22***
2	Cooked, no smoke; $+NO_2$ vs. no NO_2	28/36***
3	Cooked, no smoke; $+NO_2$ vs. no NO_2	18/24***
4	Cooked, smoke; $+NO_2$ vs. no NO_2	11/17**
5	Cooked, smoke; $+NO_2$ vs. no NO_2	13/24*
6	Cooked, smoke; 50% NO_2 vs. no NO_2	12/17**
7	Cooked, smoke; 50% NO_2 vs. 100% NO_2	9/17^{NS}

*P=.05, **P=.01; ***P=.001; NS = not significant

Wasserman and Talley (1972).

In addition, the frankfurters produced for testing were subjected to a scaling test (0 = no hot dog flavor, 10 = excellent hot dog flavor) by the taste panel. In the absence of smoke a highly significant difference in flavor was produced on incorporating nitrite into the frankfurter ($P < 0.01$). When smoked frankfurters were subjected to hedonic scale evaluation, however, there was essentially no difference in taste panel scores for the cured and uncured frankfurters. As stated previously, these samples were differentiated using a triangle test procedure.

The flavor quality of frankfurters also has been investigated by Simon *et al.* (1972). Frankfurters were produced using formulations which contained either beef and pork or beef only. Sodium nitrite additions of 0, 1/16, 1/8 and 1/4 oz. per hundred weight of meat were added to different batches of frankfurters (equivalent to 0, 39, 78, 156 ppm, respectively). Batches of these frankfurters also were prepared with additions of 0 and 3/4 oz. sodium nitrate per hundred weight of meat. The frankfurters were smoked with kiln-dried maple sawdust smoke for 5 minutes at 140°F and then they were cooked to an internal temperature of 160°F. The frankfurters were either vacuum packaged or bulk packaged and placed in a lighted display case at 40-42°F for storage tests. The frankfurters were evaluated

periodically using a hedonic scale (1 = dislike extremely, 9 = like extremely) in a judging area lighted by green fluorescent light to eliminate visual color differences in lightness and darkness.

For the frankfurters produced from a formulation containing both beef and pork, taste panel results (table 2) indicated that for both vacuum packaged and bulk packaged product significant differences ($P < 0.01$) in taste acceptance were associated with nitrite level, storage time and for the replicates produced on different production dates. It is not understood why differences were obtained in taste panel scores for replicate samples unless it was associated with slight quality differences in starting meat components. The inclusion of nitrate into the formulation was found not to affect taste acceptance. Flavor scores were significantly different ($P < 0.05$) between 39 and 156 ppm nitrite levels; but not between 39 and 78 ppm and 78 and 156 ppm nitrite. However, a definite trend in taste panel scores was found as consistently higher taste panel acceptance was obtained as the nitrite content added initially was increased.

The taste acceptance for both vacuum packaged and bulk packaged frankfurters decreased with time and was found not to be associated with nitrite level. On analysis of the taste panel results obtained with the frankfurters produced from beef only it was found that nitrite level did not affect the general flavor of the frankfurters initially or on storage (table 3) for both vacuum packaged and bulk packaged product. As observed with all meat frankfurters, the inclusion of sodium nitrate did not affect the taste acceptance significantly. Taste panel scores slowly decreased with storage time but were not associated with added nitrite level.

Since significant differences in taste quality resulted when all meat frankfurters were prepared containing no added nitrite, experiments were performed to see if these differences could be eliminated by incorporating legal limits of either BHA or BHT (0.01% by weight). The nitrite levels selected for this study were 0 and 156 ppm and all frankfurters contained permissible levels of nitrate. Examination of the taste panel results indicated that the five minute smoke used in this study did not affect significantly the flavor of the frankfurters produced (table 4). Only BHA of the 2 antioxidants studied improved significantly the flavor of uncured frankfurters. BHT produced a slight but not significant improvement in the flavor of uncured frankfurters. The flavor panel scores of the uncured frankfurters containing BHA began to decrease after about one week of storage to an unacceptable level. These results indicated some improvement in flavor acceptance could be obtained by including antioxidants in the formulation of uncured frankfurters but the taste acceptance was not to the level of frankfurters cured with sodium nitrite.

