

Shelf Life of Ground Poultry Meat Stored Under Modified Atmosphere¹

L. Saucier,² C. Gendron, and C. Gariépy

Food Research and Development Centre, Agriculture and Agri-Food Canada, St-Hyacinthe, Québec, Canada J2S 8E3

ABSTRACT The shelf life of ground chicken and turkey meat packaged under a modified atmosphere containing O₂ and a high level of CO₂ (62% CO₂, 8% O₂, and 30% N₂; gas-1), or a gas mixture without O₂ (20% CO₂ and 80% N₂; gas-2) was evaluated for 20 d at 1 C. Meat packaged under gas-2 maintained a higher a* value (redness) throughout the experiment and generally had a more appealing color than the meat packaged using gas-1. Microbial populations were assessed after 8, 12, and 15 d of storage. Total aerobic mesophilic counts were higher in

chicken meat than in turkey throughout storage. Coliforms and *Escherichia coli* counts were lower in meat packaged under gas-1. After 15 d of storage at 1 C, *Brochothrix thermosphacta* was detected only in ground chicken meat packaged using gas-2. Meat packaged under the gas mixtures tested had similar counts for presumptive pseudomonads, *Staphylococcus aureus*, and lactic acid bacteria. These results indicate that an appropriate gas mixture can maintain a desirable color in ground poultry meat but offers no guarantees with respect to the microbial profile of meat.

(Key words: ground meat, modified atmosphere, poultry, shelf life, storage)

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INTRODUCTION

Conventional mechanically deboned poultry meat is obtained through the processing of turkey frames and poultry backs and necks using an automatic extrusion deboner. Mechanically deboned poultry meat is a finely comminuted product whose paste-like texture makes it more appropriate for use in emulsion-type products. By using belt-meat-bone separation technology, a coarse product can now be sold as fresh-ground poultry meat at the retail level. Because ground meat is a highly perishable commodity, its shelf life must be optimized to meet the requirements of market conditions. Modified atmosphere packaging (MAP) was proven useful for that purpose (Dainty and Mackey, 1992). Microflora, as well as pigment and unsaturated lipid contents of poultry meat, may justify the need for different packaging gas mixtures than those used with red meat to optimize the appearance and shelf life of ground poultry (Dawson et al., 1995).

The initial microflora of meat is mesophilic and can reach 10² to 10⁴ bacteria/cm² after carcass evisceration (Dainty and Mackey, 1992). This microflora varies with

storage conditions. When meat is refrigerated, a psychrotrophic flora develops. Because of a shorter generation time than the other microorganisms under aerobic conditions and low temperature (<5 C), *Pseudomonas* spp. prevail and constitute up to 50 to 90% of the overall microbial population (Stiles, 1991b; Dainty and Mackey, 1992). *Enterobacteriaceae* prevail under conditions of poor refrigeration (10 C) and spoil the meat (Stiles, 1991b; Dainty and Mackey, 1992). In an anaerobic environment, lactic acid-producing bacteria prevail because they are more tolerant to CO₂ than pseudomonads or *Enterobacteriaceae* (Stiles, 1991b; Dainty and Mackey, 1992). By using an atmosphere of 100% N₂, it has been demonstrated that the effect of CO₂ goes beyond the simple displacement of O₂, as a mixture of N₂ and CO₂ is more inhibitory. The CO₂ affects microbial growth by extending the lag phase and increasing the generation time (Daniels et al., 1985; Stiles, 1991b). A minimum concentration of 20 to 30% is necessary to have an inhibitory effect (Stiles, 1991a). An extended storage life of meat under anaerobic conditions is observed because the spoilage caused by the lactic acid bacteria (LAB) that grow on meat occurs later compared to the spoilage caused by the aerobic bacteria under aerobic conditions. In general, the defect caused by LAB is described as "souring," which is less offensive than the putrefaction that develops aerobically (Stiles, 1991b; Dainty and Mackey, 1992). The LAB are generally viewed

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²To whom correspondence should be addressed: saucierl@EM.AGR.CA.

Abbreviation Key: APT = All Purpose Tween Agar; LAB = lactic acid bacteria; gas-1 = with O₂; gas-2 = without O₂; MAP = modified atmosphere packaging; MRS = deMan, Rogosa, and Sharpe Agar.

as preservative agents for meats packaged under modified atmosphere (Stiles, 1991b). However, some LAB, like *Lactobacillus sakei*, can cause spoilage by production of hydrogen sulfide from the degradation of cysteine in glucose-limiting (e.g., raw meat) or O₂-limiting conditions (Egan et al., 1989).

