## Research Note

# Utilization of buffered vinegar to increase the shelf life of chicken retail cuts packaged in carbon dioxide

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**ABSTRACT** Poultry processors commonly place whole parts of broilers in plastic packages and seal them in an atmosphere of 100% carbon dioxide before shipping them to food service and retail customers. This practice extends the shelf life of retail cuts to approximately 12 d under refrigerated conditions. The objective of this study was to determine the antimicrobial efficacy of vinegar for growth inhibition of mesophilic and lactic acid bacterial counts and enhancement of shelf life in $CO_2$-packaged refrigerated chicken thigh samples. Meat quality, sensory differences, and microbial enumeration were evaluated for chicken thighs that were sprayed with 0, 0.5, or 1.0% vinegar. No differences were observed ($P > 0.05$) among treatments (control vs. 0.5 and 1.0% vinegar-treated chicken thighs) with respect to pH and Commission Internationale d'Eclairage L*a*b*for both chicken skin and the meat tissue. The difference from the control test indicated that trained panelists were not able to detect a difference ($P > 0.05$) in flavor between the chicken thigh treatments. The mesophilic and *Lactobacillus* bacterial counts were enumerated after 0, 4, 8, 12, 16, and 20 d of storage. The mesophilic bacterial load for the 1.0% vinegar treatment was less than all other treatments after 8, 12, 16, and 20 d of storage, whereas the 0.5% vinegar treatment had lower bacterial counts at d 12 than both controls and had an approximate shelf life of 16 d. For lactic acid bacteria, the vinegar 1.0% treatment had lower counts than the control treatments at d 12 and 16. The results from the study indicate that a combination of 1.0% vinegar with $CO_2$ packaging can extend the shelf life from 12 to 20 d for chicken retail cuts without negatively affecting the quality and sensory properties of the broiler meat.

**Key words:** broiler meat, vinegar, mesophilic, lactic acid bacteria, shelf life

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## INTRODUCTION

Organic acids such as lactic acid, acetic acid, and citric acid are effective at reducing *Salmonella* spp., *Escherichia coli*, coliforms, and aerobic bacteria in poultry and meat processing. Organic acids work very well at inhibiting bacteria due to their ability to penetrate and disrupt the cell membrane and to acidify the cell contents (Keener et al., 2004). Carpenter and Broadbent (2009) explained that the inhibitory effects of weak acids can not only be attributed to the effects that they have on pH, but also to their effect on membrane function. The high levels of weak acid anions that accumulate in the cytoplasm cause an osmotic effect on the cell and metabolic processes that occur within the cytoplasm. Lactic acid, acetic acid, buffered lactic acid, and gluconic acid can all be applied as decontamination treatments on poultry and meat carcasses (Bolder, 1997). Acetic acid (vinegar) is generally regarded as safe (GRAS) and is a potent antimicrobial that has been used to control *Salmonella* contamination in meat and poultry products (Mani-López et al., 2012). Vinegar is used in meat products to slow the growth of spoilage bacteria and assist in the inhibition of pathogen survival and growth. In addition, many poultry processors use carbon dioxide to package poultry retail cuts before shipping to lengthen microbial shelf life.

The practical application for the present study was the evaluation of a potential synergistic effect when using vinegar and carbon dioxide packaging to extend the shelf life of broiler thigh meat. The specific objectives of the study were (a) to measure the differences in pH and color (CIE L*, a* and b*) values between control and vinegar-treated chicken thighs, (b) to identify the sensory flavor differences in cooked thigh meat using a difference from control test, and (c) microbial enumeration for mesophilic and lactic acid bacteria counts for control and vinegar-treated samples after 0, 4, 8, 12, 16, and 20 d of refrigerated storage.


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## MATERIALS AND METHODS

### Chicken Thigh Sample Procurement

Bone-in broiler thighs, with the skin on and no prior antimicrobial treatment (0.25–0.30 kg per thigh), were obtained from a commercial poultry processing plant within 24 h of harvest and stored at 2°C on 3 separate occasions. For each treatment, 2 thighs were placed in a package (VAK*3.0 R, Winpak, Winnepeg, CA) and randomly assigned storage times of 0, 4, 8, 12, 16, and 20 d.