Bulk stored frankfurters produced from beef, pork and mechanically deboned chicken (15%) with a spice extract of rosemary (Gemini trade name produced by Fritzsche D and O) as a substitute for nitrates and nitrites were studied by MacNeil and Mast (1973). The frankfurters were

TABLE 2. TASTE PANEL SCORES OF VACUUM OR BULK PACKAGED ALL MEAT FRANKFURTERS STORED AT 40°F.

Total nitrite added/cwt. meat (ppm)	Taste Panel Scores											
	Initial		Vacuum packaged (weeks) 1		2		3		4		Bulk packaged (days) 10	
	With NO_3	No NO_3	With NO_3	No NO_3	With NO_3	No NO_3	With NO_3	No NO_3	With NO_3	No NO_3	With NO_3	No NO_3
0	2.6	3.3	3.5	2.6	3.6	3.1	5.0	2.3	3.9	2.0	4.0	2.0
	3.3	3.5	3.1	2.5	3.3	3.1	2.5	3.4	2.6	2.0	3.4	3.3
	2.9	1.6	2.9	2.6	3.4	3.5	2.1	3.3	2.4	2.9	2.5	2.5
Average	2.9	2.8	3.2	2.6	3.4	3.2	3.2	3.0	3.0	2.3	3.3	2.6
39	4.3	5.9	4.9	5.3	4.9	4.8	5.4	6.5	6.0	5.0	2.5	3.4
	5.9	5.0	5.1	4.3	4.6	3.8	3.1	2.4	3.3	3.3	4.0	6.0
	3.3	3.3	2.8	2.6	4.5	3.8	4.0	2.5	2.1	2.6	3.1	3.5
Average	4.5	4.7	4.3	4.1	4.7	4.1	4.2	4.7	3.8	3.6	3.2	4.3
78	5.3	6.0	5.8	5.1	5.4	6.4	4.9	5.0	5.1	5.6	4.5	4.8
	5.5	6.0	4.8	5.0	4.3	4.5	5.6	4.8	3.8	4.3	3.4	3.4
	4.0	4.8	4.4	4.8	6.3	6.0	3.4	3.4	2.4	3.0	3.5	2.9
Average	4.9	5.6	5.0	5.0	5.3	5.6	4.6	4.4	3.8	4.3	3.8	3.7
156	5.5	6.0	5.6	6.9	5.4	6.1	5.1	5.0	5.4	5.8	3.4	4.8
	6.0	7.0	6.3	6.4	5.6	5.1	5.1	5.0	5.1	5.8	6.4	5.6
	5.8	5.0	4.9	4.5	6.1	6.4	5.9	5.1	4.5	3.8	6.1	5.9
Average	5.8	6.0	5.6	5.9	5.7	5.9	5.4	5.0	5.0	5.1	5.3	5.4

TABLE 3. TASTE PANEL SCORES OF VACUUM OR BULK PACKAGED ALL BEEF FRANKFURTERS STORED AT 40°F.

