Spoilage Bacteria of Fresh Broiler Chicken Carcasses

S. M. RUSSELL,[1,2] D. L. FLETCHER,[1] and N. A. COX[3]

Department of Poultry Science, The University of Georgia, Athens, Georgia 30602-2772

and

USDA, Agricultural Research Service, Richard B. Russell Agricultural Research Center, Athens, Georgia 30604-5677

ABSTRACT Studies were conducted to identify the bacteria responsible for spoilage of fresh broiler chicken carcasses and to characterize the off-odors these bacteria produce. Broiler carcasses were collected from processing plants in the northeast Georgia area, the southeastern U.S., Arkansas, California, and North Carolina. The carcasses were allowed to spoil under controlled conditions at 3 C and spoilage bacteria were isolated. Each spoilage bacterium was separately inoculated into a sterile chicken skin medium, incubated at 25 C for 48 h, and subjectively evaluated for odor. The bacteria isolated from spoiled carcasses that consistently produced off-odors in the chicken skin medium, regardless of the geographical location from which the chickens were obtained, were *Shewanella putrefaciens* A, B, and D, *Pseudomonas fluorescens* A, B, and D, and *Pseudomonas fragi*. These bacteria produced off-odors that resembled "sulfur", "dishrag", "ammonia", "wet dog", "skunk", "dirty socks", "rancid fish", "unspecified bad odor", or a sweet smell resembling "canned corn". Odors produced by the spoilage bacteria were varied; however, odors most associated with spoiled poultry, such as "dishraggy" odors, were produced by the bacteria that were most consistently isolated, such as *S. putrefaciens* and the pseudomonads.

(*Key words*: broiler carcasses, spoilage bacteria, *Shewanella putrefaciens*, *Pseudomonas fluorescens*, off-odors)

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INTRODUCTION

Because broiler chicken carcasses are generally sold fresh, as opposed to frozen, in the U.S., identification of the bacteria associated with their spoilage is essential to understand the process by which carcasses become aesthetically unacceptable. Many studies were conducted in the 1950s and 1960s (Ayres *et al.*, 1950; Barnes and Thornley, 1966; Barnes and Impey, 1968) to isolate and identify the bacteria that are responsible for producing off-odors on spoiled poultry. Poultry production, processing, and handling methods have changed considerably over the past 30 yr, which may have an effect on the types of bacteria that produce spoilage odor defects on poultry.

The bacteria found on freshly processed poultry are primarily mesophilic and have an optimum growth temperature of about 35 C. In contrast, the populations of bacteria found on spoiled poultry are generally psychrotrophic. Psychrotrophic bacteria multiply readily at temperatures of 20 to 30 C and can grow at refrigeration temperatures.

Barnes and Thornley (1966) reported that the bacteria on broiler carcasses

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[1]The University of Georgia.
[2]To whom correspondence should be addressed.
[3]USDA.

immediately after processing were: micrococci (50%), Gram-positive rods (14%), flavobacteria (14%), Enterobacteriaceae (8%), *Pseudomonas* (2%), *Acinetobacter* (7%), and unidentified (5%). Of these genera, only *Pseudomonas* and *Acinetobacter* grow well at refrigeration temperatures. After carcasses were stored at 1 C for 10 to 11 d, the bacterial flora changed to predominantly psychrotrophs, including: 90% *Pseudomonas* spp., 7% *Acinetobacter*, and 3% Enterobacteriaceae (Barnes and Thornley, 1966). Barnes and Impey (1968) and Cox *et al.* (1975) similarly reported that pigmented and nonpigmented strains of *Pseudomonas* and strains of *Acinetobacter* were most commonly found on poultry carcasses stored under refrigeration temperatures. Most psychrotrophic bacteria originate from the feathers and feet of the bird, the water supply, chill tank, and equipment in the processing plant. Barnes (1960) determined that psychrotrophic bacteria are not found in the intestines of the bird before processing.

Many of the psychrotrophic bacteria associated with spoilage of poultry have been reclassified within the past 10 yr. Several related species from the genus *Achromobacter* were transferred to the genus *Pseudomonas* in the seventh edition of *Bergey's Manual* (Breed *et al.*, 1948; Ayres *et al.*, 1950). *Acinetobacter* spp. were once part of the genus *Achromobacter* (Thornley, 1960). *Shewanella putrefaciens* was originally classified as *Alteromonas putrefaciens* and later, *Pseudomonas putrefaciens* (MacDonell and Colwell, 1985).

