Broiler Skin Color as Affected by Organic Acids: Influence of Concentration and Method of Application[1]

S. F. BILGILI,[2] D. E. CONNER, J. L. PINION, and K. C. TAMBLYN

Department of Poultry Science and Alabama Agricultural Experiment Station, Auburn University, Alabama 36849-5416

ABSTRACT Color of broiler skin was evaluated after exposure to organic acids under various concentrations and simulated potential plant application conditions. Breast skin from chilled broiler carcasses was treated with acetic (AA), citric (CA), lactic (LA), malic (ML), mandelic (MN), propionic (PA), or tartaric (TA) acids at 0.5, 1, 2, 4, and 6% concentrations. Each acid and concentration was applied in simulated dip (23 C for 15 s), scalder (50 C for 2 min), and immersion chiller (1 C for 60 min) conditions. A tap water control was included with each application method. Objective color values of L* (lightness), a* (redness), and b* (yellowness) were measured before and after the treatments to calculate color differentials under a factorial arrangement of organic acids and concentrations.

Skin lightness increased ($P < 0.01$) in simulated chiller as compared to dip and scalder applications. Skin redness was reduced significantly in scalder, and yellowness in dip and scalder applications, respectively. In simulated dip application, with the exception of PA, all acids decreased lightness and increased redness and yellowness values. Propionic acid had little affect on lightness and redness values, but decreased yellowness values. In simulated scalder application, with the exception of PA, all acids decreased lightness with increasing concentration. The redness values changed little in scalder application. However, yellowness values were increased with all acids, except for PA, which decreased yellowness values. In simulated chiller conditions, all acids, except for PA, decreased lightness and redness and increased yellowness values. Propionic acid increased lightness and decreased yellowness values significantly in chiller conditions. Alterations in skin color should be taken into account in the selection and application of organic acids as carcass disinfectants.

(*Key words*: skin color, organic acids, carcass disinfectants, broiler)

1998 Poultry Science 77:751–757

INTRODUCTION

Physical removal and death of bacteria from carcass surfaces by frequent rinses with hot or cold water and subsequent application of disinfectants may be the most practical and effective means of improving the microbiological quality and safety of poultry. Carcass disinfectants, such as chlorine (Dixon and Pooley, 1961; Thomson *et al*., 1967; Mead *et al*., 1975), antibiotics (Thomson *et al*., 1967), poly {hexamethylene-biguanide hydrochloride} (Thomson *et al*., 1981), ozone (Sheldon and Brown, 1986), potassium sorbate (Morrison and Fleet, 1985), sodium hydroxide (Humphrey *et al*., 1981), hydrogen peroxide, either alone (Lillard and Thomson, 1983; Mulder *et al*., 1987) or in combination with sodium bicarbonate (Fletcher *et al*., 1993), and trisodium phosphate (Bender, 1992) have been tested for their efficacy against human enteropathogens. Organic acids and salts (Mountney and O'Malley, 1965; Robach, 1979; Lillard *et al*., 1987; Izat *et al*., 1990; Dickson and Anderson, 1992; Zeitoun and Debevere, 1992; Dickens *et al*., 1994) have been studied as potential carcass disinfectants because they exhibit good bactericidal activity and are generally regarded as safe (GRAS) food additives (Dickson and Anderson, 1992). However, Mulder *et al.* (1987), Izat *et al.* (1990), and Dickens *et al.* (1994) reported subjective alterations in the visual appearance of the carcasses (bleaching or darkening) when the carcasses were treated with various organic acids.

Because microbiological efficacy of organic acids are reported to vary with concentration, contact time, and temperature (Dickson and Anderson, 1992), objective assessment of the influence of organic acids on broiler skin color would be desirable. In this study, the influence of various organic acids on broiler skin color was evaluated under simulated carcass dip, scalder, and chiller conditions.

Received for publication April 8, 1997.
Accepted for publication December 22, 1997.
[1]Alabama Agricultural Experiment Station Journal Number 12-965742.
[2]To whom correspondence should be addressed: sbilgili@acesag.auburn.edu

Abbreviation Key: AA = acetic acid; CA = citric acid; GRAS = generally regarded as safe; LA = lactic acid; ML = malic acid; MN = mandelic acid; PA = propionic acid; TA = tartaric acid.