Total nitrite added/cwt. meat (ppm)	Taste Panel Scores											
	Vacuum Packaged (weeks)										Bulk packaged (days)	
	Initial		1		2		3		4		10	
	With NO_3	No NO_3	With NO_3	No NO_3	With NO_3	No NO_3	With NO_3	No NO_3	With NO_3	No NO_3	With NO_3	No NO_3
0	6.9	6.1	5.5	5.3	5.3	5.8	4.4	4.1	2.8	3.6	4.5	5.1
	6.3	7.0	4.8	5.4	5.0	4.6	4.1	4.5	3.3	3.1	4.0	3.9
	5.5	6.8	5.3	5.3	4.0	6.3	4.0	4.0	6.0	5.3	2.3	2.8
Average	6.2	6.6	5.2	5.3	4.8	5.6	4.2	4.2	4.0	4.0	3.6	3.9
38	7.1	5.0	6.6	7.5	4.3	6.8	4.6	4.3	3.9	3.9	4.5	4.3
	6.4	5.5	6.3	5.9	4.9	3.6	3.9	4.3	2.9	3.0	3.3	3.6
	7.0	7.0	6.9	6.6	4.6	5.9	4.4	3.9	5.5	5.9	2.3	5.5
Average	6.0	5.8	6.6	6.7	4.6	5.4	4.3	4.2	4.1	4.3	3.4	4.5
78	6.1	5.9	6.9	6.8	5.0	5.1	3.4	4.1	3.5	4.3	4.1	6.1
	5.9	5.9	6.5	7.0	4.4	5.0	6.3	3.5	3.3	3.0	3.5	5.3
	6.3	6.3	6.1	7.0	5.8	5.0	5.1	4.5	4.9	5.5	4.0	4.3
Average	6.1	6.0	6.5	6.9	5.1	5.0	4.9	4.0	3.9	4.3	3.9	5.2
156	5.8	6.6	6.1	6.5	5.5	5.8	5.4	4.5	4.8	3.4	4.9	5.9
	5.6	6.6	7.5	5.5	6.1	5.3	4.1	5.0	2.6	3.4	5.8	5.9
	6.4	5.5	6.8	6.5	5.5	5.9	5.0	4.1	4.8	5.9	5.9	6.1
Average	5.9	6.2	6.8	6.1	5.7	5.7	4.8	4.5	4.1	4.3	5.5	6.0

TABLE 4. TASTE PANEL SCORES OF VACUUM PACKAGED ALL MEAT FRANKFURTERS STORED AT 40°F. PREPARED TO EVALUATE THE EFFECT OF ANTIOXIDANTS

Total nitrite added/cwt. meat (ppm)	Antioxidant	Smoke application	Taste panel scores 0	1	2	3
0	No	Yes	3.4	3.6	2.0	2.5
		No	3.0	4.0	2.9	3.5
		No	3.8	2.8	3.4	2.1
0	BHA	Yes	5.3	4.6	4.0	3.3
		No	5.1	5.5	6.1	4.3
		No	6.6	4.9	4.9	4.6
0	BHT	Yes	3.8	4.4	2.8	3.3
		No	4.0	3.4	4.9	3.3
		No	4.6	3.9	3.5	4.0
156	No	Yes	6.6	7.0	6.9	6.1
		No	7.0	7.5	6.9	5.4
		No	7.8	7.3	7.5	6.8
156	BHA	Yes	5.9	7.3	6.8	6.9
		No	7.0	7.4	7.8	6.9
156	BHT	Yes	6.6	6.9	3.3	4.0
		No	6.4	4.8	5.9	4.8

smoked and cooked using a 140°-175°F cooking cycle for 104 minutes. Frankfurters were held in plastic bags at 45°F prior to testing. Batches of frankfurters were produced containing the base formulation only, legal limits of sodium nitrite, and either 0.03, 0.05, or 0.08% of the spice extract of rosemary. The initial hedonic flavor values for the cured frankfurters and those containing either 0.03% or 0.05% of the spice extract were higher than the uncured frankfurters or those containing 0.08% of the spice extract (table 5). The hedonic flavor values remained high for these samples during the 16 day storage period.

TBA values as indicative of oxidative changes (figure 2) obtained on the frankfurters during the storage period indicate that significant decreases in TBA values ($P < 0.01$) occurred when either nitrite or the spice extract was included in the frankfurter formulation. No significant changes in TBA values occurred on storage. The TBA values may indicate that flavor acceptance in this testing was measuring oxidative changes in the frankfurters since extracts of rosemary as well as nitrite inhibit oxidation (Chipault et al., 1956; Rac and Ostric, 1954).