Microflora and spoilage defects of chicken carcasses packaged anaerobically are similar to those observed for red meat (Gill et al., 1990). Baker et al. (1985) confirmed that lactic acid producing-bacteria develop and that the product shelf life improves with a MAP high in CO₂ for ground chicken. The authors recommended a concentration as high as 60 to 80% for a storage of 28 d. Sawaya et al. (1995) also recommend a high concentration of CO₂ (70%) for chicken carcasses refrigerated under MAP.

Discoloration and lipid oxidation in fresh red meat are closely related (Greene et al., 1971). At high concentration in MAP, O₂ can react with myoglobin to form bright red, stable oxymyoglobin. Under low partial pressures, oxidation to brown metmyoglobin is promoted (Faustman and Cassens, 1990). However, the literature is not clear on the color stability and discoloration of ground poultry meat under MAP conditions. For poultry, Gill (1995) reported that little is gained by using high O₂ concentrations in terms of color improvement. According to Hotchkiss and Langston (1995), however, inclusion of O₂ in the MAP gas mixture can have beneficial effects on color of meat and poultry, in spite of the apparent color stability of most fresh poultry products. They reported "graying" of conventionally ground poultry meat under MAP, a phenomenon also noted by Baker et al. (1985). Ground meat is much more susceptible to oxidation because oxygen is incorporated during the mixing of fat with lean tissue. The concomitant liberation of catalytically active iron amplifies the oxidation process (Jensen et al., 1998).

The purpose of this study was to evaluate the shelf life of ground chicken and turkey meat packaged under modified atmosphere. Meat was obtained through meat-bone-separation machinery, and conditions involving two different O₂ and CO₂ levels in the gas mixture were tested.

MATERIALS AND METHODS

MAP Ground Poultry Meat

Fifteen kilograms of ground turkey and chicken meat were supplied by Exceldor (St-Damase, Québec, Canada).

The ground meat was obtained from a Baader BA 601 belt-meat-bone separator³ and was kept in the freezer until it was carried on ice to the laboratory the same day. Samples were prepared in a cold room (5 C) where 180 g of meat were placed in a Dynopack tray⁴ and sealed with Dynoseal ST 1575 film⁴ (15 μm of bi-oriented polyamide and 75 μm of laminated polyethylene; O₂ transmission rate < 35 cm³/m² per 24 h at 25 C; 0% RH under a pressure of 1 atmosphere). Meat was packaged under two different modified atmospheres and stored at 1 C. The gas mixture comprised 62% CO₂, 8% O₂, and 30% N₂ (gas-1⁵) or 20% CO₂ and 80% N₂ (gas-2)⁵. Gas composition was analyzed at 0, 8, 12, 15, 20, and 22 d of storage using an O₂/CO₂ analyzer⁶. The dynamics of gas concentration observed throughout the storage period was typical of MAP of meat. The O₂ level decreased due to consumption by the tissues as well as microbial growth, and the CO₂ level decreased due to solubilization in the tissue (Dainty and Mackey, 1992).

Meat Composition

Fat content was determined on four replicates of freeze-dried samples according to procedure 991.36 of the Association of Official Analytical Chemists (AOAC, 1995); results are expressed on a wet weight basis. Weight differences before and after lyophilization were used to determine water content. Total protein determination was carried out according to procedure 992.15 of the AOAC (1995) with a LECO protein analyzer (model FP428)⁷ using ground meat without prior treatment. Results are expressed as a mean (n = 4) percentages on a wet weight basis (AOAC, 1995). Total myoglobin content was analyzed using the procedure described by Trout (1991) and is expressed as mg/g (wet weight basis). The pH measurements were carried out on four replicates of ground meat tightly packed around a xerolyte meat probe electrode⁸.

Color Analysis

Color indices (L*, a*, and b* values) were measured with a Chroma Meter II⁹ upon opening of the tray following 30 min blooming period. Results are expressed as the average of four measurements taken at the surface of each sample.

