THE MICROBIOLOGICAL SAFETY OF CANNED, CURED, PERISHABLE MEAT PRODUCTS

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INTRODUCTION

Canned, cured, perishable meat products are prepared and sold in large volumes in the United States. In addition to domestic production, large volumes of these products are imported mostly from Europe. These products have been extensively marketed in both domestic and international trade for many decades. Complaints of spoilage or food-borne illness involvement have been extremely rare in the U.S., particularly in view of the volume of the product consumed. This is a particularly impressive achievement since much of the product is removed from the cans, sliced, and vacuum packaged for consumption without additional heating (11). Canned, cured, perishable meat was reported to be the cause of an outbreak of botulism in 1965 (5), however, the cause of this outbreak was never verified by laboratory procedures.

In 1968, cured, perishable, chopped chicken liver packed in small glass jars caused an outbreak of botulism that resulted in one death (6). The product was labeled "keep refrigerated" but had been stored at ambient temperature at the market. This case resulted in concern for adequate size of lettering of perishable products packed in jars or tins similar to those used to pack shelf stable items. These two incidents which occurred relatively close to each other renewed regulatory concern in the U.S. for proper labeling and refrigeration of canned, cured, perishable meats.

Most canned, cured, perishable meat products are heated after sealing to center internal temperatures of 68-71°C. These temperatures require relatively long periods of time to attain and as a consequence, vegetative bacteria are nearly always destroyed but the heat treatment has little or no effect on spores present in the cans. Accordingly, the product has a high protein content, competitive bacteria particularly the lactic acid bacteria have been destroyed, and it is packed in a hermetically sealed container that excludes oxygen and acts as an oxygen receptor (metal). Without nitrite, such products have an optimum environment for the growth of clostridial species of bacteria including Clostridium botulinum.

The most important safety aspect of perishable, canned product is the "keep refrigerated" caption on the label. If this were routinely followed, the product would always be safe as regards C. botulinum. Experience in the U.S. has shown that regardless of the "keep refrigerated" label, some confuse it with canned shelf stable product. Accordingly, these "keep refrigerated" products are sometimes out of refrigeration for considerable periods of time during warehousing, transporting and retailing. Several decades ago, U.S. regulatory officials wisely limited the production and importation of canned pasteurized products to only those cured with nitrite and/or nitrate. This action recognized the effect of nitrite as an anticlostridial agent under conditions of temperature abuse. In 1974, a prior requirement for the mandatory use of nitrate in canned, comminuted, perishable meat was rescinded; however, at the same time, the mandatory use of 1/4 ounce of nitrite per 100 pounds of meat was established (156 ppm). This provides a well controlled anticlostridial effect in comminuted, perishable, canned meats. No minimum nitrite requirements exist, however, for non-comminuted product such as canned hams which are prepared by injecting curing solutions (pumping) into large chunks of meat as opposed to formulating by comminuting dry cure mixes directly into meat. The pumping process results in greater variation of nitrite and salt content than does comminution. Different combinations of nitrite, salt and acidity (pH) provide varying levels of anticlostridial effects in meats. In general, the anticlostridial effect increases with increasing levels of nitrite and this effect is potentiated by increasing salt and/or decreasing pH in the products (8).

During the past decade, several issues or changes in processing procedures have developed each of which could deteriorate the safety and stability of canned, perishable meats.

- Nitrite has been under investigation to determine whether or not it is carcinogenic. A ban of nitrite would impact heavily upon canned, perishable meats.
- The use of nitrite in meat products has led to scientific concerns over the formation of carcinogenic nitrosamines when cured products are cooked to high temperatures. This concern may cause some processors or even countries to lower ingoing nitrite levels. While this may be a reasonable and safe response for some perishable meat products such as bacon, reductions in canned, cured, perishable meats constitutes an erosion of safety proportional to the degree of reduction and the unknown degree to which the products are abused.
- Salt which is important in potentiating the anticlostridial effect of nitrite is believed to be a significant dietary factor in hypertension. Accordingly, meat processors may be reducing salt usage slowly to satisfy emerging consumer trends.
- The use of phosphates in perishable meats has increased. While their usage improves water retention and product tenderness, most of the phosphates used increase the pH of the product. As mentioned earlier, increasing the product pH in the nitrite/salt/meat system decreases the anticlostridial effect of nitrite.
- Tumbling is a relatively recent innovation in the cured meat industry. Its use results in faster cure

penetration and better binding of the pressed meat (1). Tumbling may change nitrite residuals and because the equipment is large and baffled, it is difficult to clean. This could lead to higher microbial levels. Elevated spore loads have historically been associated with a tendency to overcome the anticlostridial effects of cured meat.