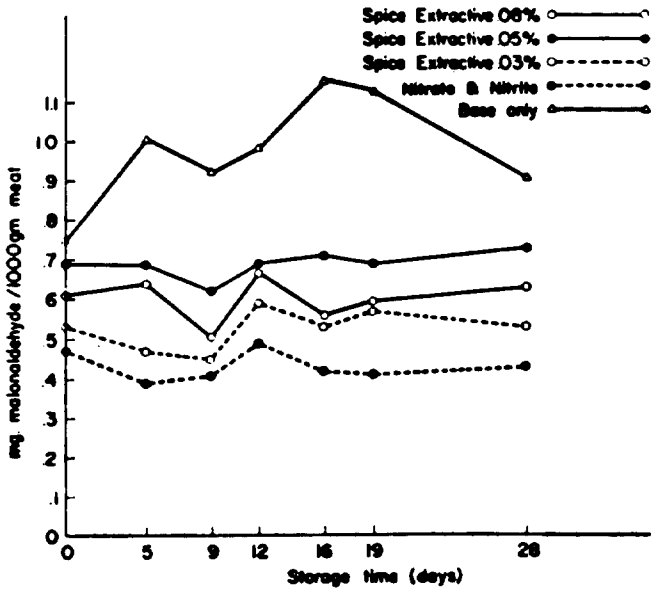

Fig.2 **TBA values of frankfurters stored for 28 days at 45° F (mg of malonaldehyde per 1000 g of sample).**

TABLE 5. MEAN HEDONIC FLAVOR RESPONSES FROM PANEL MEMBERS EVALUATING FRANKFURTERS HELD IN A 45°F STORAGE

Treatment	Storage time (days)				
	0	5	9	12	16
Spice extractive (0.08%)	3.2	4.0	3.7	4.3	3.6
Spice extractive (0.05%)	3.8	5.0	5.4	4.8	4.8
Spice extractive (0.03%)	4.7	5.0	5.3	5.5	5.1
Base formulation	4.8	3.9	4.3	3.4	3.6
Nitrates and nitrites	5.2	5.4	5.2	5.9	5.2

Hedonic scale: 9=like extremely; 1=dislike extremely.
Each value is the mean of 12 observations.

MacNeil and Mast (1973).

The published data cited above indicate that nitrite contributes to the flavor attributes of cured whole muscle or comminuted meat products by some mechanism. This flavor attribute is usually referred to as "cured meat flavor" by most authors. These papers do not, however, answer the questions as to what compounds are contributing to the cured meat flavor or the mechanism by which nitrite promotes flavor.

One procedure which has been used in an attempt to ellucidate "cured meat flavor" is to isolate possible flavor components by extraction from the meat product and analyzing for compounds present. The aroma from country style hams is distinctive and resembles the flavor. Ockerman et al. (1964), therefore, investigated the volatile constituents to objectively evaluate quality criteria.

The hams used in this investigation were cured with a mixture of salt, sucrose, and potassium nitrate for 28 to 32 days at 4°C. The hams were then smoked at 21°C using hardwood sawdust. They were sampled periodically during a 24 month aging period. Volatile compounds were separated from ground ham slices freed from subcutaneous fat by vacuum distillation. Typical aroma and flavor were developed. Trapping procedures were used to isolate carbonyl compounds, acids, basic materials, and sulfur compounds.

Gas chromatography and infrared analysis of the carbonyl fraction indicated the major constituents were acetaldehyde, propionaldehyde, isobutyraldehyde, diacetyl, 2-butanone and isovaleraldehyde. The ratios among the carbonyl compounds remained quite constant during the entire aging period except for 2-butanone which increased during the latter part of the aging period.

The major volatile acids isolated by the procedures used were tentatively identified as formic, acetic, propionic, butyric, and isocaproic while the major volatile base was ammonia. Volatile sulfur compounds were precipitated in a lead acetate trap indicating hydrogen sulfide had been liberated from the ham.

Similar studies of volatile compounds were performed by Lillard and Ayres (1969) on fully aged country cured hams obtained commercially. Volatile compounds were isolated by steam distillation under vacuum. Separation of components was by gas chromotography with identification by ultraviolet and infrared spectrophotometry.

The carbonyl and acetic compounds identified agreed with the results obtained by Ockerman (1964). Additional fatty acids (hexanoic, octanoic, decanoic, and lauric) and alcohols (methanol, propanol, hexanol, heptanol, octanol) were found because of the separation techniques used.