Microbial Counts

Meat samples of 25 g were removed aseptically from the tray and homogenized in 225 ml of 0.1% peptone water for 2 min using a Stomacher 400 Lab Blender¹⁰. Cell counts were determined by plating serial dilutions of the meat homogenate. Total aerobic plate counts were performed on Plate Count Agar¹¹, and plates were incubated aerobically at 35 C for 2 d. Coliforms were enumerated on Violet Red Bile Agar¹¹ according to the supplier's recommendations, and plates were incubated at 35 C for 18 to 24 h. *Escherichia coli* counts were determined on Petrifilms™ *Escherichia coli* Count Plates¹² after an incuba-

³Nordischer Maschinenbau Rud. Baader GmbH, Lübeck, Germany D-23556.

⁴Dynopack, Kristian Sand, Norway, N4602.

⁵Praxair, St.-Hubert, Canada, J3Y 8Y7.

⁶Illinois Instruments, Inc., Ingleside, IL 60041.

⁷LECO Corp., St. Joseph, MO 49085-2396.

⁸Ingold, Wilmington, MA 01887.

⁹Minolta, Ramsay, NJ 07446.

¹⁰Seward Medical, London, UK N2 0GN.

¹¹Difco Laboratories, Inc., Detroit, MI 48232-7058.

¹²Microbiology Products 3M Health Care, St. Paul, MN 55144-1000.

TABLE 1. Proximate analysis and pH values of ground poultry meat¹

Poultry meat	Water [%]	Fat [%]	Proteins [%]	pH	Myoglobin [mg/g]
Chicken	70.34 ^b (0.07)	10.85 ^a (0.17)	17.49 ^b (0.24)	6.18 ^a (0.01)	3.26 ^a (0.16)
Turkey	74.28 ^a (0.21)	3.61 ^b (0.27)	21.99 ^a (0.18)	5.95 ^b (0.01)	0.95 ^b (0.05)

^{a,b}Means in the same column followed by a different superscript are significantly different ($P < 0.001$).

¹Results are expressed as a mean of two samples done in duplicate, and SEM are in parentheses.

tion of 18 to 24 h at 35 C. After 15 d of storage, presumptive *Pseudomonas* spp. were counted on Cephaloridine Fucidin Cetrimide Agar (Baird et al., 1987; Gill and Greer, 1993) and *Brochothrix thermosphacta* on Streptomycin Thallous Acetate Actidione Agar (Gill and Greer, 1993). Plates were incubated aerobically at 25 C for 2 d. Presumptive *Staphylococcus aureus* were determined on Baird-Parker Agar base¹¹ enriched with Egg Yolk Tellurite¹¹ and plates were incubated aerobically at 35 C for 2 d. The LAB were determined using deMan, Rogosa, and Sharpe Agar¹¹ (MRS). All-Purpose Tween Agar¹¹ (APT) was also used because *Carnobacterium* spp. do not grow well on MRS due to the presence of acetate as a carbon source (McMullen and Stiles, 1993). The MRS and APT plates were incubated anaerobically at 25 C in anaerobic jars with a disposable H₂ and CO₂ generator envelope no. 70304 (Gas PaK®, BBL®)¹³.

Statistical Analysis

This experiment was replicated as a split-plot design with the effect of repetition and meat type in the main plot, the effect of gas atmosphere in the subplot, and the effect of storage length in the sub-subplot. The ANOVA was carried out with the GLM procedure of SASTM (1989) according to the following mixed model:

$$Y_{ijkl} = \mu + r_i + T_j + w_{ij} + A_k + (TA)_{jk} + v_{ijk} + t_l + (Tt)_{jl} + (At)_{kl} + (TAt)_{jkl} + \varepsilon_{ijkl}$$

where μ is the overall mean, r_i is the effect of i th replication, T_j is the effect of the j th level of meat type, w_{ij} is the main plots error term, A_k is the effect of the k th level of atmosphere, $(TA)_{jk}$ is the interaction between meat types and atmospheres, v_{ijk} is the subplot error term, $(Tt)_{jl}$ is the interaction of meat types and time, $(At)_{kl}$ is the interaction of atmospheres and time, $(TAt)_{jkl}$ is the triple interaction of factors, and ε_{ijkl} is the sub-subplot error term.

