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Research Article

Effect of Antimicrobial Agents on Physical and Chemical Properties of Ready-to-eat Bologna

Ayca Gedikoglu and Andrew Douglas Clarke
Department of Food Science, University of Missouri, Columbia, Missouri 65211, United States of America

Abstract: Quality and safety of ready-to-eat meat products can be altered by antimicrobial agents such as lactates, diacetates and citrates. This project evaluated the effect of Ional (1.5, 2.5, 3.5%), Ional LC (1.5, 2.5, 3.5%) and Optiform SD4 (2.5%) compared to a control on selected physical and chemical characteristics of ready-to-eat vacuum-packaged bologna slices stored less than 4°C for up to 112 days of retail display. Water activity (a_w), expressible moisture (WHC), pH, fat and moisture content, cooking yield, texture profile analysis, puncture test, Hunter color values were evaluated. Addition of antimicrobials decreased pH. Product with Optiform SD4 (2.5%) had the highest cooking yield. Bologna formulated with Optiform SD4 (2.5%) had the highest springiness and hardness values after control and the highest puncture value. Water activity was not significantly different (p>0.05) between treatments. Furthermore, day of display had no significant effect on a_w. *L* and *a* values were not significantly different between treatments, except for Ional LC (3.5%) compared to the control. Overall, treatments with Ional (1.5%), (2.5%) and Optiform SD4 (2.5%) were most effective for preserving the quality of the bologna (s). Also, the highest levels of antimicrobial agents had a detrimental effect on the quality of ready-to-eat bolognas.

Keywords: Antimicrobial, pH, quality, sausage, texture

INTRODUCTION

Over the years, food scientists have been researching how to produce safe, high-quality meat products. An important safety problem that meat producers have been facing is post-process contamination. This type of contamination can happen during the slicing and packaging of the product. This is an important issue especially regarding deli meats and non-reheated frankfurters due to their being identified as a high-risk product for listeriosis on a per serving basis (FDA, 2003). Sliced, vacuum-packaged ready-to-eat meat products such as bologna and poultry products are high-risk products for listeriosis, with a 6.7% incidence rate (Samelis and Metaxopoulos, 1999). High incidence rate and persistency of the *Listeria monocytogenes'* in the food production environment makes this pathogen a bacterium of major concern in this type of product.

In order to minimize the presence of *Listeria monocytogenes* in ready-to-eat meat products and to reduce post-process contamination, many techniques have been developed. Addition of antimicrobial ingredients into the formulation of the meat products, or the treatment of meat products with antimicrobial solutions after processing, is one of the techniques used as an extra hurdle to prevent pathogenic bacteria growth and it improves the shelf life of meat products.

Organic acids such as lactic acid, acetic acid, citric acid and propionic acid as dipping solutions, or their salts, such as sodium lactate, sodium diacetate and sodium citrate, are commonly used. Sodium lactate has been used in the food industry for many years as a humectant (Reid, 1969), a flavor enhancer and improver of shelf life (Duxbury, 1988; Wederquist *et al*., 1994). Also, organic acid of sodium lactate has been used as a carcass decontaminant (Acuff, 1991). Due to its bacteriostatic properties (Lamkey *et al*., 1991), sodium lactate or lactic acid have been used in the formulation or as a dipping solution to prevent the growth of pathogenic organisms in meat products. It is suggested that antilisterial activity of sodium lactate in formulation of meat products comes from its humectant property that reduces the water activity of the products (Shelef, 1994; Samelis *et al*., 2001). Additionally, Jensen *et al*. (2003) suggested that inhibition of *L. monocytogenes* by lactic acid could be due to a pH-reducing property (pK_a = 3.86). Sodium lactate's antilisterial activities have been shown in different meat products such as turkey bologna (Wederquist *et al*., 1994), frankfurters (Bedie *et al*., 2001) and wieners and cooked bratwurst (Glass *et al*., 2002). Furthermore, its effectiveness as an antimicrobial agent has been

Corresponding Author: Ayca Gedikoglu, Department of Food Science, University of Missouri, Columbia, Missouri 65211, United States of America

demonstrated on spoilage organisms in different meat products such as fresh pork sausage (Brewer and Harbers, 1991; Lamkey *et al*., 1991), catfish fillets (Williams *et al*., 1995), chicken breast meat (Williams and Phillips, 1998) and beef top rounds (Maca *et al*., 1999).