The compounds analyzed are not characteristic of ham alone but have been isolated from other meats (Hornstein et al., 1964) or identified as oxidation products of pork fat (Gaddis et al., 1957; Ellis et al., 1961).

Lillard and Ayres (1969) also conducted a preliminary experiment to determine if the flavor precursors of country cured ham were water soluble as reported for meat (for example, Hornstein et al., 1960; Wasserman, et al., 1965). The lypholyzed water extract was a white powder which had a salty taste and an odor of roasted meat when heated. This experiment indicated that the country cured flavor or its precursors were not water soluble.

Although many chemical compounds were found in this study, no attempt was made to correlate any single compound or groups of compounds to the flavor of country cured hams.

The investigation of volatile ham components was extended by Cross and Ziegler (1965) to cured and uncured ham samples in an attempt to determine the effects of curing on the volatile constituents. The cured hams had been injected with pickle to a level of 13% and cured for 5 days. The semimembranosus muscle was canned and cooked to an internal temperature of 70°C. Uncured samples were prepared in the same manner and all cans stored at 3°C. until examined. The carbonyl compounds were separated by flushing with nitrogen at elevated temperatures and separated by gas chromatography.

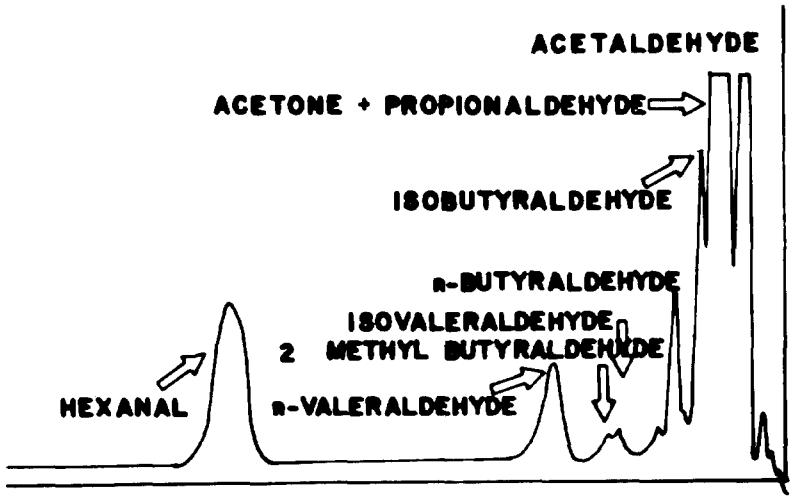

Fig. 3
Gas Chromotograph of volatile carbonyl compounds isolated from uncured ham (Cross and Ziegler, 1965).

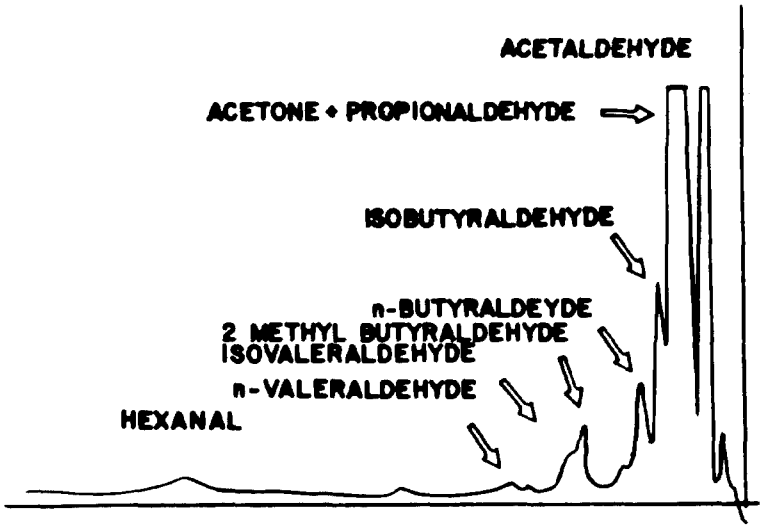

Fig. 4
Gas Chromatograph of volatile carbonyl compounds isolated from cured ham. (Cross and Ziegler, 1965).

