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Microbial Profiles of Country-Cured Hams Aged in Stockinettes, Barrier Bags, and Paraffin Wax

F. A. DRAUGHON,* C. C. MELTON, AND D. MAXEDON

Department of Food Technology and Science, University of Tennessee, Knoxville, Tennessee 37916

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No significant differences were found in surface microflora of country-cured hams covered with stockinettes, barrier bags, or a coating of paraffin wax during aging, except for a reduction in mold growth on waxed hams. The incidence of *Clostridium* spp. was low in all treatments. *Micrococcus* spp. and *Streptococcus* spp. were the most common contaminants, but caused no apparent spoilage problem in any treatment.

Cured country hams are dry-cured meats commonly produced in the southern United States. They have a ripening time of 6 months to 2 years. The dry-cure method has been abandoned commercially for hams, except in the processing of country-cured hams, because of its high incidence of spoilage (2). The slow loss of water and uneven penetration of curing ingredients may permit growth of putrefactive anaerobes, causing "ham souring" or "bone taint." Uniformity of results is a problem in the country ham industry because hams of different shapes and thicknesses absorb salt and lose water at different rates. Flat lean hams lose water and cure faster than thicker, fatter hams. Lean hams are frequently too dry and salty for consumer taste (8). Thick or fat hams cure slower and thus are more susceptible to putrefactive spoilage.

Abundant mold growth is often observed on the surface of country-cured hams and is associated with sufficient age time (2). However, some researchers have reported that fungi isolated from country-cured hams are capable of producing mycotoxins (3, 5, 9, 11). In addition, many people find the appearance of mold on food distasteful. Dipping cured hams in melted paraffin wax before aging has been suggested as a means to maintain the desired moisture level and reduce surface mold growth. However, concern has been expressed that increasing moisture and limiting oxygen at the surface of the ham might favor the growth of spoilage microorganisms, such as those of the genera *Lactobacillus* and *Clostridium*.

This study was undertaken to compare the surface microflora and core samples of country-cured hams covered during aging in stockinettes, barrier bags (packaged with vacuum), and paraffin wax.

Country hams were dry cured at the University of Tennessee meat laboratory for 2 days per lb (1 lb = ~453.592 g) with 10% by weight of 8 lbs of NaCl, 2 lbs of cane sugar, and 1 oz. (ca. 29.57 ml) of $NaNO_2$. After equalization at 10°C for 30 days, 15 hams were placed in nets, 15 were placed in barrier bags (vapor proof) under vacuum, and 15 were dipped twice in hot (82°C) paraffin wax. Hams were aged at 25°C for 6 months. Surface swab samples and core samples were then taken from the outer butt side of each ham. Swab samples were diluted in 0.1% peptone water containing 3% NaCl. Serial dilutions were made and plated on standard methods agar (aerobic counts), reinforced clostridial agar (anaerobic count), violet red bile agar (coliforms), and sulfite polymyxin sulfadiazine agar (*Clostridium perfringens*) (6). Core samples were taken by aseptically removing the outer layer of fat (ca. 1 cm) and using a sterile cork borer. Core samples were placed in reinforced clostridial medium, flushed with nitrogen, and blended for 1 min. Serial dilutions were prepared in reinforced clostridial medium (6) and plated as described above. Coliform counts were not taken. Aerobic and anaerobic samples were incubated at 32°C for 48 h. Anaerobic conditions were provided by a GasPak jar (BBL, Cockeysville, Md.) with a hydrogen plus carbon dioxide generator. Violet red bile agar and sulfite polymyxin sulfadiazene agar plates were incubated at 37°C for 24 h. All plating was done in duplicate. For each treatment (stockinette, barrier bag, wax), 100 colonies were selected for identification.

Each separate colony of mold on each ham was sampled with a sterile swab and inoculated onto potato dextrose agar (acidified) and malt extract agar for isolation and identification.

Of the 300 yeast and bacterial isolates taken from 45 country-cured hams (100 per treatment), the primary isolates were bacteria of the genera *Micrococcus*, followed in number by *Streptococcus*, *Bacillus*, coagulase-negative

Staphylococcus and *Lactobacillus* (Table 1). The yeasts of the genera *Debaryomyces* and *Candida* were isolated in small numbers from waxed hams and hams held in barrier bags. Of the nine clostridia isolated, six were nonmotile long rods (ca. 10 to 15 μm) which formed spherical spores terminally swelling the cell. They liquefied gelatin and formed acid and gas from glucose and were identified as *Clostridium putrefaciens*. The remaining clostridia were similar except for not liquifying gelatin. They were not identified, but may have been a variant of *C. putrefaciens*. No *C. perfringens* were isolated.