Sodium diacetate has been widely used as an antimicrobial agent, a flavoring agent and a pH control agent for more than a decade (Branen *et al*., 2002; Stekelenburg, 2003). Its effectiveness as an antimicrobial agent is due to its undissociated acids. When undissociated acids become dissociated inside the cell membrane of organisms, the cell interior becomes acidified (Hunter and Segal, 1973), which could affect the physiological or metabolic activities of the cell (Jensen *et al*., 2003). The effect of sodium diacetate alone and its combination with other organic salts, such as sodium lactate, to prevent pathogen growth in different meat products have been demonstrated in different studies (Bedie *et al*., 2001; Samelis *et al*., 2002; Uhart *et al*., 2004; Geornaras *et al*., 2006). In addition to some of the beneficial properties, sodium diacetate is a cheap and easily available antimicrobial agent. However, using high levels of acetate or diacetate (in a formulation), as a dipping solution or spray solution, may cause discoloration of meat products (Lawrie, 1985) and off flavor formation (Maca *et al*., 1997a). This problem could be prevented by using low levels of sodium diacetate with a combination of other salts of organic acids.

Sodium citrate and its acid form, citric acid, have been widely used in the food industry to control pH of foods and as a synergistic antioxidant (Anderson and Marshall, 1990) and carcass decontaminant (Acuff, 1991). Recent studies demonstrated the possible use of sodium citrate as a meat tenderizer (Sitz *et al*., 2005). Furthermore, it has been demonstrated that sodium citrate is an effective antimicrobial agent against some food-borne pathogens such as *Clostridium perfringens* (Thippareddi *et al*., 2003; Juneja and Thippareddi, 2004). Moreover, Palumbo and Williams (1994) demonstrated the effect of citric acid in combination with acetic acid as a dipping solution on frankfurters for preventing growth of *Listeria monocytogenes.*

The antilisterial effect of sodium or potassium benzoate has been demonstrated by Samelis *et al*. (2001) in sliced pork bologna and by Geornaras *et al*. (2005) in vacuum-packaged bologna and ham.

Sodium propionate is mainly used as a mold inhibitor based on its fungistatic action (Jay *et al*., 2005). In addition to mold inhibition, some studies investigated the effect of this antimicrobial agent on foodborne pathogens such as *Listeria monocytogenes* by El-Shenawy and Marth (1992), *Salmonella* spp. by Cherrington *et al*. (1992). Furthermore, Maca *et al*. (1997b) found that sodium propionate combined with sodium lactate reduced the total aerobic plate count in vacuum-packaged cooked top beef rounds.

From those antimicrobials, sodium lactate and sodium diacetate are the ones used most widely as individual compounds or in combination for control of *Listeria monocytogenes* growth (Tompkin, 2002). However, there are few studies that assess the effect of these antimicrobials on quality attributes of the ready-to-eat meat products.

The objective of this study is to determine the effect of selected antimicrobial agents on physical and chemical characteristics of ready-to-eat bologna stored at less than 4°C up to 112 days of retail display.

MATERIALS AND METHODS

Sample preparation: Beef and pork trim were ground in the grinder (BIRO Model, AFMG-52, OH, U.S.A.) as 13,608 g separate batches for 8 treatments. Treatments for this experiment were Optiform SD4 (2.5%), Ional (1.5%), (2.5%), (3.5%) and Ional LC (1.5%), (2.5%), (3.5%) as well as the Control, which had no antimicrobial ingredient in the formulation.

After grinding, a 10,989.5 g batch of ground meat was transferred into the chopper (Mainca, CM-41, UK) for emulsification. During this process, each batch was processed separately and between the batches the chopper was scraped to prevent antimicrobial transfer from one batch to another. After the chopping was started, the curing agent, containing an antimicrobial ingredient except in the control, spices and ice were slowly introduced into the batches and chopped until the mix was emulsified. Then, each batch's final temperature in the chopper was measured using a temperature probe and the temperature of each batch was ranged around 1 to 4°C. After the emulsification, batches were transferred into the stuffer (Vemag, Robot 500, UK) and processed separately.