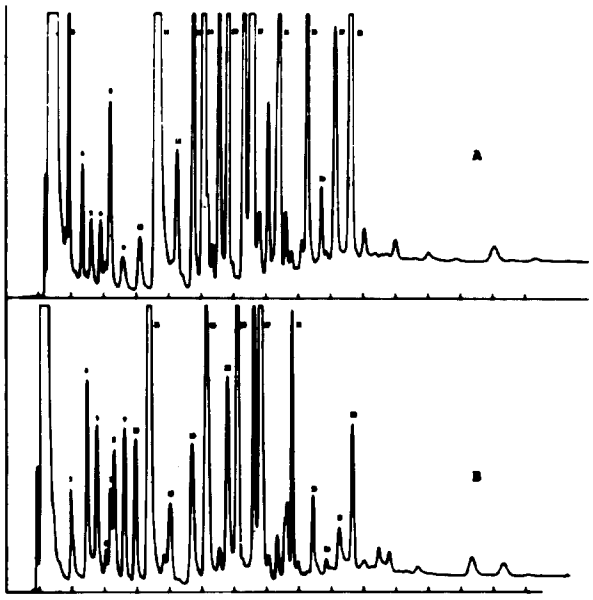

Fig. 5
Chromatogram of volatiles from non nitrite (A) and nitrited treated (B) ham extracted immediately after cooking.
(Swain (1972).

This investigation indicated that certain aldehydes were present to a much greater extent in uncured ham than in cured ham (figures 3 and 4). This was especially evident for hexanal and valeraldehyde. These compounds can be reasonably assumed to be derived by oxidative cleavage of unsaturated fatty acid residues such as linoleate. Branch chained aldehydes (isobutyraldehyde, isovaleraldehyde and 2-methylbutyralehyde) were found to the same extent in the volatiles from cured and uncured samples. These branch chained aldehydes were believed to be derived from valine, leucine, and isoleucine; the results indicate that curing with nitrite does not affect the conversion of these amino acids to aldehydes. On extraction of the volatiles, the volatiles remaining after passage through the 2,4-dinitrophenylhydrazine solution were found to have the characteristic aroma for both cured and uncured ham samples. The volatiles which were contributing to the cured ham aroma were trapped by mercury salts. Analysis of the trapped precipitate indicated the bulk of material was mercuric sulfide. The investigators considered that cured ham flavor represents the basic meat flavor derived from precursors other than triglycerides and aroma obtained from meats depends on the spectra of carbonyl compounds derived by oxidation of fat.

A similar comprehensive study of the volatiles from cured and uncured ham was performed by Swain (1972) who also examined the volatiles obtained on heating cured and uncured ham samples and extracted by ether. Qualitatively, the chromatogram for cured and uncured hams, immediately following curing, were very similar (figure 5). Many of the early peaks for the cured samples contained more solute than those for the uncured samples. Isobutanal (peak 3), n-pentanal (peak 8) and the higher molecular weight compounds (higher molecular weight aldehydes) were more concentrated in the uncured sample than the cured sample. There was even greater quantitative differences in the level of these compounds when the hams were stored 8 hours at 4°C prior to evaluation. Formation of higher molecular weight aldehydes in uncured ham is indicative of oxidation of unsaturated fatty acids and supports the results obtained by Cross and Ziegler (1965). Nitrite apparently retarded formation of these constituents.

Piotrowski *et al.* (1970) also found that cured and uncured hams could be identified readily by taste and odor on frying and that aqueous extracts also could be identified by heating. Dialysis of the aqueous extracts indicated diffusate from cured hams gave on heating a cured meat aroma while uncured ham diffusates gave an aroma of cooked meat. Chloroform-methanol extraction of ham samples to obtain lipid fraction indicated that cured samples could easily be distinguished from uncured samples when heated and their odors observed. The cured ham odor was more intense in the chloroform-methanol extract than the water extract indicating the cured odor components were essentially in the lipid phase.