Recently, studies have been conducted to determine the volatiles produced by spoilage bacteria growing on the surface of broiler carcasses. Viehweg *et al.* (1989) individually inoculated broiler chicken carcasses with 15 different strains of *Pseudomonas fluorescens, Pseudomonas putida, Pseudomonas fragi, Alteromonas putrefaciens, Serratia liquefaciens,* and *Brochothrix thermosphacta* and stored the carcasses in a dessicator at 4 C for 7 d. The headspace around the carcasses was analyzed using gas chromatography-mass spectrometry to identify the volatile compounds produced by each bacterial strain. The authors reported finding 102 different volatiles on the artificially inoculated carcasses. Of these volatiles, there were 22 sulfur compounds, 3 ethers, 22 alcohols, 6 aldehydes, 16 ketones, 20 saturated and 9 unsaturated fatty esters, 3 fatty acids, and indole (Viehweg *et al.*, 1989). No effort was made in this study to isolate and identify bacteria from spoiled carcasses, to characterize the odors produced by these bacteria, or to survey spoilage flora from different regions.

The objectives of this study were to: identify the bacteria responsible for the production of off-odors on spoiled broiler chicken carcasses; characterize the odors they produce; and survey carcasses produced in different areas of the U.S. to determine how consistently these spoilage organisms were found.

MATERIALS AND METHODS

Sample Collection and Carcass Spoilage

Fresh whole broiler chicken carcasses were collected from processing plants or from grocery stores in each of three separate trials. For the first trial, 10 carcasses were collected from a processing plant located in northeast Georgia and transported on ice to the laboratory. For the second trial, 12 carcasses from four processing plants (3 carcasses per plant) located throughout the southeastern U.S., were purchased from retail outlets. For the third trial, carcasses were collected, placed into coolers, surrounded by ice, and shipped overnight from processing plants in Arkansas (four carcasses), California (four carcasses), and North Carolina (three carcasses). Upon arrival at the laboratory, carcasses tested in Trials 1 and 3 were individually placed into sterile polyethylene bags (3,000 cc O_2 at 22.8 C/m^2 per 24 h at 1 atm); whereas, carcasses tested in Trial 2 were left in the plastic bags (4,000 cc O_2 at 22.8 C/m^2 per 24 h at 1 atm) in which they were purchased. In all three trials, the bagged broiler carcasses were placed into an incubator at 3 ± .5 C for 15 d to spoil as determined by subjective evaluation of odor.

Isolation of Spoilage Bacteria

After spoilage, carcasses were individually rinsed using 100 mL of sterile deionized water according to the procedure described

by Cox *et al.* (1981). The rinse fluid was diluted to 10^{-6}, 10^{-7}, and 10^{-8} using a sterile 1% solution of Bacto-peptone[4] and 1 mL was spread onto duplicate plate count agar[4] (PCA) plates. Plates were incubated at 25 C for 48 h. Ten colonies per carcass were randomly selected based on colonial morphological differences (if any were observed). In most instances, only three or four different morphological types were observed on plates at the highest dilution. Selected colonies were then restreaked for isolation and purity on PCA, and incubated at 25 C for 48 h. Bacterial isolates were incubated at 25 C because the ideal growth temperature for most psychrotrophic spoilage bacteria is approximately 25 C. Each bacterial colony was then individually inoculated into chicken skin medium.

Preparation of Chicken Skin Medium

Chicken skin medium was prepared by thoroughly blending 3 kg of freshly frozen chicken skin with 3 L of deionized water, similar to the procedure described by Cox and Lovell (1973) for crayfish. This mixture was placed into cheese cloth and the exudate was expressed and passed through Whatman number 1 filter paper.[5] The particulate matter was removed by centrifugation at 51,247 × *g* (relative centrifical force) for 30 min at 2 C. The supernatant fluid was decanted and filtered through a .2 μ sterile filter to remove bacteria from the medium. The medium was assayed for sterility by placing 5 mL into each of four separate sterile test tubes. Two tubes were incubated at 25 C for 48 h and the remaining two were incubated at 35 C for 48 h. After incubation, the chicken skin medium exhibited no signs of bacterial contamination, as evidenced by lack of turbidity or odor in the test tube samples. Two .1-mL aliquots of the medium were also spread-plated onto plate count agar and incubated at 25 C for 48 h. After 48 h, no colonies were observed.

To ensure that the chicken skin medium would support the growth of bacteria, common spoilage organisms, such as *P. fragi*, *P. putida*, *P. fluorescens*, and *Acinetobacter* spp., were inoculated into the medium and incubated at 25 C for 48 h. All species grew readily in the medium, as evidenced by an increase in turbidity and the production of characteristic off-odors. The pH of the medium was 6.1 after filtration.