TABLE 1. Pretreatment objective color values and color differentials of broiler breast skin in simulated dip, scalder, and chiller conditions

	L* (Lightness)		a* (Redness)		b* (Yellowness)	
Treatment[1]	Value[2]	Δ[3]	Value	Δ	Value	Δ
Dip	75.57	0.62[b]	6.17	–0.34[a]	18.72	–0.83[b]
Scalder	75.52	1.17[b]	6.37	–1.02[b]	20.63	–0.98[b]
Chiller	75.64	2.71[a]	6.18	–0.46[a]	19.38	0.24[a]
SEM[4]	0.38	0.33	0.41	0.13	0.83	0.22
Source of variation	Probability					
Application	NS	**	NS	**	NS	**

[a,b]Means within a column with no common superscript differ significantly ($P < 0.05$). n = 6.
[1]Simulated dip (23 C for 15 s), scalder (50 C for 2 min), and chiller (1 C for 60 min).
[2]Pretreatment color value.
[3]Color differential (pretreatment – post-treatment value).
[4]Pooled standard error of mean.
**$P < 0.01$.

MATERIALS AND METHODS

Skin samples used in this study were obtained from a commercial broiler processing plant. In this plant, birds were hard-scalded at 57 C for 100 s to remove the cuticle. Breast skin was removed from broiler carcasses after chilling and cut into 10 cm diameter pieces to include pectoral pterylae and apteria, using a template. All samples were individually packaged in sterile plastic bags, maintained at –20 C, and thawed at 4 C prior to the application of treatments. Preparation and storage of skin samples were consistent with methods described for the Skin Attachment Model (Conner and Bilgili, 1994). Skin treatments consisted of seven organic acids: acetic (AA), citric (CA), lactic (LA), malic (ML), mandelic (MN), propionic (PA), and tartaric (TA) acids. Each acid was applied under simulated carcass dip, scalder, and immersion chiller conditions at 0.5, 1, 2, 4, and 6% concentrations. For dip and chiller simulations, skin pieces (three replicate skins per acid and concentration) were attached separately to clips mounted on a plate and dipped into 600-mL beakers filled with treatment solution, either for 15 s at 23 C (dip) or agitated (125 rpm) for 60 min with a Gyrotory shaker[3] at 1 C (chiller). For the scalder simulation, skin pieces were similarly dipped into treatment solutions and agitated (90 strokes per minute) for 2 min with a Tecator[4] shaking water bath at 50 C. Water was also used as a control to compare the influence of each simulation on skin color.

Objective color values were determined on all skin before (at room temperature) and immediately after the application of treatments, using a Hunter Miniscan[5] reflectance colorimeter. The colorimeter was calibrated with a reflectance standard plate supplied by the manufacturer (Plate No. M01087). The L* (lightness), a* (redness), and b* (yellowness) values were recorded by placing the hand-held colorimeter directly in contact with the skin. Duplicate measurements were taken from each skin sample and averaged for analysis.

Color differentials (Δ) were calculated by subtracting pretreatment color values from post-treatment values. The 315 skin samples taken from the processing plant were randomly assigned to one of three replications.

Three skin samples were exposed to each of 35 treatments within each replication, for a total of 105 samples per replication. The 35 treatments were a combination of 7 different acids used at 5 different levels. Color data were analyzed separately for each application simulation as a 7×5 factorial arrangement of acids and concentrations, using the General Linear

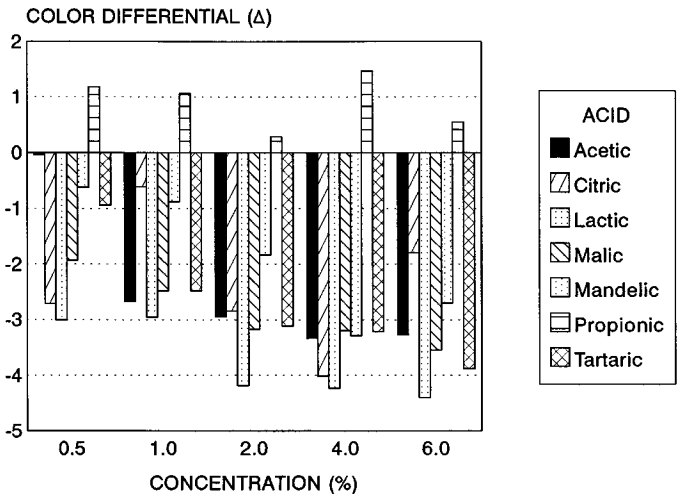

FIGURE 1. Acid by concentration interaction ($P < 0.01$) for L* (Lightness) color differential of broiler breast skin in simulated dip (23 C for 15 s) conditions. (Pooled SEM = 0.49).