During the stuffing, between each batch, 0.4 to 1 kg of each new batch was used to clean the stuffer and then discarded. Sausages were stuffed into approximately 9 cm diameter clear fibrous casings. Before the stuffing, casings were soaked in potable water to prepare casings for stuffing. For each batch, 3,000 to 4,000 g of 4 bolognas were produced. The loose ends of the stuffed bolognas were stapled using a pressurized automatic stapler (Tipper Clipper, Model C437L, CA, U.S.A.). After this, each bologna was labeled and their initial weight before cooking was recorded. Bolognas were hung on the smoke truck and placed in the smoker (Enviro-Pak Microprocessor, Micro Pak Series, MP1000, OR, U.S.A.). A temperature probe was inserted into representative bologna and then bolognas were cooked in the smoke house until the internal temperature reached 66.67°C. Later, bolognas were transferred into a cooler and kept in the cooler until the temperature of the bolognas was equilibrated with the cooler's temperature of 3.2°C. This was verified by using a temperature probe.

After the equilibrium was reached, each bologna's cooked weight was measured and recorded. The bologna casings were peeled off and bolognas were sliced into 1 to 2 cm thick slices. Slices were vacuum packaged in specific bags using a Multivac vacuum machine (Type-AG800, Germany) and labeled. Then packaged bologna slices were transferred to the retail display cooler (CRS-S1-96, Commercial refrigerator manufacturers association, WI, U.S.A.). This process was replicated two more times. Each treatment was tested for cooking yield, pH, WHC, a_w, texture profile analysis, puncture test and Hunter *L*, a, b values for days 0, 28, 56, 84 and 112. Also, proximate analysis was conducted on 3 replications.

Antimicrobial ingredients of the study: In this study, three different antimicrobial ingredients were used. All of these antimicrobial ingredients are generally recognized as safe. The first one was Optiform SD 4 (PURAC, Blair, NE). This is a combination of L-sodium lactate and food grade sodium diacetate in a liquid form. It was used for only one level (2.5%) in this study. The other antimicrobial ingredients used in this experiment were Ional and Ional LC (World Technology Ingredients Inc., GA, U.S.A.). Ional is water-soluble, buffered sodium citrate granules. On the other hand, Ional LC is a water-soluble blend of buffered sodium citrate and sodium diacetate granules. Both Ional and Ional LC were used in three different levels in this study (1.5, 2.5 and 3.5%).

Cooking yield: Cooking yield of the bolognas was determined by using the formula shown below (Bishop *et al*., 1993):

$$\text{Cooking Yield \%} = \left[\frac{\text{Cooked weight of the product}}{\text{Uncooked weight of the product}}\right] * 100$$

Water holding capacity: Water holding capacity of the samples was determined according to methods reported by Wierbicki (1958). Between 0.48 to 0.52 g of the bologna sample was placed on the center of the Whatman® No. 1 filter paper. The paper with the meat sample was placed between two plexiglass plates. The plates were pressed 1 min with 500 psi of pressure using a Carver press (Laboratory Press Model C, Carver, Inc., Wabash, IN, U.S.A.). After this, the meat and wet area were calculated by using a ribeye area grid transparent sheet. The formula used to calculate Water Holding Capacity (WHC) is shown below (Grau and Hamm, 1953; Price and Schweigert, 1987) and WHC was determined in duplicate for each treatment:

$$\text{WHC} = \left[\frac{\text{Area of free water}}{\text{Area of meat}}\right]$$

Water activity and Ph: Water activity (a_w) of the samples was determined by using an Aqualab machine (Model CX 2, Decagon Devices, Pullman, WA, U.S.A.). Temperature of the samples was kept less than 21°C.

A cooked 5 g sample was homogenized with 45 mL distilled water by using a blender and then the pH of the slurry was determined by using a Fisher ACCUMET® model 230A pH/ion meter. Measurements of both pH and a_W were duplicated for each treatment.

Proximate analysis: Moisture, protein and fat content of the samples were determined based on AOAC International (1995) methods. Moisture content was determined by using a dry oven method, protein content by Kjeldahl method and fat content by Soxhlet method. Proximate analysis was conducted by the University of Missouri-Columbia Experiment Station Chemical Laboratories.

Texture profile analysis and puncture test: Sliced bolognas were cut into approximately 2 cm length diameter samples. Three samples were prepared for each treatment. Each sample was compressed to 50% of its original height in two consecutive cycles at a crosshead speed of 50 mm/min by using a TA-TX2 texture analyzer (Stable Micro Systems, Surrey, UK) for the evaluation of texture profile analysis, which was described by Bourne (1978). Triplicates of each treatment were evaluated for springiness, cohesiveness, chewiness, gumminess and hardness.