O The anticlostridial activity of nitrite/salt and pH has been primarily studied in red meat muscle systems. The substitution of heart meat for muscle was observed to greatly reduce the anticlostridial effect of nitrite (13). This reduction was shown to be due to a higher level of readily available iron in the heart meat. This observation indicates that the effectiveness of the nitrite system has been assumed to be similar for all product formulations but that very few commercial formulations have been tested. The impact of this concern is primarily focused upon canned, perishable meat loaves which can contain meat tissue of non skeletal muscle origin, spices, cereal extenders and non-meat proteins. Any of these ingredients could have properties that reduce or neutralize the nitrite effect.

O Perishable, canned, cured meats are expected to be stable for prolonged periods. In the U.S., many commercial purchasers buy a 1-2 year supply during depressed market periods. Most workers have assumed that as in the shelf stable system, the nitrite effect is constant with time. This assumption has recently been shown to be erroneous (12). In this study, canned, cured meat inoculated with C. botulinum was stored under refrigeration for varying times before abusing the product at 27°C. During the refrigerated storage, the residual nitrite and degree of inhibitory effect both decreased. These observations indicate the possibility that the safety of a perishable, canned meat product may depend upon the age of the product at the time that the abuse takes place.

Because of these issues and processing changes, FSQS has investigated spoilage incidents involving perishable, canned, cured meats with particular emphasis on those caused by Clostridia as compared with leakage.

MATERIALS AND METHODS

During the past several years, incidents involving swollen canned perishable loaves or hams have been investigated by microbiological methods (3, 10). The incidents reported have involved significant swell rates for the lot involved and most were either known to have been temperature abused or suspected to have been abused.

In addition to the microbiological investigation of abnormal containers, we assembled data on the brine concentration of canned, perishable hams derived from routine sampling of both domestic and imported production lots. The brine concentration data was obtained from normal containers of freshly prepared domestic product or imported product as it entered the U.S. Brine concentrations were determined by previously described methods (2).

RESULTS AND DISCUSSION

Perishable, canned meat products owe their stability primarily to a good pasteurization process and subsequent storage under refrigeration. A secondary level of protection is provided by the presence and levels of salt and nitrite and by pH. The salt and nitrite content of perishable canned products may vary significantly because of composition. The pH ranges of these products may vary slightly because of the use of phosphates but appears to be influenced mostly by the meat itself as compared with formulation or processing procedures. Although acidulation would improve the microbiological stability of these products during abuse, acidulants are not commercially used, thus, salt and nitrite are the most important additives in the perishable canned meat system as regards preservation during abuse. Nitrite depletes during formulation and storage, thus, it is difficult to relate residual nitrite levels with either those originally used or variations encountered in formulating the products. However, in canned, perishable ham, nitrite is added by pumping prepared pickle solutions which also contain the salt. Consequently, analysis of canned, perishable hams for brine concentration (salt in water) provides an analytical basis for processing and formulation variations that occur. During the period when this work was done, it is believed that most domestic and imported canned, perishable hams were pumped to contain target levels of about 3.5% brine concentration and from 150-170 ppm nitrite. Pumping procedures for cuts of meat are subject to considerable variations and some processors have much better controls over this than others. From a microbiological stability during abuse standpoint, it is important to consider that canned, perishable hams produced during this period with brine concentrations of about 1.2% were not only low in salt but probably contained only about 50 ppm nitrite at the time of pump. It is likely that such a unit would contain little or no residual nitrite after processing and preparing for shipment. It is equally likely that a canned, perishable ham with a brine concentration of 1.2% would have little or no anticlostridial effect if subjected to abuse. As the brine concentration (and nitrite) moves downward from the targeted 3.5%, the secondary protective system of salt and nitrite decreases. Table 1 shows the cumulative frequency by percent of brine concentrations in imported canned hams from 1973-1977. Table 2 shows the same information for domestically prepared hams. While it appears that imported product, on the average, had a slightly higher brine concentration, both the imported and the domestic products showed large numbers of units below the generally targeted 3.5%. In addition, occasional units from both domestic and imported product were observed to contain less than 1.5%. These findings indicate that for both domestic and imported canned, perishable hams, pumping variations result in many freshly prepared units that have less anticlostridial activity than that targeted for. In addition, it appears that a low percentage of units with brine concentrations so low that their anticlostridial activity is negligible to non-existent. These observations help explain why some units in an abused lot swell and others don't.