### Treatments

Treatments consisted of 1.0% vinegar, 0.5% vinegar, a positive control, and a negative control. For the 1.0% vinegar treatment, 5 mL of vinegar [e(Lm)inate V, Hawkins Inc., Minneapolis, MN] was sprayed into the bag (Winpak VAK*3.0 R, oxygen transmission 24 h/23°C Dry-63 $cm^3/m^2$ and Moisture Vapor Transmission 24 h/37.8°C at 90% RH, 4.8 $g/m^2$) on the thighs (500 ± 20 g) and mixed on the surface through pulling a vacuum before filling the bag with $CO_2$. The $CO_2$ gas packaging was done using a Turbovac ST-320 (HFE Vacuum Systems, Hertogenbosch, the Netherlands), vacuum packager. For the 0.5% vinegar treatment, 2.5 mL of vinegar was sprayed on the thigh samples. The positive control was sprayed with 5 mL of deionized/distilled water in the place of vinegar, and the negative control group was not sprayed with vinegar or water.

After treatment, each bag was filled with approximately 100% $CO_2$ (verified using a gas analyzer) so that the bag volume was filled to 50% capacity (to minimize headspace) and then stored at 2 to 4°C in a walk-in cooler. After 6 d of storage, color and pH were evaluated, and trained panelists (n = 6–8) evaluated the flavor of cooked thigh meat (170°F) using a difference from control test. In addition, mesophilic and lactic acid bacteria were enumerated after 0, 4, 8, 12, 16, and 20 d of storage.

### pH Measurement

The pH of the chicken thigh samples was measured using a pH meter (model Accumet 61, Fisher Scientific, Hampton, NH) with an attached meat penetrating probe (penetration tip, Cole Palmer, Vernon Hills, IL), which was inserted directly into the chicken thigh muscle at 3 different locations. Two chicken thighs were used for each treatment per replication (Kin et al., 2009, 2010).

### Instrumental Color Evaluation

Instrumental color was determined using a chroma meter (model CR-400, Minolta Camera Co Ltd., Osaka, Japan) with an 8-mm port size, 2° observer, and illuminant D65. Calibration of the instrument was carried out using a standard white Minolta calibration plate (model no. 20933026). Color of chicken thighs (negative control and 0.5%, 1.0% sprayed vinegar treatment) were measured and expressed as CIE L* (lightness), a* (redness), and b* (yellowness). For each chicken thigh sample, color was determined at 3 different locations (2 thighs for each treatment per replication) and averaged before statistical analysis.

### Microbial Enumeration

The mesophilic and lactic acid bacteria counts were enumerated after 0, 4, 8, 12, 16, and 20 d of storage at 2°C. Bacto peptone water (0.1%, Remel, Thermo Fisher Scientific, Hampton, NH) containing 0.02% Tween-80 was used as an extraction medium. Peptone water was added to chicken thigh samples in a 1:1 ratio, and samples were hand massaged for 2 min. Homogenates were plated on aerobic plate count petrifilms for mesophilic plate counts (room temperature incubation for 3 d) and de Man, Rogosa and Sharpe agar (Thermo Scientific Remel MRS Agar, Hampton, NH) for *Lactobacillus* count at 37°C for 3 d under anaerobic condition.