Approximately 8 by 4 cm length bologna slices were prepared for each treatment in order to triplicate the test. A TA+D*i* texture analyzer (Texture Technologies Corp., Scarsdale, NY, U.S.A.) was used for evaluation of the maximum force required to puncture samples. Diameter of the probe was 6.38 mm and traveled 10 mm with the speed of 50 mm/min. Cell load capacity was 50 kg.

Before puncture and texture profile analysis testing, samples were kept in their vacuum packaging for two hours until their temperature reached room temperature.

Hunter color values: Hunter color L (lightness), *a* (redness) and *b* (yellowness) values were evaluated by using a Minolta color meter (Konica Minolta Chroma Meter (CR-410) colorimeter, Minolta Ltd., Milton Keynes, UK). Vacuum packaged sliced bolognas were kept at room temperature for two hours before use and their vacuum package was removed. Minolta color meter was directly placed on sliced bolognas' surfaces. Color values were measured in triplicate for each treatment.

Statistical Analysis: Three replications of ready-to-eat bolognas were evaluated for cooking yields, WHC, a_w, pH, TPA, puncture test, Hunter color values and proximate analysis. Data was analyzed by Analysis of

Variance (ANOVA) using the General Linear Model (GLM) procedure of the SAS Institute Inc. (2003). Means were separated by Least Significant Difference (LSD), when significant ($p<0.05$) treatment effects were found.

RESULTS

Cooking yield of the bolognas was not significantly ($p>0.05$) affected by the treatments. However, there was a significant difference of cooking yield between treatments of Optiform SD 4 (2.5%) and Ional (3.5%). Wherein Ional (3.5%) had the lowest cooking yield and Optiform SD 4 (2.5%) had the highest cooking yield, which was shown at Table 1. Our results confirmed the earlier studies. Maca *et al*. (1997b) found that treating the top beef rounds with sodium lactate increased the cooking yield up to 13%. Papadopoulos *et al*. (1991) found that injecting the beef top rounds up to 4% sodium lactate increased the cooking yield of the product.

Water holding capacity of the ready-to-eat bolognas was significantly ($p<0.05$) affected by the treatments. Increase in the antimicrobial agent level caused the decrease in water holding capacity of the treated bolognas. Choi *et al*. (2003) also reported that increase in the sodium lactate level from 3.3 to 5% caused decrease in water holding capacity of low-fat sausages.

Water activity (a_W) of the ready-to-eat bolognas was not significantly ($p>0.05$) affected by addition of antimicrobial ingredients. Barmpalia *et al*. (2005) obtained similar results with pork bologna. Results of Wederquist *et al*. (1994) are also in line with these data. Control bolognas had the highest water activity on each of the storage days. Furthermore, water activity of samples was not significantly ($p>0.05$) increased during the storage period (Data not shown).

The product pH was significantly ($p<0.05$) affected by the treatments. As expected, addition of antimicrobials in the formulations decreased the pH of the bolognas. Similar results were reported by Barmpalia *et al*. (2005).

The initial pH of Control was 5.95. During storage, pH of the bolognas slightly increased (Data not shown). Mbandi and Shelef (2002) also reported the increase in pH of bolognas during storage. Lowest pH was observed from treatments of Ional LC (3.5%) with pH of 5.75. Optiform SD 4 (2.5%) was the only treatment that had no significant difference ($p>0.05$) of pH in comparison to Control over the 112 days of storage.

Treatment had (a) significant ($p<0.05$) effect on moisture and ash content. On the other hand, crude fat and crude protein values were not significantly ($p>0.05$) affected by the treatments. Mean moisture value was highest in bolognas formulated with Optiform SD 4 (2.5%). This could be the result of the addition of antimicrobial agent as a buffer solution. Treatment with Ional LC (3.5%) followed by Ional (3.5%) had the highest ash content. Control had the lowest ash content and was significantly ($p<0.05$) different from all the treatments.