Microbial counts for surface swab and core samples are shown in Table 2. The highest counts were total aerobic counts from surface swab samples. These were significantly higher ($P < F = 0.05$) than other counts. Surface samples contained low levels of anaerobes and coliforms. Surface samples were essentially free of *C. perfringens*, since none were detected at the 10^1 dilution. Aerobic and anaerobic counts for core samples were low ($\log_{10}$ counts, 1.11 to 2.91). Langlois and Kemp (7) reported that total aerobic $\log_{10}$ counts on core samples decreased from 3.26 to 2.01 ($\log_{10}$/g) at 1 and 3 months of aging, respectively. All country hams in this study had counts of $\log_{10}$ 5 or less at 6 months of aging.

One ham from the stockinette treatment and one ham from the barrier bag treatment had internal spoilage. The term "souring" is often used to describe putrefactive spoilage. Souring also may refer to other important types of spoilage, from nonodorous proteolysis to genuine putrefaction with its obnoxious odors (4). Salt tolerant bacteria in the genera *Alcaligenes*, *Bacillus*, *Pseudomonas*, *Lactobacillus*, *Proteus*, *Serratia*, *Micrococcus*, and *Clostridium* are reported to cause souring (4). However, aerobic bacteria such as those of the genera *Pseudomonas*, *Alcaligenes*, and *Micrococcus* are seldom, if ever, a problem since the salt content at the surface is high. Spoilage of a serious nature is usually encountered internally when salt and nitrites do not migrate into the meat in sufficient concentrations to reduce water activity and limit anaerobic growth. The souring observed in the current study was along the femur bone. The smell was putrefactive and probably due to *C. putrefaciens*, since this organism was isolated six times from core samples of barrier bag and netted hams. Since 2 of a total of 45 hams exhibited spoilage, the rate of spoilage was 4.4%. Commercially, the incidence of spoilage has been reported to be as high as 5 to 7% in early studies (1941 to 1951). However, spoilage occurs less often today due to good sanitation and proper handling of carcasses (2).

The predominant genus of mold isolated was *Penicillium*. *Aspergillus*, *Cladosporium*, *Scopulariopsis*, and *Epicoccum* molds were also isolated. Waxing substantially reduced the growth of mold on ham surfaces. *Cladosporium* and *Epicoccum* molds, which cause "black spot" on hams, were not isolated from waxed hams. Since black spot must be cut out of hams, thus causing an economic loss, their elimination by waxing is a distinct advantage. The penicillia which grew did so primarily along cracks in the wax and in air pockets. Approximately the same numbers and types of molds were isolated from hams held in barrier bags as from stockinettes. Although barrier bags have some vacuum and

TABLE 1. *Microorganisms isolated from country-cured hams held for 6 months at 25°C in stockinettes, barrier bags, and wax coating*[a]

Genus of microorganism isolated	Stockinette[b]		Barrier bag[b]		Wax coating	
	Exterior	Core	Exterior	Core	Exterior	Core
Bacillus	13	0	22	0	17	0
Micrococcus	20	0	28	0	13	0
Staphylococcus[c]	13	5	14	0	19	0
Lactobacillus	1	5	0	4	6	0
Streptococcus	13	16	14	7	14	16
Clostridium	0	4	0	3	0	2
Aerococcus	0	2	0	0	0	0
Vibrio/Pseudomonas	8	0	1	0	6	0
Debaryomyces	0	0	5	0	6	0
Candida	0	0	2	0	1	0
Aspergillus	7		1		0	
Penicillium	12		14		6	
Cladosporium	3		3		0	
Scopulariopsis	2		2		0	
Epicoccum	1		0		0	

[a] Values shown represent total numbers of isolates from each treatment.
[b] One ham exhibited putrefactive spoilage in this group.
[c] Coagulase negative, deoxyribonuclease negative.

TABLE 2. *Microbial counts for core and surface samples from country-cured hams held for 6 months at 25°C in stockinettes, barrier bags, and wax coatings*[a]

Treatment of:	Stockinette	Barrier bag	Wax coating
Surface samples			
Aerobic	4.34	4.83	4.30
Anaerobic	ND[b]	ND	1.89
Coliform	<1	<1	<1
C. perfringens	ND	ND	ND
Core samples			
Aerobic	1.34	1.48	1.11
Anaerobic	2.91	2.09	2.51
C. perfringens	ND	ND	ND

[a] All data are the mean of 15 samples plated in duplicate and are given as $\log_{10}/cm^2$ for surface samples and as $\log_{10}$/g for core samples.
[b] ND, None detected.

are vapor proof, air pockets and leakage allowed entrance of sufficient oxygen for mold growth. Country hams age satisfactorily without mold activity; however, Ayres et al. (1) reported that the fat of hams cured with mold growth was less yellow and rancid than that of hams free of mold growth. Since ultraviolet light has been shown to increase oxidative rancidity of country-cured hams (10), mold growth may provide a physical barrier to prevent the ultraviolet light initiated oxidation.

Overall, there were no significant differences in microbial quality of country-cured hams held in stockinettes, barrier bags, or wax during ripening, except for the reduction in mold on the waxed hams. The incidence of *Clostridium* spp. was low in all treatments. *Micrococcus* spp. and *Streptococcus* spp. were the most common contaminants, but caused no apparent spoilage problem in any treatment.

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