**Table 1.** The pH, color,[1] and difference from control scores[2] for chicken thighs that were sprayed with 0, 0.5, or 1.0% vinegar before packaging in $CO_2$ and storage for 6 d (2–4°C)

| Item | pH | CIE L* chicken skin | CIE a* chicken skin | CIE b* chicken skin | CIE L* thigh meat | CIE a* thigh meat | CIE b* thigh meat | Difference from control score[2] |
|---|---|---|---|---|---|---|---|---|
| Treatment | | | | | | | | |
| Positive control | NA[3] | NA | NA | NA | NA | NA | NA | NA |
| Negative control | 6.11 | 75.7 | 0.84 | 9.3 | 54.4 | 3.9 | 5.1 | 0.90 |
| 0.5% vinegar | 6.07 | 76.0 | 0.71 | 9.4 | 54.0 | 3.6 | 4.9 | 0.95 |
| 1.0% vinegar | 6.15 | 76.1 | −0.20 | 11.1 | 55.3 | 3.1 | 5.1 | 0.90 |
| Pooled SEM | 0.023 | 0.25 | 0.35 | 0.72 | 0.42 | 0.32 | 0.33 | 0.11 |
| *P*-value | 0.36 | 0.77 | 0.43 | 0.52 | 0.44 | 0.58 | 0.96 | 0.97 |

[1]Raw color of chicken skin [Commission Internationale d'Eclairage (CIE) L* (lightness) = 0 to 100; CIE a* (redness) = −60 to 60; CIE b* (yellowness) = −60 to 60].

[2]Difference from control scale: 0 = no difference; 1 = slight difference; 2 = moderate difference; 3 = large difference; 4 = very large difference. The negative control was both the control and blind control sample in the test.

[3]NA = not applicable.

## Sensory Evaluation

The difference from control test was conducted according to Desai et al. (2012) with slight modifications. The panelists who participated in the difference from control sensory testing of chicken thighs have more than 100 h of experience in muscle food sensory evaluation and training on beef, pork, poultry, and catfish products between 2010 and 2013. Prior to sensory testing, the chicken thigh treatments (1.0% vinegar, 0.5% vinegar sprayed, and negative control) were stored for 6 d at 2°C. The chicken thighs were cooked in an oven (Viking, Greenwood, MS) to an internal temperature of 170°F on a drip pan. Cooked chicken thigh samples were cooled for 15 min in aluminum foil bags and then were cut into approximate 2.54-cm cubes and placed in labeled plastic cups. Each panelist was served with 4 samples, one labeled control (negative control) and 3 treatments (1.0% vinegar, 0.5% vinegar sprayed, and blind control) that were assigned 3-digit random codes. The blind control was the negative control, but its identity was hidden from the panelists because it was assigned a random 3-digit number along with the other 2 treatments and served to the panelists during the difference from control test. The blind control serves as an anchor to ensure that differences between samples and the control are greater than differences between the control and the identical blind control. Panelists evaluated the flavor of cooked chicken thigh samples on a 0- to 4-point scale (0 = no difference, 1 = slight difference, 2 = moderate difference, 3 = large difference, 4 = very large difference). In addition, 2 members of the trained sensory panel sniffed the aroma coming from the package 30 s after the bag was opened and evaluated the aroma. This was an objective measurement to determine if there was any vinegar aroma or spoilage.

## Statistical Analysis

A randomized complete block design (replications as blocks) with 3 replications was used to test the effect of vinegar ($P < 0.05$) on pH, color, and sensory differences (SAS version 9.2, SAS Institute Inc., Cary, NC). A randomized complete block design with a factorial structure was used to determine differences in mesophilic and lactic acid bacteria counts over storage time. When significant differences occurred ($P < 0.05$) among treatments, the Duncan's multiple range test was used to separate treatment means.