Springiness of the treatments was not significantly ($p>0.05$) affected by the day of storage and trt*day effect. However, treatment had a significant ($p<0.05$) effect on springiness values. Results were shown at Table 2. Choi *et al*. (2003) investigated the effect of different sodium lactate levels on the texture of low-fat sausages. Their results showed that addition of sodium lactate increased springiness up to 3.3%, but with the addition of 5% sodium lactate springiness of low-fat sausages decreased. This was parallel with our results that high levels of antimicrobial agents had a negative effect on the texture of bolognas. Furthermore, Choi and Chin (2003) results showed that addition of 3.3% sodium lactate caused a decrease in the springiness

Table 1: Effect of antimicrobial agents on mean value of chemical and physical attributes of ready-to-eat bologna at day 0

Parameters	C	O 2.5%	I 1.5%	I 2.5%	I 3.5%	LC 1.5%	LC 2.5%	LC 3.5%
Water activity	0.9428	0.9355	0.9403	0.9375	0.9375	0.9387	0.936	0.9338
Expressible moisture	0.869^{a}	1.02^{abc}	1.005^{abc}	1.314^{bc}	1.273^{bc}	1.021^{abc}	1.208^{bc}	1.298^{bc}
Cooking yield %	94.56^{ab}	94.75^{a}	94.31^{ab}	94.34^{ab}	94.06^{b}	94.58^{ab}	94.37^{ab}	94.36^{ab}
pH	5.95^{a}	5.85^{ab}	5.85^{ab}	5.83^{b}	5.76^{b}	5.82^{b}	5.76^{b}	5.75^{b}
Proximate analysis								
Moisture	59.48^{ab}	60.91^{a}	59.75^{ab}	59.19^{ab}	57.25^{c}	58.79^{bc}	58.65^{bc}	58.47^{bc}
Crude protein	15.83^{a}	15.31^{ab}	15.83^{a}	15.61^{ab}	15.56^{ab}	15.19^{ab}	15.04^{ab}	14.94^{b}
Crude fat	20.57^{ab}	18.62^{b}	19.66^{ab}	19.81^{ab}	21.04^{a}	21.55^{a}	21.17^{a}	20.87^{a}
Ash	3.05^{a}	3.61^{b}	3.51^{b}	3.88^{c}	4.07^{d}	3.46^{b}	3.8^{c}	4.08^{d}

$^{a, b, c, d}$: Different letters of same row indicate significant difference ($p<0.05$); C: Control, which has no antimicrobial agent; O: Optiform SD 4 (PURAC): Liquid form of l-sodium lactate and sodium diacetate; I: Ional (World Technology Ingredients Inc.): Granule form of sodium citrate; LC: Ional LC (World Technology Ingredients Inc.): Granule form of sodium citrate and sodium diacetate

Table 2: Effect of antimicrobial agents on mean value of textural properties of ready-to-eat bologna at day 0

Texture parameters	C	O 2.5%	I 1.5%	I 2.5%	I 3.5%	LC 1.5%	LC 2.5%	LC 3.5%
Springiness	0.839^{a}	0.763^{abc}	0.747^{abc}	0.749^{abc}	0.689^{c}	0.789^{ab}	0.773^{abc}	0.695^{bc}
Cohesiveness	0.359^{a}	0.282^{ab}	0.258^{b}	0.276^{ab}	0.266^{ab}	0.343^{ab}	0.309^{ab}	0.323^{ab}
Chewiness	669.92^{a}	482.18^{ab}	262.27^{b}	343.99^{b}	249.66^{b}	405.85^{b}	331.79^{b}	323.65^{b}
Gumminess	739.91^{a}	600.52^{ab}	340.46^{b}	414.75^{b}	349.45^{b}	483.54^{ab}	415.66^{b}	445.98^{b}
Hardness	1939.8^{a}	1704.2^{ab}	1337.5^{b}	1347.1^{ab}	1332.6^{b}	1305.9^{b}	1368.5^{ab}	1337.9^{b}

$^{a, b, c}$: Different letters of same row indicate significant difference ($p<0.05$); C: Control, which has no antimicrobial agent; O: Optiform SD 4 (PURAC): Liquid form of l-sodium lactate and sodium diacetate; I: Ional (World Technology Ingredients Inc.): Granule form of sodium citrate; LC: Ional LC (World Technology Ingredients Inc.): Granule form of sodium citrate and sodium diacetate

Table 3: Effect of treatment and day of storage on mean value of puncture force (gram) of ready-to-eat bolognas