Odor Analyses

To evaluate odor production, one loopful (10 μL) of each isolate was inoculated into sterile chicken skin medium (5 mL) and incubated at 25 C for 48 h. An incubation temperature of 25 C was used to ensure the growth of psychrotrophic bacteria, some of which do not grow at temperatures above 30 C. Refrigeration temperatures were not used for culturing isolates because spoilage bacteria multiply most rapidly and produce off-odors at approximately 25 C. After incubation, each tube was uncapped briefly and sniffed by three different trained panel members. Each odor was subjectively associated with "common" scents such as "ammonia", "canned corn", "dishrag", "dirty socks", "isopropyl alcohol", "mulched lawn clippings", "fresh paint", "rancid fish", "skunk", "sulfur", "unspecified bad odor", and "wet dog". Two uninoculated tubes were incubated as controls and were compared to inoculated samples for odor production. The uninoculated samples produced no detectable off-odors. After sniffing each sample, the panel members agreed on the category into which each off-odor should be placed. Bacteria that produced objectionable off-odors were identified and classified by the odors they produced. Although 10 colonies per carcass were isolated and purified, not all bacterial isolates were identified because many isolates did not produce objectionable odors in the chicken skin medium.

Identification

Each odor-producing isolate was assayed for Gram reaction, cytochrome oxidase activity, and production of catalase. Bacteria were identified using either the Vitek,[6] Biolog,[7] or Micro-ID[8] rapid identification methods.

[4]Difco Laboratories, Detroit, MI 48232.
[5]Whatman, Inc., Clifton, NJ 07014.
[6]bioMérieux Vitek, Inc., Hazelwood, MO 63042-2395.
[7]Biolog, Inc., Hayward, CA 94545.
[8]Organon Teknika Corp., Durham, NC 27704.

RESULTS AND DISCUSSION

The generation time of pseudomonads on refrigerated chicken is approximately 30% shorter than other populations of bacteria involved in spoilage (Viehweg *et al.*, 1989). This explains the fact that species of *Pseudomonas* and *Shewanella* (formerly *Pseudomonas* or *Alteromonas*) have been repeatedly reported as the primary spoilers of fresh poultry since the 1930s (Lockhead and Landerkin, 1935; Haines, 1937; Empey and Scott, 1939; Ayres *et al.*, 1950; Kirsch *et al.*, 1952; Wolin *et al.*, 1957). Viehweg *et al.* (1989) observed that the pseudomonads and *Shewanella* produced more sulfur compounds than any of the other common spoilage bacteria and that these sulfur compounds masked other less odoriferous volatiles when conducting subjective odor evaluations. These sulfur compounds are not produced on fresh meat until bacterial concentrations reach 1.6×10^5 to 1×10^8 cfu/cm^2 (Lockhead and Landerkin, 1935, and Elliott and Michener, 1961). Based on these studies, the bacteria that are responsible for producing the predominant off-odors on fresh poultry should be those that are highest in number (exceed a concentration of 10^5) and produce the most odoriferous sulfur compounds. Therefore, plates at the highest dilution were used for selection of colonies to be analyzed for odor production and subsequent identification.

The results for broiler carcasses obtained in northeast Georgia are presented in Table 1. Spoilage bacteria isolated from these carcasses were similar to those reported by Vanderzant and Ousley (1963), Barnes and Thornley (1966), and Barnes and Impey (1968). The bacterial species most commonly isolated were *S. putrefaciens* A, B, and D (formerly *Pseudomonas putrefaciens*), pigmented and nonpigmented strains of *Pseudomonas*, such as *P. fluorescens* A and B, *P. putida*, and *P. fragi*, and Gram-positive enterococci, such as *Enterococcus faecalis* and *Enterococcus faecium*. Similar to results reported by Barnes and Thornley (1966), one genera of Enterobacteriaceae, *Serratia liquefaciens*, remained at high levels during cold storage. Other bacteria that have been shown to grow on spoiled broiler carcasses such as *Acinetobacter* spp., *Aeromonas* spp., and *Alteromonas* spp. were also isolated; however, they were less common.