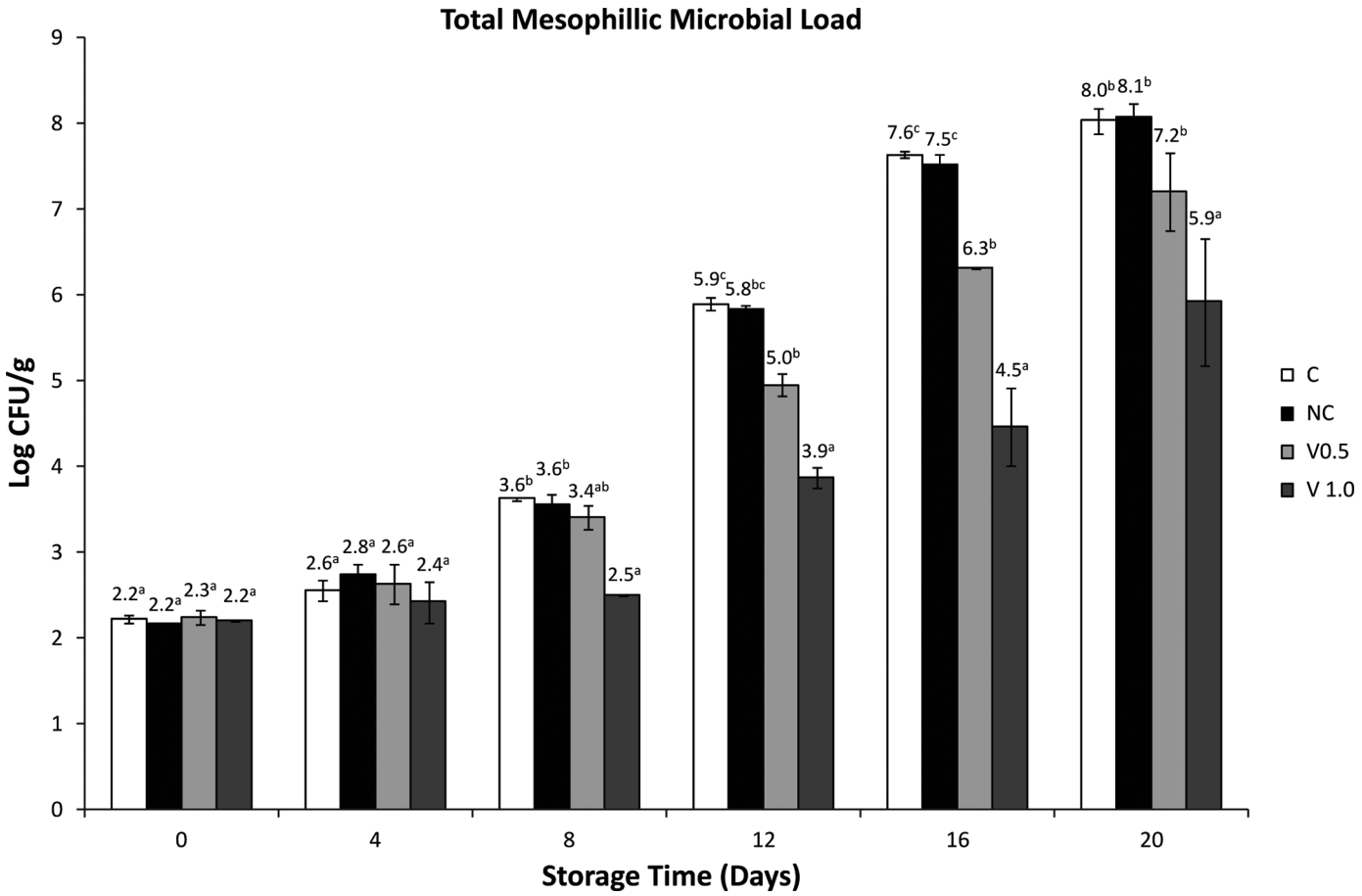


**Figure 1.** Total mesophilic microbial load of chicken thighs that were treated with 0, 0.5, or 1.0% vinegar before packaging in $CO_2$ and stored (2–4°C) for up to 20 d. C = control with 1.0% deionized water; NC = negative control; V0.5 = 0.5% vinegar; V1.0 = 1.0% vinegar. Means with different letters (a–c) within each storage time are different ($P < 0.05$).

