Microbial and Shelflife Characteristics of Beef Variety Meats Under Actual and Simulated Export Conditions

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INTRODUCTION

The United States is a major supplier of variety meats (edible offals) to the European Market. In 1979, the U.S. supplied 30.9% of the total edible beef and pork variety meats to the EEC (Miller and Bongers, 1981). This market is a valuable outlet for U.S. variety meats for which the demand is very limited in the United States. According to Miller and Bongers (1981) there are several problems accompanying the export of U.S. variety meats to Europe; these include: (1) failure to adhere to product quality standards and specifications, (2) inappropriate processing, chilling, and freezing procedures, (3) uncontrolled systems of product assembly for export by brokers, and (4) deterioration of product and packaging during transit. Matthews (1967) also noted the occasional irresponsible attitude of all segments involved in the export of U.S. variety meats.

Only limited information is available on the microbial and shelflife changes which occur with variety meats either as a result of actual shipping conditions or simulated abuse conditions. Marriott et al. (1977) noted that during long-distance transoceanic shipment of fresh beef (21 days duration) bacterial numbers were significantly ($P<0.05$) lower on samples placed in a refrigerated van with a modified atmosphere (60% CO_2, 25% O_2, 15% N_2) than those shipped under normal atmosphere conditions. Gardner (1971) studied the aerobic microflora of fresh and frozen porcine livers stored at 5° C and found that microbial contamination was primarily on the surface of livers and that freezing did not alter the spoilage characteristics once the product was thawed. Patterson and Gibbs (1978) found that variety meats produced with a minimum of handling and thus having low levels of microorganisms ($10^4/cm^2$), were capable of being stored 1-2 weeks longer under vacuum packaging than variety meats having high levels of microorganisms (10^5-$10^6/cm^2$).

Since information is so limited on microbial and shelflife characteristics of variety meats, these studies were undertaken to determine the effects of actual transcontinental and transoceanic shipping and simulated temperature abuse conditions on these characteristics.

EXPERIMENTAL

Evaluation of variety meats under actual export conditions. Beef livers and tongues were selected and evaluated for microbial and shelflife characteristics at a large meat packing plant in the United States. Normal washing, chilling and packaging procedures were used with these organs. Each variety meat was sampled for surface bacteria according to the procedures of Lazarus et al. (1977). Aerobic plate counts (APC) at 20° C were the only microbiological analyses performed at the packing plant. Trained evaluators scored the variety meats before freezing, following transcontinental shipping and following transoceanic shipping for off-odor and surface muscle color. Color scores were assigned using Munsell color chips and nomenclature as standards.

Following 7 days of frozen storage at -40° C, the variety meats were transported 2264 km to Jacksonville, Florida at a temperature of 4.5° ± 2° C. The frozen variety meats were shipped transcontinentally at a temperature above freezing in order to evaluate this system as a means of conserving energy. Microbiological analyses following transcontinental shipping included aerobic plate counts at 7°, 20°, and 35° C, coliform counts and total Enterobacteriaceae counts.

These boxed variety meats were then held in frozen storage for 184 days prior to transoceanic shipping to Rotterdam, The Netherlands. The samples were then transported to Zeist, The Netherlands where shelflife evaluation and microbiological analyses (aerobic plate counts at 7°, 20° and 35° C, coliform counts and total Enterobacteriaceae counts) were determined.

Evaluation of variety meats under simulated temperature abuse conditions. Beef tongues and livers were obtained at the time of slaughter from two processing plants on several occasions. The organs were swabbed prior to chilling to determine the initial microbial contamination. Following swabbing, the organs were chilled for 12 hr at 3° C prior to packaging. The tongues and livers were either vacuum packaged, wrapped in polyvinyl chloride (PVC) film or had no packaging material (naked) prior to boxing. The product was frozen at -29° C and stored up to 42 days before simulated shipping temperature abuse.

The temperature abuse consisted of storing the palletized boxes of livers and tongues at 22-28° C for 24 hr (simulated loading of a ship) followed by storage at -1.0° C for 13 days. The 13 days storage simulated shipping conditions where product which is temperature abused during loading does not get refrozen in the hold of a ship. At the end of the abuse storage, the samples were reassessed for microbiological and shelflife characteristics. Microbiological tests included counts for aerobic bacteria at 7°, 20° and 35° C, coliforms, coagulase-positive Staphylococcus aureus, Clostridium perfringens, KF Streptococcus, total anaerobes, yeasts and molds and total Enterobacteriaceae. An additional set of samples were removed from frozen storage which did not receive the shipping-temperature abuse. These were used as controls to determine the effects of the frozen storage, without temperature abuse, on microbial numbers and shelflife characteristics. Shelflife characteristics were scored as previously described.

Statistical analyses. Data were analyzed according to analysis of variance procedures (Snedecor and Cochran, 1972). When the analysis of variance revealed a significant ($P<0.05$) effect, Duncan's (1955) Multiple Range test was employed for mean separation. Frequency distributions were calculated for all color score data. However, only color scores showing dramatic changes following storage, abuse or transport are given in the tables.

RESULTS AND DISCUSSION

Evaluation of variety meats under actual export conditions. Microbial enumerations of beef tongues prior to and following transcontinental and transoceanic shipment showed similar patterns in regard to changes in bacterial numbers (Table 1). APC at 35° C underwent a significant ($P<0.05$) decrease following transoceanic shipment for both tongues and livers. The 7° C and 20° C APC did not change as a result of transoceanic shipping. However, for tongues, transcontinental shipping produced a significant ($P<0.05$) reduction in 20° C APC.