RESULTS AND DISCUSSION

Irrespective of packaging conditions, the composition of ground chicken meat was significantly different from that of ground turkey (Table 1). The pH ($P \leq 0.001$), amount of fat ($P \leq 0.001$), and myoglobin content ($P \leq$

0.001) were higher in chicken meat, whereas the percentage of protein and the water content were lower ($P \leq 0.001$). The higher pH value and myoglobin content are reflective of a larger proportion of red muscles entering into the preparation of ground chicken meat. These differences are also exemplified by the higher a^* value of chicken meat (redness; Figure 1A), which is almost twice that of ground turkey meat at the time of packaging (P

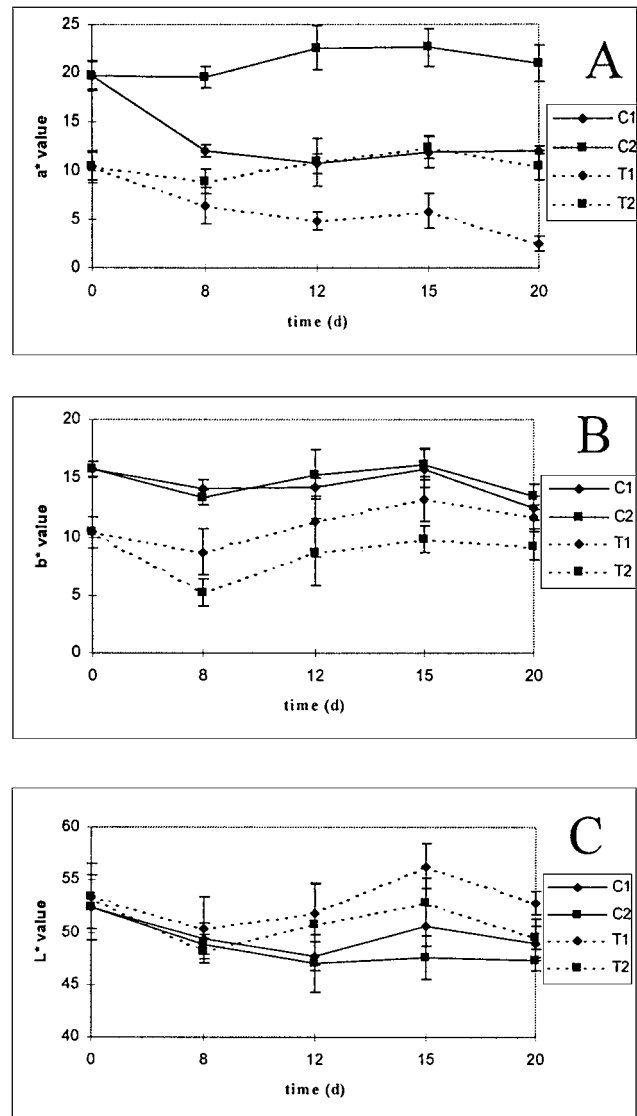


FIGURE 1. Color of ground poultry meat as expressed by the a^* (A), b^* (B), and L^* (C) values. C1 = chicken with gas-1 (62% CO₂, 8% O₂, and 30% N₂), C2 = chicken with gas-2 (20% CO₂ and 80% N₂), T1 = turkey with gas-1, and T2 = turkey with gas-2.

¹³Becton-Dickinson Microbiology Systems, Cockeysville, MD 21152.

≤ 0.05). The b^* value (yellowness) was also initially higher in ground chicken meat than in turkey meat, probably due to its greater fat content (Figure 1B).

As a result of a significant interaction between gas and meat types, a larger decrease in a^* values was observed during storage of ground chicken than for turkey meat when using gas-1 ($P \leq 0.001$), whereas using gas-2, a^* values slightly increased after 8 d for both types of meat as a result of a significant gas \times storage time interaction ($P \leq 0.001$). According to Mercier et al. (1998), an increase in a^* values indicates that packaging with gas-2 has maintained the oxygenation capacity of myoglobin, probably through the metmyoglobin-reducing activity. On the other hand, a decrease in a^* values due to oxygen content in gas-1 would reflect myoglobin oxidation. This conclusion is supported by the results of Sante and Lacourt (1994), who demonstrated that dietary supplementation with the antioxidant, α -tocopherol, improved color stability of turkey meat. This oxidation process is also supported by the increase in b^* values (yellowness) after 8 d of storage, which appeared to be more important for turkey stored in presence of O_2 than for chicken meat (Figure 1B) following interactions of meat type \times gas ($P \leq 0.001$) and meat type \times storage time ($P \leq 0.001$). Mercier et al. (1998), have observed an increase in the hue angle ($\arctan b^*/a^*$) of stored turkey pectoralis muscle, suggesting a degree of change from red to yellow, an indication of increased oxidation with time. In the present study, calculation of hue angle values (not reported) showed an increase for ground chicken and turkey meat during storage under gas-1, whereas with gas-2, values for both types of meat remained relatively stable. Overall, ground poultry meat stored under gas-1 ($L^* = 50.9$) leads to a slightly paler appearance than with gas-2 ($L^* = 49.2$; $P \leq 0.004$). Such differences were not of practical magnitude, however. Meat discoloration after 20 d is shown in Figure 1D. Factors other than the amounts of fat and pigment and the oxidation-reduction state of myoglobin might have contributed to the lighter appearance of turkey meat, as shown by the increase in L^* values during storage ($P \leq 0.001$). Turkey oxidizes faster than chicken due to a lower level of α -tocopherol in the muscles (Mielche and Bestelsen, 1994), but in the present study, ground chicken meat contained a higher proportion of pro-oxidant factors, such as fat and myoglobin content, than can explain its discoloration.