We have reviewed our records of examinations of abnormal, canned, perishable products from 1974 through early 1980. During this period there were a number of instances where a single or rare abnormal can was found in a lot. The microbiological and sometimes seam analyses of these were consistant with leakage and no microorganisms of public health significance were found. These cases will not be reported here. Three instances (domestic) were observed where one or more cans missed the cook. These resulted in rapid spoilage prior to reaching the retail market. Three incidents were investigated which were characterized by high swell percentages and the isolation of

Lactobacillus species of relatively high heat resistance. These three incidents all involved canned perishable ham patties. Although this product is ground, it is formulated with pumped ham trimmings. Again, no micro-organisms of public health significance were observed and no evidence of temperature abuse was found. Although the causative spoilage bacteria had a higher heat resistance than most non-spore forming bacteria, they were capable of growing slowly under refrigeration.

The remainder of the incidents investigated were characterized by elevated swell rates, the presence of elevated levels of Clostridia and in most cases the contents showed some evidence of putrefaction. The lots involving these incidents except for one were either known to be temperature abused or strongly suspected to have been. The incidents are summarized individually as follows:

1974 - Domestically canned, perishable hams were recalled. The recall involved three production lots and the level of abnormal cans was high. These hams had been transported in an unrefrigerated truck and stored in unrefrigerated areas. The product was approximately 6 weeks old at the time of the abuse. All swells examined contained high levels of Clostridia. Non-spore forming bacteria were not found. Salt levels were not determined.

1975 - Domestically canned, perishable hams from a single processor were involved in three separate incidents. In each case, the temperature abuse occurred during military distribution and involved elevated swell rates. Analysis of swells showed high levels of Clostridia. Non-spore forming bacteria were not found. The percent salt content found in the contents of six abnormal cans tested ranged from 0.5 to 1.5%. These values are quite low.

1977 - A shipment of domestic canned, perishable hams was recalled because of swells. The abnormalities were found only in one region of the U.S. Product from the same lots shipped to other areas did not show abnormalities indicating a probability of temperature abuse during transport. Analysis of multiple swells showed elevated levels of Clostridia. These Clostridia were found to be almost entirely Clostridium perfringens. Non-spore forming bacteria were not found. The product had a sour, non-putrefactive odor. The hams had been processed approximately 2 months before swells were noticed. Low salt levels ranging down to 1.1% were found in the contents of the swollen cans.

1978 - A small lot of canned, perishable corned beef (pumped) was found to contain a high percentage of swells. Investigation revealed that the lot had been out of refrigeration in transit for a prolonged period of time. Analysis of a limited number of swells prior to voluntary destruction showed elevated levels of Clostridia and bacteria that appeared to be lactobacilli. The product was several months old at the time of temperature abuse and the brine concentrations ranged from 3.5 - 5.0%.

1979 - A lot of imported, canned, perishable, pork shoulder picnic ham was examined and passed at entry and shipped to destination. The processor examined the lot upon receipt. No swells were observed at either inspection point and the product was stored for several weeks. When these were removed for use, a low swell rate was observed and the large lot was detained pending laboratory analysis. The contents of these swells had a sour odor and all contained elevated levels of slow growing Clostridia and some gram positive aerobic spore forming rods. Because of strong evidence against domestic temperature abuse and the slow growth of the clostridia observed at 35°C, isolates from multiple cans were inoculated to cooked meat tubes and incubated at 35, 20 and 9°C. Growth was first observed at 3 days at 35°C, at 7 days at 20° and surprisingly at 7 days at 9°C. After the unusual finding of an apparent psychrotropic Clostridia in commercial canned, perishable product, we determined whether the spores of this microorganism could germinate and grow at these same temperatures. This Clostridia sporulated poorly and slowly, however, prolonged incubation in plate count agar tubes containing added $FeCl_2$ and incubated anaerobically yielded modest numbers of oval subterminal spores that swelled the cell. These cultures were mascerated and alcoholized to destroy vegetative cells (4). The spores were then inoculated into cooked meat tubes and again incubated at 35, 20 and 9°C. Growth was first observed at 3 days after 35°C, after 3 days at 20°C and after 14 days at 9°C. When the lot of product was sorted after several weeks of additional storage under refrigeration, progressive swelling had occurred and the lot contained approximately 14% swells. Information was obtained that these hams were tumbled or massaged.