The results of odor-producing spoilage bacteria isolated from broiler carcasses obtained in the southeastern U.S. are presented in Table 2. Although the packaging material used in Trial 2 had a

TABLE 1. Off-odor producing spoilage bacteria isolated from 10 broiler chicken carcasses obtained from a processing plant in northeast Georgia using a carcass rinse procedure

Species	Gram reaction	Number[1]	Odor[2]
Acinetobacter lwoffi	–	1	RF
Aeromonas veronii DNA group 8	–	1	SUL, AMO
Alteromonas haloplanktis	–	1	SUL
Enterococcus faecalis	+	4	MLC
Enterococcus faecium	+	1	MLC
Leclercia adecarboxylata	–	1	SUL
Pseudomonas fluorescens A	–	1	SUL
Pseudomonas fluorescens B	–	1	CC, DR
Pseudomonas fragi	–	8	CC, DR, SUL
Pseudomonas putida A	–	2	SUL, PA
Serratia liquefaciens	–	1	UBO
Shewanella putrefaciens A	–	4	DR, SUL
Shewanella putrefaciens B	–	3	DR, WD
Shewanella putrefaciens D	–	1	SUL

[1]Number of times a particular off-odor producing bacterial species was isolated from carcasses obtained from a processing plant located in northeast Georgia.

[2]Bacteria produced the following off-odors when grown in sterile chicken skin medium at 25 C for 48 h: AMO = "ammonia", CC = "canned corn", DR = "dishrag", MLC = "mulched lawn clippings", RF = "rancid fish", PA = "paint", SUL = "sulfur", UBO = "unspecified bad odor", and WD = "wet dog".

TABLE 2. Off-odor producing spoilage bacteria isolated using a carcass rinse procedure from 12 broiler chicken carcasses obtained from a grocery store representing four processing plants located throughout the southeastern U.S.

Species	Gram reaction	Number[1]	Odor[2]
Alcaligenes faecalis	–	1	AMO
Aeromonas veronii DNA group 11	–	1	SUL
Pseudomonas fluorescens A	–	4	SUL
Pseudomonas fluorescens D	–	1	SUL
Pseudomonas fragi	–	4	AMO, RF, DR, SUL
Serratia fonticola	–	1	UBO
Serratia liquefaciens	–	1	IA
Shewanella putrefaciens A	–	13	SK, SUL
Shewanella putrefaciens B	–	3	SUL
Shewanella putrefaciens D	–	7	SUL

[1]Number of times a particular off-odor producing bacterial species was isolated from carcasses obtained from a grocery store representing four processing plants located throughout the southeastern U.S.

[2]Bacteria produced the following off-odors when grown in sterile chicken skin medium at 25 C for 48 h: AMO = "ammonia", DR = "dishrag", IA = "isopropyl alcohol", RF = "rancid fish", SK = "skunk", SUL = "sulfur", and UBO = "unspecified bad odor".

slightly higher oxygen permeability than the material used in Trials 1 and 3 (4,000 vs 3,000 cc), the results obtained in Trial 2 closely resembled those in Trials 1 and 3. The primary spoilage bacteria isolated from carcasses obtained in the southeast were *Shewanella putrefaciens* A, B, and D, and pigmented and unpigmented strains of *Pseudomonas* (*P. fluorescens* A and D and *P. fragi*). Gram-positive enterococci were not isolated. Other Gram-negative bacteria identified less frequently than *Shewanella* or *Pseudomonas* were *Alcaligenes* spp. and *Aeromonas* spp. Also, the Enterobacteriaceae were represented by two groups of *Serratia* (*S. liquefaciens* and *S. fonticola*).

The results of spoilage bacteria isolated from carcasses obtained from three different states in the midwestern, western, and eastern parts of the U.S. are presented in Table 3. For carcasses collected from Arkansas, *S. putrefaciens* A and B and

TABLE 3. Odor-producing spoilage bacteria isolated from broiler chicken carcasses, using a carcass rinse procedure, obtained from processing plants located in Arkansas (four carcasses), California (four carcasses), or North Carolina (three carcasses)

Species	Gram reaction	Number[1]	Odor[2]
Arkansas			
Acinetobacter calcoaceticus (genosp. 1)	–	1	SUL
Enterococcus faecalis	+	2	DS, UBO
Shewanella putrefaciens A	–	1	SUL
Shewanella putrefaciens B	–	2	DR, DS
California			
Pseudomonas fluorescens A	–	2	DR, SUL
Pseudomonas fluorescens B	–	3	DR
Shewanella putrefaciens A	–	6	DR, SUL, UBO
North Carolina			
Pseudomonas fluorescens A	–	3	CC, SUL
Pseudomonas fluorescens B	–	2	DR, SK

[1]Number of times a particular off-odor producing bacterial species was isolated from carcasses obtained from processing plants located in Arkansas, California, and North Carolina.