Microbial populations in ground meat were assessed after 8, 12, and 15 d of storage at 1 C. Counts were compared to the maximum number of bacteria that no sample should exceed according to the guidelines from the Meat Hygiene Manual (Canadian Food Inspection Agency, 1999). These maximum values are 7 and 2.7 log cfu/g for the total aerobic mesophilic, and *E. coli* counts, respectively, and 3 log cfu/g for the coliforms and *S. aureus* counts. Total aerobic mesophilic counts (Figure 2A) increased significantly with time ($P \leq 0.005$) and are significantly higher in chicken than in turkey ($P \leq 0.05$). However, counts remained under the maximum value (7 log cfu/g) for all samples tested. A significant interaction

between meat type, atmosphere, and time for the coliform counts was observed ($P \leq 0.0004$; Figure 2B). With gas-2, the number of coliforms was significantly higher in chicken meat from Day 12; counts were, in fact, over the accepted limit (3 log cfu/g). Coliform counts were also greater than the accepted limit (3 log cfu/g) for turkey meat packaged in the same gas mixture; all counts were below the limit with gas-1. With respect to *E. coli* counts, two interactions were significant: meat type \times time ($P \leq 0.01$) and gas mixture \times time ($P \leq 0.005$). Counts in chicken meat were significantly greater than in turkey meat at Day 15, and counts were significantly higher using gas-2 than with gas-1 from samples stored for 12 d. At Day 15, both meat types packaged under gas-1 were still under the maximum value (2.7 log cfu/g). Dainty and Mackey (1992) reported that a higher pH will favor the development of *Enterobacteriaceae* such as coliforms and *E. coli*.