[3]Model G2, New Brunswick Scientific Co., Inc., Edison, NJ 08818.
[4]Model 1024, Tecator, Inc., Herndon, VA 22071.
[5]Hunter Associates Lab Inc., Reston, VA 22090.

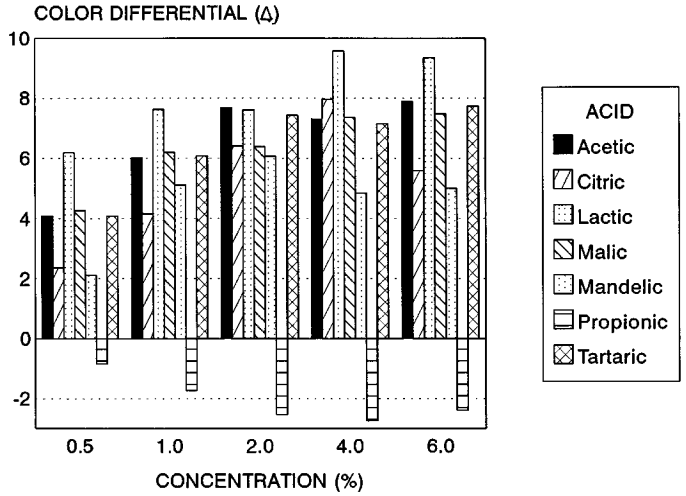

FIGURE 2. Acid by concentration interaction ($P < 0.001$) for b* (yellowness) color differential of broiler breast skin in simulated dip (23 C for 15 s) conditions. (Pooled SEM = 0.69).

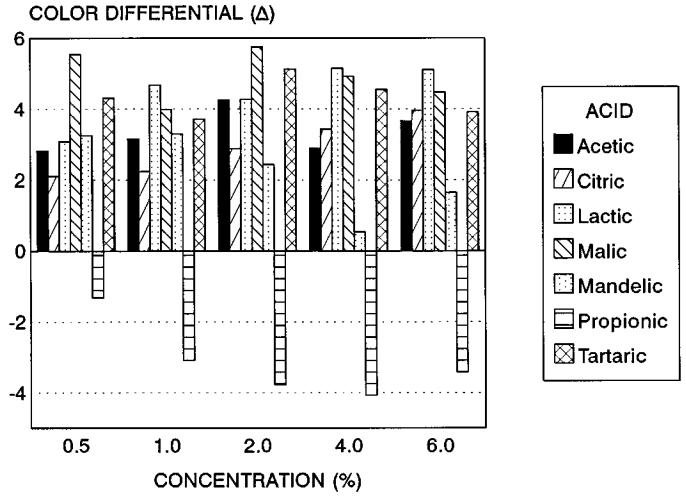

FIGURE 3. Acid by concentration interaction ($P < 0.05$) for b* (yellowness) color differential of broiler breast skin in simulated chiller (1 C for 60 min) conditions. (Pooled SEM = 0.69).

Models procedure of SAS® (SAS Institute, 1987). Because replication was not significant, it was not included in the model. The error term included replication and all interaction effects that included replication. When significant ($P < 0.05$), means were separated with Tukey's Studentized range test.

RESULTS AND DISCUSSION

Color differentials of broiler breast skin treated with tap water in simulated dip (23 C for 15 s), scalder (50 C for 2 min), and chiller (1 C for 60 min) conditions are presented in Table 1. Chilling resulted in significantly higher Δ L* (lightness) and Δ b* (yellowness) values

TABLE 2. Pretreatment objective color values and color differentials of broiler breast skin treated with organic acids at various concentrations in simulated dip (23 C for 15 s) conditions

	L* (Lightness)		a* (Redness)		b* (Yellowness)	
Treatment[1]	Value[2]	Δ[3]	Value	Δ	Value	Δ
Acid						
AA	74.74	–2.45^{bc}	5.75	0.65^{ab}	18.70	6.59^{b}
CA	74.43	–2.39^{bc}	6.54	0.18^{bc}	19.34	5.30^{bc}
LA	75.47	–3.75^{d}	6.07	0.89^{a}	18.72	8.07^{a}
ML	74.14	–2.86^{cd}	6.94	0.58^{ab}	19.78	6.34^{b}
MN	75.32	–1.87^{b}	6.22	–0.05^{c}	19.73	4.63^{c}
PA	75.49	0.91^{a}	6.17	–0.74^{d}	19.14	–2.05^{d}
TA	75.33	–2.73^{bc}	6.53	0.45^{abc}	19.62	6.50^{b}
SEM[4]	0.42	0.22	0.32	0.12	0.44	0.31
Concentration						
0.5%	75.00	–1.15^{a}	5.77	0.08	19.00	3.18^{c}
1.0%	74.43	–1.58^{a}	6.64	0.28	19.49	4.78^{b}
2.0%	75.53	–2.54^{b}	6.17	0.26	18.58	5.58^{ab}
4.0%	74.92	–2.83^{b}	6.84	0.41	19.93	5.92^{a}
6.0%	75.08	–2.72^{b}	6.16	0.37	19.46	5.81^{ab}
SEM	0.36	0.19	0.27	0.10	0.38	0.26
Source of variation	Probability					
Acid	NS	***	NS	***	NS	***
Concentration	NS	***	NS	NS	NS	***
Interaction	NS	**	NS	NS	NS	***