	Day of storage				
Treatment	0	28	56	84	112
Control	866.2	733.2	761.9	719.2	852.6^{a}
Optiform SD4 (2.5%)	906.5$_{x}$	857.2$_{xy}$	790.5$_{xy}$	680.7$_{y}$	839.1$^{ab}{}_{xy}$
Ional (1.5%)	835.1	743.5	741.7	682.4	760.6^{abc}
Ional (2.5%)	877.5	780.3	760.4	730.1	805.5^{abc}
Ional (3.5%)	802.7$_{x}$	648.2$_{xy}$	673.7$_{xy}$	603.8$_{y}$	654.7$^{c}{}_{xy}$
Ional LC (1.5%)	809.9	767.9	697.9	654.1	725.3^{abc}
Ional LC (2.5%)	924.8$_{x}$	700.7$_{y}$	695.5$_{y}$	602.6$_{y}$	697.9$^{bc}{}_{y}$
Ional LC (3.5%)	806.7	756.7	651.3	620.5	654.4^{c}

$^{a, b, c}$: Different letters of same column indicate significant difference ($p<0.05$); $_{x, y}$: Different letters of same row indicate significant difference ($p<0.05$); Optiform SD 4 (PURAC): Liquid form of l-sodium lactate and sodium diacetate; Ional (World Technology Ingredients Inc.): Granule form of sodium citrate; Ional LC (World Technology Ingredients Inc.): Granule form of sodium citrate and sodium diacetate

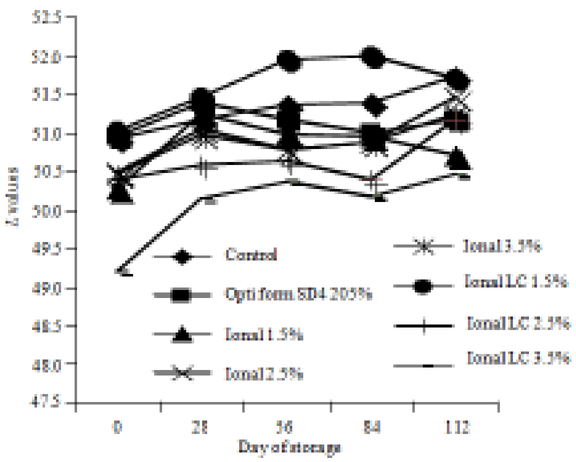

Fig. 1: Effect of treatment and day of storage on mean value of lightness of ready-to-eat bolognas

value of comminuted sausages, which agreed with our results. Treatment had a significant ($p<0.05$) effect on cohesiveness of ready-to-eat bolognas. Addition of antimicrobial agents decreased the cohesiveness of ready-to-eat bologna. Also, increasing the level of treatment did follow an irregular pattern for cohesiveness of the texture of bolognas. Chin *et al.* (2000) found that the addition of fat replacements decreased the cohesiveness of the low-fat bolognas. Another study investigated the effect of different citrus fibers on the texture of bolognas. Addition of citrus fibers caused a decrease in cohesiveness of bologna samples (Fernandez-Gines *et al.*, 2003). On the contrary, Xiong *et al.* (1999) found that increasing the NaCl content of the beef sausages caused an increase in cohesiveness of the samples. Furthermore, the results of Choi *et al.* (2003) also showed that addition of sodium lactate caused an increase in cohesiveness of low-fat sausages. Both chewiness and gumminess were significantly affected by the treatments. Addition of antimicrobial agents caused a decrease in both chewiness and gumminess. Decrease in chewiness of sausages was also reported by Choi *et al.* (2003). On the other hand, results of gumminess were contradictory to the studies of Choi and Chin (2003) and Choi *et al.* (2003). Hardness of control bolognas was highest and was not significantly ($p>0.05$) different from treatments with 2.5%. Decreasing hardness by addition of organic acids salts have been demonstrated by Jensen *et al.* (2003), Sitz *et al.* (2005) and Knock *et al.* (2006).

Required force to puncture samples was not significantly ($p>0.05$) different between treatments during days 0, 28, 56 and 84. The only significant difference between control and treatment Ional (3.5%) and Ional LC (2.5%) and (3.5%) was at day 112, shown on Table 3. Day of storage had a significant ($p<0.05$) effect on puncture values of Optiform SD 4 (2.5%), Ional (3.5%) and Ional LC (2.5%). Over time puncture values decreased.

Lightness of the samples was not significantly ($p>0.05$) affected by both treatments and day of storage. Lightness of samples increased over time, but the only significant ($p<0.05$) increase was observed on treatment with Ional LC (3.5%) between days 0 and 112, which is shown in Fig. 1. Similar results were observed by Brewer *et al.* (1991) and Maca *et al.* (1999). Furthermore, an increase in level of antimicrobial agents caused a decrease in lightness values. This was parallel with the results of Papadopoulos *et al.* (1991), Maca *et al.* (1999) and Calhoun *et al.* (1999).