[2]Bacteria produced the following off-odors when grown in sterile chicken skin medium at 25 C for 48 h: CC = "canned corn", DR = "dishrag", DS = "dirty socks", SK = "skunk", SUL = "sulfur", and UBO = "unspecified bad odor".

Gram-positive *E. faecalis* predominated. *Acinetobacter calcoaceticus* was also isolated. For carcasses collected from California and North Carolina, surprisingly few genera of bacteria were isolated at the highest dilution. For carcasses collected from California, *P. fluorescens* A and B and *S. putrefaciens* A were the only bacteria selected. For carcasses collected from North Carolina, the only bacteria that produced spoilage odors were *P. fluorescens* A and B. The lack of diversity among the genera of spoilage bacteria isolated from carcasses from North Carolina or California may be explained by differences in the environment used to rear the chickens or possibly subtle differences in processing procedures.

Pseudomonads and *S. putrefaciens* were the spoilage bacteria most commonly isolated of those selected from spoiled broiler chickens regardless of the geographical location from which the carcasses were obtained. These data are consistent with previous studies (Cox *et al.*, 1975) in which these Gram-negative, cytochrome-oxidase-positive bacteria are most commonly associated with spoiled poultry.

During the initial stages of spoilage, the off-odors produced by poultry spoilage bacteria have been described as sour, tainted, acid, or dishraggy, and upon prolonged storage may become ammoniacal or dishraggy (Ayres *et al.*, 1950). Vanderzant and Ousley (1963) reported that *P. fluorescens, P. fragi,* and *P. putrefaciens* cause a variety of flavor and odor defects in foods by their proteolytic and lipolytic activities. In the initial stages of spoilage, off-odors are not caused by proteolysis but from the direct microbial utilization of low molecular weight nitrogenous compounds such as amino acids in skin and muscle (Vanderzant and Ousley, 1963). Spoilage occurs when the carbohydrate source in a growth medium is exhausted by the bacteria. Once the carbohydrate supply is depleted, spoilage bacteria, such as the pseudomonads, begin to utilize other sources of energy which produce odoriferous end-products (Pooni and Mead, 1984). Bacteria must multiply to a high number before the supply of carbohydrate is exhausted. Off-odors are produced when the population of spoilage bacteria reaches between 5.2 to 8.0 $\log_{10}$ cfu/cm^2 or when the pseudomonads reach populations of 10^8 cfu/g (Elliott and Michener, 1961).

Off-odors produced by the spoilage bacteria isolated were varied. Presumably, because all other variables except temperature were held constant, spoilage bacteria should produce similar compounds when incubated at 25 C as they do when incubated at refrigeration temperature (actual spoilage conditions). *Shewanella putrefaciens* produced odors that were described as "sulfur", "dishrag", "wet dog", "skunk", "dirty socks" or "unspecified bad odor". Off-odors produced by *P. fluorescens* A, B and D smelled like "sulfur", "dishrag", "skunk", or a sweet smell resembling "canned corn". *Pseudomonas fragi* produced odors that were similar to "sulfur", "dishrag", "ammonia", "rancid fish", or "canned corn". *Pseudomonas putida* A produced "sulfur" or "fresh paint" odors. Upon growth in the chicken skin medium, *E. faecalis* and *E. faecium* smelled like "mulched lawn clippings", "dirty socks" or "unspecified bad odor". The odors produced by *Acinetobacter* spp. were described as "sulfur" and "rancid fish". *Aeromonas, Alteromonas, Alcaligenes,* or *Leclercia* produced "sulfur" or "ammonia" odors. The Enterobacteriaceae, namely *Serratia* spp., produced "isopropyl alcohol" or "unspecified bad odors". *Pseudomonas* spp. and *Shewanella* spp. in this study produced characteristic "dishrag" or "sulfur" off-odors that have been associated with spoiled poultry by numerous researchers (Ayres *et al.*, 1950, and Viehweg *et al.*, 1989); whereas, Gram-positive organisms such as *Enterococcus* spp. produce "dirty" or "soil-like" odors. The other bacteria identified produced compounds that contributed to a variety of different off-odors.

It is possible that one species of bacteria may produce different odors. The factors that may contribute to more than one off-odor being produced include: 1) time of incubation and 2) consistency of the nutrients in the medium.

Results from this study are in agreement with previous research in which *Pseudomonas* and *Shewanella* are named as the primary genera of bacteria responsible for the spoilage of fresh chicken. If a

medium is developed to select for the growth of these spoilage organisms, it may be possible to obtain a reliable estimation of their number on day of processing, which could correlate with subsequent shelf-life.

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