$^{a–d}$Means within a column with no common superscript differ significantly ($P < 0.05$).

[1]AA = acetic acid; CA = citric acid; LA = lactic acid; ML = malic acid; MN = mandelic acid; PA = propionic acid; and TA = tartaric acid.

[2]Pretreatment color value.

[3]Color differential (pretreatment – post-treatment value).

[4]Pooled SEM.

**$P < 0.01$.

***$P < 0.001$.

TABLE 3. Pretreatment objective color values and color differentials of broiler breast skin treated with organic acids at various concentrations in simulated scalder (50 C for 2 min) conditions

	L* (Lightness)		a* (Redness)		b* (Yellowness)	
Treatment[1]	Value[2]	Δ[3]	Value	Δ	Value	Δ
Acid						
AA	74.43	–3.51^{bc}	6.60	–1.95^{e}	19.49	4.65^{bc}
CA	74.69	–3.43^{b}	6.41	–0.46^{bcd}	19.43	5.92^{ab}
LA	74.37	–4.45^{bcd}	6.94	–0.96^{d}	19.52	6.77^{a}
ML	75.29	–4.59^{cd}	5.72	–0.13^{abc}	18.77	6.29^{ab}
MN	75.05	–3.54^{bc}	6.14	0.0^{ab}	19.63	3.09^{c}
PA	75.21	1.30^{a}	6.04	–0.85^{cd}	19.43	–3.17^{d}
TA	76.14	–5.12^{d}	5.62	–0.41^{a}	18.45	6.97^{a}
SEM[4]	0.48	0.27	0.31	0.18	0.39	0.39
Concentration						
0.5%	74.86	–2.20^{a}	6.06	–0.78	19.22	3.85
1.0%	75.18	–2.59^{a}	5.82	–0.47	19.18	4.15
2.0%	75.31	–3.60^{b}	6.14	–0.46	18.98	4.40
4.0%	75.14	–4.05^{b}	6.49	–0.57	19.76	4.68
6.0%	74.63	–4.23^{b}	6.54	–0.53	19.08	4.72
SEM	0.41	0.22	0.26	0.15	0.33	0.33
Source of variation	Probability					
Acid	NS	***	NS	***	NS	***
Concentration	NS	***	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS

$^{a–e}$Means within a column with no common superscript differ significantly ($P < 0.05$).

[1]AA = acetic acid; CA = citric acid; LA = lactic acid; ML = malic acid; MN = mandelic acid; PA = propionic acid; and TA = tartaric acid.

[2]Pretreatment color value.

[3]Color differential (pretreatment – post-treatment value).

[4]Pooled SEM.

***$P < 0.001$.

than dip and scalder simulations. Scalding significantly reduced the Δ a* (redness) values. The effect of dip simulation on skin color was similar to the scalder simulation for lightness and yellowness and to the chiller simulation for redness. These results, although consistent with those reported by Lyon and Cason (1995), were somewhat surprising. The skin samples used in this study were obtained from broiler carcasses that had previously been scalded, washed, and chilled. Apparently, the color of broiler skin can be further altered beyond immersion chilling.

The influence of organic acids applied in simulated dip conditions at various concentrations are summarized in Table 2. Significant acid (L*, a*, and b*) and concentration (L* and b*) main effects and interaction (L* and b*) were present. A significant acid by concentration interaction was observed with dip and chiller applications (Tables 2 and 4), because of PA, which consistently altered skin color differently than all other acids tested. These interactions are presented in Figures 1 to 3. With the exception of PA, all acids decreased lightness and increased yellowness values with increasing concentration simulated dip conditions. Redness values were only slightly increased with most acids. Propionic acid had little effect on lightness and redness values, but decreased yellowness value significantly.