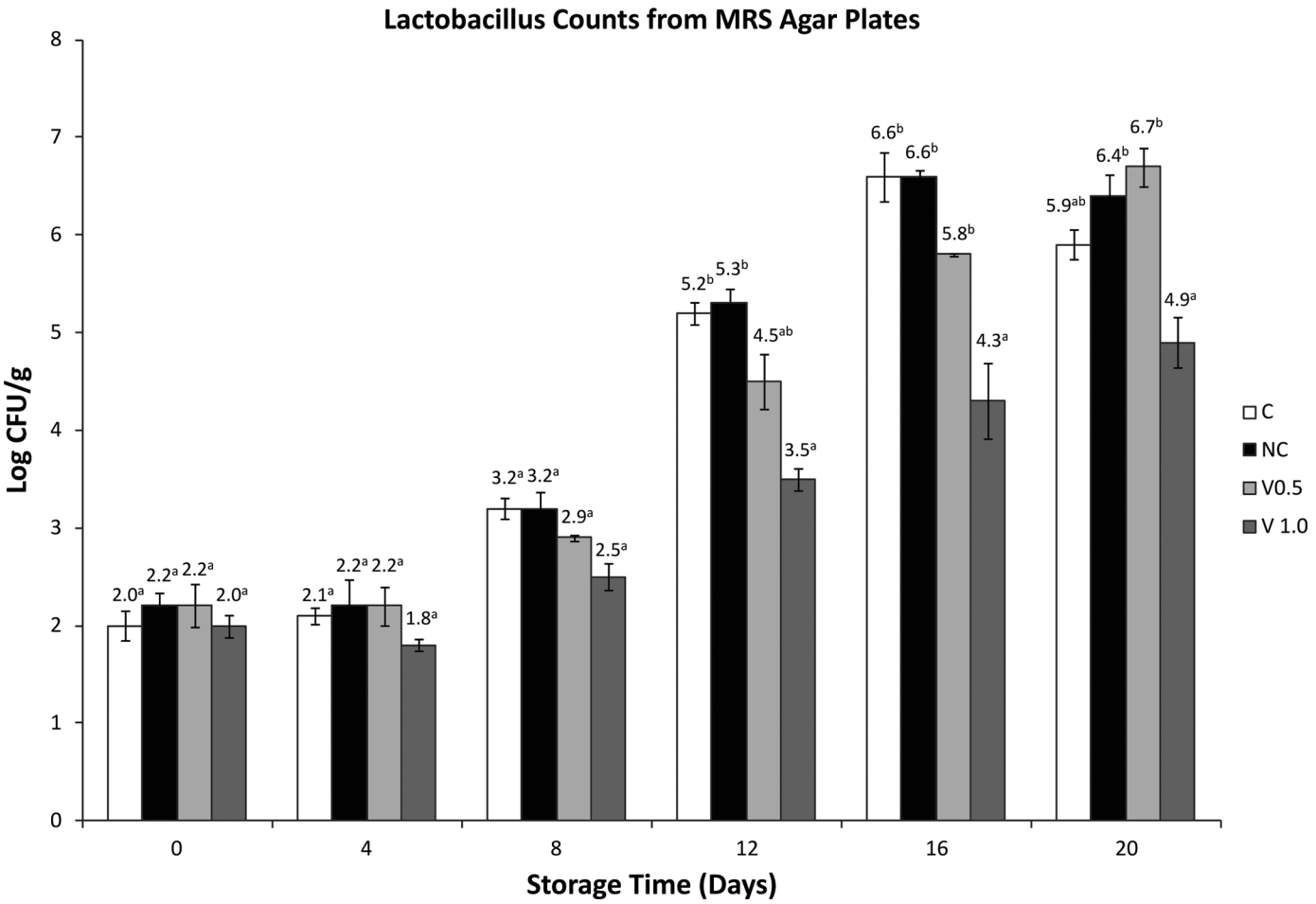


**Figure 2.** Lactic acid bacterial counts of chicken thighs that were treated with 0, 0.5, or 1.0% vinegar before packaging in $CO_2$ and stored (2–4°C) for up to 20 d. C = control with 1.0% dionized water; NC = negative control; V0.5 = 0.5% vinegar; V1.0 = 1.0% vinegar. Means with different letters (a,b) within each storage time are different ($P < 0.05$). MRS = de Man, Rogosa, and Sharpe.