Freezing usually results in a reduction of the number of viable microorganisms and this was evident in regard to the 35° C APC in our study. While the reduction in bacterial numbers between Florida and Rotterdam was significant, this reduction was less than one $\log_{10}$ cycle and is probably of little practical significance. It would appear that frozen beef livers and tongues can be shipped for 72 hrs at above freezing temperatures (4.5° C) without any appreciable change in aerobic bacterial numbers. Coliform and total Enterobacteriaceae counts on product were less than 10 organisms per cm^2 following both transcontinental and transoceanic shipping.

Light brown, light reddish brown and vivid red were colors found initially on fresh tongues. After transport, light brown was virtually nonexistent, while light reddish brown did not occur at all. While vivid red accounted for over 26% of the total colors initially, it only accounted for 3% of all colors assigned tongues after transcontinental shipping and was nonexistent after transoceanic shipment. Following transoceanic shipping, moderate reddish brown accounted for 98% of the observed colors on tongues. This color was probably due to the occurrence of the metmyoglobin pigment which could result from prolonged exposure to oxygen during transport.

Moderate reddish brown and dark red occurred more frequently on fresh livers than on post transit livers. Blackish purple did not occur initially, but accounted for approximately 21% of the assigned colors following transcontinental transport. Surface dehydration is the probable cause for the presence of this color. The predominant colors following transoceanic shipping were moderate reddish brown (different pigment than that given in Table 1) which accounted for 50% of the observed colors and dark red which accounted for 21% of the colors. Virtually no off-odor was detected initially or following transcontinental or transoceanic shipment. The color differences noted between the fresh and frozen product were probably due to freezing rather than the shipping and storage conditions. The temperature abuse imposed on the variety meats during transcontinental transport and microbiological sampling in Florida was not condusive to bacterial proliferation. Thus, in instances where bacterial growth has occurred on variety meats arriving in Europe, the abuse conditions must be more severe than those of this study.

Evaluation of variety meats under simulated temperature abuse conditions. Microbial and shelflife characteristics of beef tongues and livers before and after the temperature abuse are given in Table 2. The only characteristics given in this table are those undergoing substantial changes as a result of freezing and/or the temperature abuse. Since similar patterns in counts were found for 7° and 35° C APC, only the 20° C APC are given. The highest APC for both tongues and livers were found when film wrapping or no packaging was used in conjunction with abuse. Vacuum packaging with its reduced oxygen tension appeared capable of keeping APC from proliferating even when product was subjected to a temperature abuse. For tongues, coagulase-positive Staphylococcus aureus, coliform and Clostridium perfringens counts were all very low regardless of the storage conditions. The higher anaerobic counts on naked and abused tongues vs vacuum-packaged tongues could possibly be due to the presence of facultative anaerobes. Yeasts and molds underwent an increase on abused product under aerobic conditions. The temperatures used during abuse was more favorable for yeast and mold growth than bacterial growth (Koburger, 1976).

The lower frequency of moderate reddish brown in vacuum packaged tongues is probably due to anaerobic conditions in the vacuum package which prohibited the conversion of oxymyoglobin to metmyoglobin. Vivid red which was quite prevalent initially, was greatly reduced following storage and/or abuse due to other color changes arising from oxidation, dehydration and/or bacterial proliferation. The very dark red color observed on vacuum packaged product is probably myoglobin.

Coagulase-positive Staphylococcus aureus and Clostridium perfringens counts increased from initial sampling regardless of the packaging, handling and storage conditions; although these increases were not large. Coliform counts were low and nonsignificant ($P>0.05$) between storage and handling conditions. As with tongues, the highest yeast and mold counts on livers were found on naked-abused product.

Temperature abuse resulted in a decrease in the presence of one of the moderate reddish brown colors, but not another. Color distribution for control livers was similar to livers scored initially. For livers subjected to abuse, tans and grays were also detected. This may be due to the loss of surface liver pigments in the purge, which accumulated during abuse. Frozen livers (controls) had only slight surface thawing when scored and therefore, did not have an excessive accumulation of purge.

In conclusion, if frozen beef tongues and livers are subjected to a temperature abuse similar to that of this study, vacuum packaging should allow for the least microbial proliferation and shelflife deterioration.

Table 2. Continued

Livers							
20° APC[a]	3.58[d]	3.90[d]	4.54[c]	4.93[c]	3.64[d]	3.57[d]	3.83[d]
Coagulase positive *Staphyloccus aureus*	0.19[d]	1.29[c]	1.64[c]	1.79[c]	1.34[c]	1.34[c]	1.30[c]
Clostridium perfringens	1.37[c]	0.10[d]	0.06[d]	0.00[d]	0.35[d]	0.00[d]	0.00[d]
Yeasts and molds	----	1.14[e]	2.36[c,d]	3.10[c]	1.05[d,e]	0.71[e]	2.54[c,d]
Moderate reddish brown color[b]	23.0	3.9	1.2	2.2	18.2	19.1	22.7
Dark purplish red color[b]	8.0	11.7	15.5	19.6	22.7	9.5	31.8
Moderate red color[b]	0.0	18.2	6.0	6.5	0.0	4.8	0.0
Dark reddish gray color[b]	0.0	6.5	16.7	13.0	4.6	4.8	0.0

[a]APC = Aerobic plate count, counts = $\log_{10}/cm^2$.

[b]Frequency in percent of all colors scored for either livers or tongues within packaging and storage conditions. Not all colors assigned are given.

[c,d,e]Means in the same row bearing different superscripts are significantly different ($P<0.05$).

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