Significant ($P < 0.001$) acid (L*, a*, and b*) and concentration (L*) main effects were detected in simulated scalder conditions (Table 3). All acids, except for PA, decreased lightness and increased yellowness values. The PA treatment increased lightness and decreased yellowness values. The effect of acids on redness values were small and ranged from –1.95 to 0 units, as compared to –1.02 units obtained with water alone (Table 1). The concentration effect for yellowness values were not significant ($P > 0.05$).

The L*, a*, and b* values were significantly affected by acid and concentration under simulated chiller conditions (Table 4). With the exception of PA, all acids decreased lightness and increased yellowness values. Propionic acid increased lightness and decreased redness and yellowness values. The reduction in lightness was low, as compared to those obtained in dip and scalder simulations. There were no concentration effects for yellowness values ($P > 0.05$). All acids decreased redness values on a concentration-dependent manner.

Processing conditions, such as scalding temperature and duration (Heath and Thomas, 1973, 1974), pH (Heath and Wabeck, 1975), and immersion chilling (Lyon and Cason, 1995), have been shown to affect broiler skin color. Results of this study indicate that color of processed broiler skin can be further altered by use of organic acids as carcass disinfectants. Darkening (L*) and yellowing (b*) effects observed with most of the acids in this study are consistent with those reported in literature (Dickens *et al.*, 1994). Propionic acid resulted in

TABLE 4. Pretreatment objective color values and color differentials of broiler breast skin treated with organic acids at various concentrations in simulated chiller (1 C for 60 min) conditions

	L* (Lightness)		a* (Redness)		b* (Yellowness)	
Treatment[1]	Value[2]	Δ[3]	Value	Δ	Value	Δ
Acid						
AA	74.60	–0.30^{bc}	7.03	–1.25^{ab}	19.37^{b}	3.35^{bc}
CA	74.98	–1.39^{c}	7.61	–1.19^{ab}	21.41^{a}	2.92^{c}
LA	74.81	–1.29^{c}	6.60	–0.94^{a}	19.88^{ab}	4.45^{ab}
ML	75.62	–1.10^{c}	6.33	–0.89^{a}	18.79^{b}	4.94^{a}
MN	75.06	0.78^{b}	6.50	–1.46^{ab}	20.13^{ab}	2.32^{c}
PA	73.62	4.13^{a}	7.42	–1.63^{b}	20.30^{ab}	–3.13^{d}
TA	74.83	–0.39^{bc}	6.54	–0.94^{a}	19.24^{b}	4.32^{ab}
SEM[4]	0.49	0.27	0.33	0.14	0.47	0.31
Concentration						
0.5%	74.97	0.68^{a}	6.89	–0.97^{a}	19.72	2.82
1.0%	75.11	0.10^{ab}	6.76	–1.07^{ab}	19.71	2.57
2.0%	74.78	0.09^{ab}	6.51	–0.91^{a}	19.71	2.99
4.0%	74.60	0.01^{ab}	7.06	–1.53^{b}	20.27	2.49
6.0%	74.48	–0.56^{b}	7.09	–1.45^{b}	19.98	2.76
SEM	0.42	0.23	0.28	0.12	0.40	0.26
Source of variation	Probability					
Acid	NS	***	*	**	NS	***
Concentration	NS	**	NS	***	NS	NS
Interaction	NS	NS	NS	NS	NS	*

$^{a–d}$Means within a column with no common superscript differ significantly ($P < 0.05$).

[1]AA = acetic acid; CA = citric acid; LA = lactic acid; ML = malic acid; MN = mandelic acid; PA = propionic acid; and TA = tartaric acid.

[2]Pretreatment color value.

[3]Color differential (retreatment – post-treatment value).

[4]Pooled SEM.

*$P < 0.05$.

**$P < 0.01$.

***$P < 0.001$.

lighter skin color, similar to the bleaching as observed with a hydrogen peroxide treatment (Mulder *et al*., 1987). Other visual defects frequently attributed to organic acids, such as hardening, bloating, or puckering of the skin, or off-odors (Mulder *et al*., 1987; Blankenship *et al*., 1990; Dickens *et al*., 1994) were not evaluated in this study. As effects on sensory attributes were not measured, objective color values could not be correlated to consumer acceptability. However, Dickens *et al.* (1994) could not show changes in the sensory properties and texture of cooked chicken carcasses treated with 0.6% acetic acid.

It is evident that application of organic acids can affect broiler skin color. Therefore, alterations in skin color, in addition to efficacy against surface microorganisms, should be taken into account in selecting and applying organic acids as carcass disinfectants for broiler carcasses. Further work should focus on practical significance and acceptability of color changes caused by organic acids.

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