## RESULTS AND DISCUSSION

No differences existed ($P > 0.05$) among treatments with respect to pH, skin CIE L* a * b* (lightness, redness, yellowness), and meat color (lightness, redness, yellowness; Table 1). This indicates that spraying chicken thigh retail cuts with up to 1.0% buffered vinegar does not affect the pH and color of the chicken skin or meat when it is packaged in carbon dioxide. In addition, there was no sensory difference detected ($P > 0.05$) between the control and vinegar-treated samples (Table 1). The sensory difference from control scores indicated that the trained panelists could not detect any flavor difference between the control and vinegar-treated cooked chicken thigh samples (Table 1). A sniffing test was also conducted on the control and vinegar-treated chicken thigh samples. Immediately after opening the packages, there was a slight vinegar aroma in the bag for the 0.5 to 1.0% vinegar samples on d 0, 4, and 8, but the aroma dissipated quickly. The vinegar aroma was also not detected without sniffing directly into the bag, and the aroma of the 1.0% vinegar samples at d 16 and 20 had no spoiled odor, but the control samples on d 16 and 20 smelled spoiled due to bacterial growth (data not shown). Crist et al. (2012) showed that the combination of acetic acid (2.5%) and sodium lactate (2.5%) can be useful in extending the shelf life of fresh Italian pork sausage links for up to 18 d of storage without negatively influencing the sensory qualities.

No differences existed ($P > 0.05$) in mesophilic and lactic acid bacteria counts after 0 and 4 d of storage. However, the mesophilic bacterial load was less ($P < 0.05$) in the 1.0% vinegar treatment compared with other treatments after 8, 12, 16, and 20 d of storage (Figure 1). In addition, the control samples were approaching spoilage at 12 d and had a very spoiled aroma by d 16, whereas the 1.0% vinegar treatment was not approaching spoilage until 20 d, which indicates that the microbial shelf life of the broiler thighs were extended from approximately 12 to 20 d. Previous research has indicated that fresh poultry meat products with total viable counts between $10^7$ to $10^8$ cfu/g are considered to have reached the end of their shelf life (Senter et al., 2000). In the present study, the mesophilic counts reached approximately $10^6$ cfu/g at d 12 and $10^8$ cfu/g at d 16. In addition, the 0.5% vinegar treatment had lower bacterial counts at d 12 than both controls and had an approximate shelf life of 16 d (Figure

1). Jamilah et al. (2008) showed that lactic, acetic, and citric acids were able to reduce spoilage and pathogenic microorganisms on meat products due to their ability to lower pH and cause instability in bacterial cell membranes. Previous studies have shown that acetic acid is effective against both gram-positive and gram-negative microorganisms (Owen, 1946; Woolford, 1975; Sorrells et al., 1989). The antimicrobial effect of organic acids is due to cytoplasmic acidification and accumulation of acid anions inside the microbes, which leads to inactivation of their acid sensitive glycolytic enzymes (Davidson, 2001; Taylor et al., 2012). For lactic acid bacteria, the vinegar 1.0% treatment had lower counts than the control treatments at d 12 and 16 (Figure 2), which further substantiates the mesophilic bacteria data. In a similar study, a combination of $CO_2$ packaging with organic acids such as citric acid (3%) and acetic acid (1%) was effective at extending the shelf life of fresh pork (Schirmer and Langsrud, 2010).

The results obtained from the current study suggest that combining 1.0% buffered vinegar with carbon dioxide packaging can extend the shelf life of chicken retail cuts without negatively affecting the quality and sensory properties of the broiler meat. The shelf-life extension results may be useful to poultry processing companies and their retail and foodservice customers when broiler retail cuts are shipped long distances because shelf life can be extended from approximately 12 d to approximately 20 d. In future work, a combination of other synergistic antimicrobials with $CO_2$ packaging to increase the shelf life of broiler retail cuts needs to be evaluated.

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