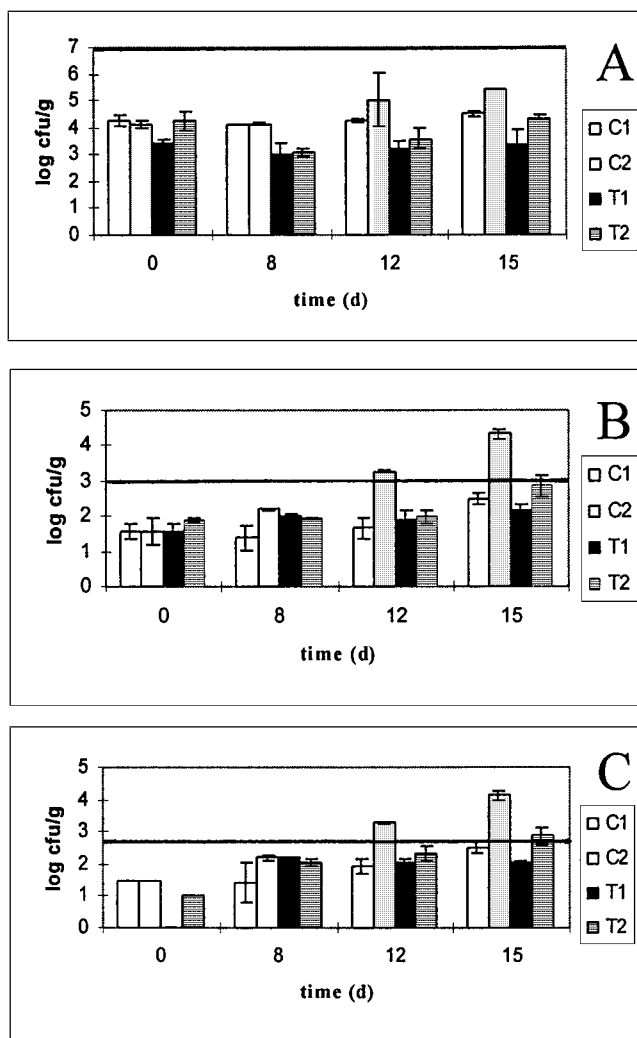


FIGURE 2. Total aerobic mesophilic (A), coliforms (B), and *Escherichia coli* (C) counts of poultry meat during storage at 1 C under two different gas atmosphere. C1 = chicken with gas-1 (62% CO_2 , 8% O_2 , and 30% N_2), C2 = chicken with gas-2 (20% CO_2 and 80% N_2), T1 = turkey with gas-1, and T2 = turkey with gas-2. Horizontal lines represent the maximum number of bacteria that no sample should exceed according to the guidelines from the Meat Hygiene Manual (Canadian Food Inspection Agency, 1999).

TABLE 2. Enumeration of presumptive *Pseudomonas* spp., *Staphylococcus aureus*, *Brochothrix thermosphacta*, and lactic acid bacteria (LAB) on poultry meat after 15 d of storage at 1 C under two different gas atmospheres¹

Poultry meat	Atmosphere ²	<i>Pseudomonas</i> spp.	<i>S. aureus</i>	<i>B. thermosphacta</i>	LAB [APT] ⁴	LAB [MRS]
Chicken	Gas-1	2.77 (0.11)	1.08 (1.52)	BDL ³	4.82 (0.36)	3.67 (0.74)
	Gas-2	3.37 (1.38)	4.77 (0.72)	1.20 (1.70)	5.94 (0.03)	4.11 (0.86)
Turkey	Gas-1	3.05 (0.49)	2.35 (0.49)	BDL	3.44 (0.50)	3.56 (0.30)
	Gas-2	1.20 (1.70)	2.50 (0.06)	BDL	4.72 (0.03)	3.10 (0.02)

¹Results are expressed as a mean of two samples done in duplicate, and SEM are in parentheses.

²Gas-1 = 62% CO₂, 8% O₂, and 30% N₂; Gas-2 = 20% CO₂ and 80% N₂.

³BDL = Below detection level; in the case of *B. thermosphacta*, it is 2 log cfu/g.

⁴APT = All Purpose Tween Agar; MRS = deMan, Rogosa, and Sharpe Agar.

The higher pH observed in chicken meat most likely contributed to their prevalence.

After 15 d of storage, enumeration of presumptive *S. aureus*, *Pseudomonas* spp., *B. thermosphacta*, and LAB was evaluated to assess more precisely the type of organisms that prevail with respect to meat types and the packaging atmosphere (Table 2). *Pseudomonas* spp. counts did not vary significantly but constituted a fair portion of the microbial population, although the conditions were anaerobic. No significant difference was observed with respect to the number of presumptive *S. aureus* for the various meat types and gas mixtures tested; however, counts were greater than the maximum value (3 log cfu/g) for chicken meat packaged using gas-2. Further analysis would be necessary to confirm the identification. *B. thermosphacta* can spoil meat packaged with a low level of oxygen by causing cheesy or dairy odors (Dainty and Mackey, 1992). The organism was only detected in small amounts (an average lower than 2 log cfu/g) in chicken meat packaged under gas-2 and therefore does not represent a major concern as long as plant sanitation is optimal. The LAB are a very diverse group of organisms, difficult to enumerate with a single medium. For example, some are homofermentatives, whereas others are heterofermentatives. Two media however, APT and MRS, are widely used to assess their prevalence. The number of cfu/g obtained on APT was significantly higher with gas-2 ($P \leq 0.03$), whereas with MRS, no significant difference was observed for all parameters and combinations of parameters tested. Numbers of LAB obtained with both media are important, and, as far as food safety is concerned, it would be judicious to find a gas mixture that favors LAB, as their presence exerts an inhibitory pressure on the potential development of pathogenic organisms (Stiles, 1994).

In conclusion, from a microbiological standpoint, poultry meat was better preserved under gas-1 but maintained a better appearance and took longer to discolor under gas-2. Ground poultry meat is likely to become a more important commodity. Furthermore, results indicate that an appropriate gas mixture that can maintain a desirable color offers no guarantee with respect to the microbial profile of the product.

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