1980 - A small lot of domestically produced canned, perishable hams was returned to the processor because of observed swells. The lot was apparently in transit for some time without refrigeration. Examination of the contents of swells from this incident showed that the product was partially digested and had a sour slightly putrid odor. Elevated levels of Clostridia were observed. No non-spore forming bacteria were found. In each of the incidents described here where Clostridia were found, some units examined contained 10^6 or more Clostridia per gram. In each of these instances both the product and representative culture filtrates were injected into mice and found to be non-toxic.

Although large volumes of canned, perishable, comminuted loaves are sold in the U.S., it is surprising that all of the incidents reported here were derived from pumped product. This information tends to agree with the brine concentration in normal cans data presented, indicating that the anticlostridial effect of salt and nitrite may be low or non-existent in some cans of canned, perishable hams. Further, it is likely that the anticlostridial effect of the higher brine units will be reduced after extended refrigerated storage with concurrent residual nitrite reduction. In two of the incidents reported, nearly all the cans examined yielded the same apparent clostridial species. This is inconsistent with the random mixture of species of Clostridia in the environment and suggests a possible contribution from processing plants and procedures. In one of these incidents, the predominant clostridial isolate was clearly psychrotropic. This is disturbing because it is rarely observed (9) and more importantly because in addition to C. botulinum type E, nonproteolytic strains of both type B and type F are capable of growth and toxin production at commercial refrigeration temperatures (7).

While the number of incidents reported here with public health implications is low, we repeatedly observed that many swells occur in such incidents. We are also acutely aware that only a small proportion of these incidents are brought to our attention.

In conclusion, the data presented here indicates that while canned, perishable meats have an outstanding safety record, the preservative effect of nitrite and salt is not as effective as generally believed because of pumping variation and disipation of nitrite during prolonged refrigerated storage. Industry and regulatory officials throughout the world should accelerate their efforts to maintain proper refrigeration of these products. In addition, research should be encouraged to carefully study the safety of perishable, canned meats and to possibly improve their preservation systems.

ACKNOWLEDGEMENT

The authors are indebted to Mr. James Barth, Chemistry Division, Science, FSQS, USDA for collecting and organizing the brine concentration data presented in Tables 1 and 2.

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TABLE 1. Brine concentrations (%): Imported perishable canned hams, 1973-1977

Cumulative frequency (%)	1973	1974	1975	1976	1977
0.5 or more	100	100	100	100	100
1.0 or more	100	100	100	100	100
1.5 or more	100	99	99.8	100	100
2.0 or more	100	97	99.5	99	100
2.5 or more	100	96	97	97	99
3.0 or more	93	88	89	93	86
3.5 or more	90	82	73	78	63
4.0 or more	34	43	46	47	39
4.5 or more	10	9	16	10	16
5.0 or more	0	1	5	2	3
5.5 or more	0	*	1	1	1
6.0 or more	0	0	0	*	0
6.5 or more	0	0	0	*	0
Samples	29	267	664	493	202
Avg. brine (%)	3.8	3.8	3.8	3.8	3.7

* Less than 1%

TABLE 2. Brine concentrations (%): Domestic perishable canned hams, 1973-1977

Cumulative frequency (%)	1973	1974	1975	1976	1977
0.5 or more	100	100	100	100	100
1.0 or more	100	99.8	99.8	100	100
1.5 or more	97	99	99	99.9	100
2.0 or more	94	96	96	99	99
2.5 or more	88	92	92	95	96
3.0 or more	61	74	73	79	91
3.5 or more	39	42	39	38	57
4.0 or more	20	18	17	15	30
4.5 or more	8	6	5	3	11
5.0 or more	0	*	*	*	2
5.5 or more	0	0	0	*	*
6.0 or more	0	0	0	*	*
6.5 or more	0	0	0	*	*
Samples	64	403	650	979	247
Avg. brine (%)	3.2	3.3	3.3	3.4	3.6

* Less than 1%