These investigators also examined the total free amino acids present in raw and cooked ham samples which were cured and uncured. The free amino acid content of raw cured ham was lower than for uncured samples. Free amino acids were considered to be converted to α-hydroxy acids by the amino group interacting with nitrous acid formed from sodium nitrite

by way of the Van Slyke reaction. Cooking generally increased the total number of free amino acids present in cured or uncured ham but the total amount was approximately the same in each although the individual amino acids obtained were different. It was considered that the cooking procedures used may contribute greatly to the free amino acid profiles obtained.

The formation of compounds mentioned above can be interpreted on the basis of oxidation of the lipid fractions. The oxidation of lipids is generally accepted to be catalyzed by ferric hemochromogens (Younthan and Watts, 1959). Nitrite functions as an antioxidant by removing the catalytical active ferric hemochromogen by the formation of inactive ferrous nitric oxide hemochromogen (Zipser et al., 1964). The role of iron compounds as catalysts in the oxidation of lipids has been reviewed recently by Love and Pearson (1971).

Recent investigations (Liu and Watts, 1970; Sato and Hegarty, 1971) also have indicated the non-heme iron as well as heme iron catalyze the oxidation of lipids in model systems. These results agree with the work of Ellis et al. (1971) regarding metal catalysis of lard. Thus it appears more than one mechanism may be important in oxidation of lipids.

The investigators mentioned above indicate that except for organoleptic differences between meat cured with nitrite and uncured product, only subtle differences may exist in the chemical composition which contributes to the organoleptic differences. Either the absence or the ratio of certain compounds present in cured or uncured meat is responsible for "cured meat flavor." The results which have been obtained in studies concerning "cured meat flavor" indicate that oxidation of lipids is responsible for the differences in flavor observed. The presence of nitrite in the meat product inhibits oxidation of the lipids while the formation of off flavor compounds by oxidation results in uncured product with less organoleptic acceptability.

The specific compounds, which because of their presence or absence, lead to "cured meat flavor" have not been completely defined. The investigation of the materials responsible for flavor of processed meats other than ham has hardly been scratched and appears to be open for extensive investigation. Studies of other processed meats should provide valuable additional information for improving processing conditions and keep a high standard of quality and shelf life.

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NED DRAUDT: I'd just like to ask a question which you really answered. What you say is that cured meat flavor is not cured meat flavor but it is the absence of bad flavor or off-flavor or something like that?

DUANE WESTERBERG: What I have been able to find from our work and what has been published I think that at the present time you have to draw that conclusion.

DICK ALSMEYER, USDA: Was nitrate used in the ham study of Swain in 1972 along with nitrite?

DUANE WESTERBERG: I believe it was, Dick, I believe it was.

UNIDENTIFIED: I have two questions I want to ask you. First question, What is the correlation between the TBA number and off flavor of cured meat? When I say off flavor I refer to rancidity. The second question is to what extent is nitrite related to the TBA number? Thank you.

DUANE WESTERBERG: The three specific references I know of relating TBA numbers to the off flavor of the product is the one I mentioned in the cure. It is also in Swain's article mentioned by Dr. Bailey last spring that they also found the TBA numbers for the uncured samples were higher than for the cured samples and that the early work of Yonathan and Watts in 1959 was in this area. Watts and Yonathan, when they did their work, studied some different levels of nitrite at the residual levels in their product and they concluded that, from the levels they were studying, there was no effect of nitrite on TBA values. We have not measured any in our work so far as the TBA is concerned.

AARON WASSERMAN: Ever since I got into the study of the chemistry of meat flavor, my wife has been complaining to me every time there has been some problem with the flavor of meats used at home. One of her common complaints has been the development of an undesirable flavor, or at least loss of desirable flavor, in roast beef after it is a day or so old. Of course, this was in the days when you could afford to buy enough beef to have leftover roast beef. In any case, I couldn't answer her questions at that time. Today perhaps we will hear some answers on this and I will be able to put her mind at rest. "The Chemistry of Warmed-Over Flavor" and the speaker is Dr. Harold K. Herring, Head of Food Chemistry, Armour and Co. Dr. Herring.