Treatment did not significantly ($p>0.05$) affect the redness of the bologna samples. Also, trt*day had no significant ($p>0.05$) effect on redness of samples. The only significant ($p<0.05$) difference between treatments was observed on day 56, which is shown in Fig. 2. Day of storage had a significant ($p<0.05$) effect on *a* values of bolognas. Redness of treatments followed a similar pattern during storage and all of the treatments had highest redness values during the storage day 84. After that, redness of all the treatments decreased at day 112. Similar results in redness values were also observed by Maca *et al.* (1999) during 21 days of storage. Furthermore, they also found that an increase in sodium lactate level caused an increase in *a* value. The results of Papadopoulos *et al.* (1991) and Choi and Chin (2003) were also parallel with our findings.

Yellowness was not significantly ($p>0.05$) affected by both treatment and day of storage. Also, trt*day had

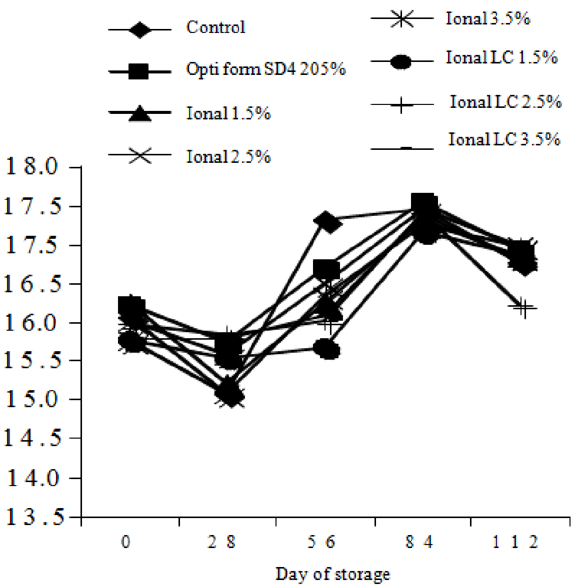

Fig. 2: Effect of treatment and day of storage on mean value of redness of ready-to-eat bolognas

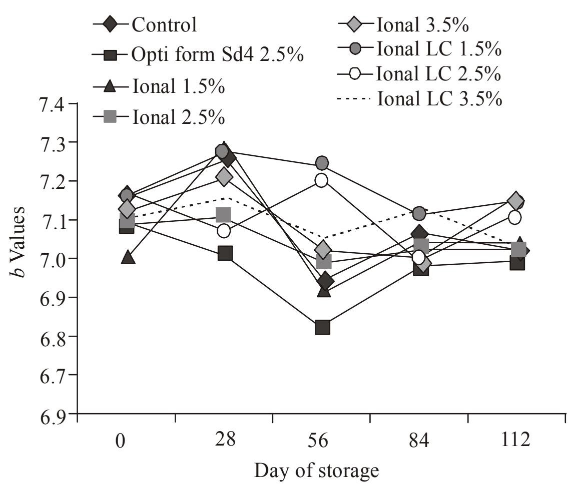

Fig. 3: Effect of treatment and day of storage on mean value of yellowness of ready-to-eat bolognas

no significant effect on *b* values of samples, which is shown in Fig. 3. Papadopoulos *et al*. (1991) found similar results.

CONCLUSION

The antimicrobial treatments did not significantly affect the water activity and water holding capacity of the RTE bolognas. Addition of antimicrobials reduced the pH of the products. Treatment that had a combination of L-sodium lactate and food grade sodium diacetate in a liquid form at 2.5% level (Optiform SD 4) had the highest cooking yield. Texture of the RTE bolognas was affected by the treatments, however, overall Optiform SD 4 (2.5%) and Ional (1.5%), (2.5%), which are water-soluble, buffered sodium citrate granules, were not significantly (p>0.05) different from the control. Increasing the level of antimicrobials to 3.5% had a negative effect on the overall quality of the product. Results of this study can provide producers information to determine what levels of antimicrobials to use to prevent pathogen growth and to minimize the possible negative effect on the quality of ready-to-eat meat products. Future studies should evaluate the use of these ingredients in RTE bolognas and their acceptance by consumers.

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