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Evaluation of sodium lactate as a replacement for conventional chemical preservatives in comminuted sausages inoculated with *Listeria monocytogenes*

Soon Hee Choi, Koo Bok Chin*

Department of Animal Science and Biotechnology Research Institute, Chonnam National University PukGwangju, PO Box 205 Gwangju, 500-600 South Korea

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Abstract

Sodium lactate (SL) as a potential replacer for potassium sorbate (PS) or sodium benzoate (SB) in comminuted sausages was evaluated. Sausages manufactured with 3.3% SL were compared with a control and 0.05 or 0.1% of PS and SB with regard to its influence on changes of chemical composition, physico-chemical and textural properties, and the growth of inoculated *Listeria monocytogenes* (LM) stored at 4 °C for up to 8 weeks. The sausages contained 62–64% moisture, 15–17% fat and 12–14% protein with pH range of 6.10–6.15 and water activity (a_w) range of 0.936–0.941. Sausages containing 3.3% SL alone had lower ($P<0.05$) thiobarbituric acid reacting substances (TBARS) values than the control and those of PS (0.05–0.1%). Lightness values of sausages varied ($P<0.05$) among preservatives and storage times, while yellowness values tended to increase with storage time. Textural attributes (springiness and hardness) were reduced after 2 and 6 weeks storage, respectively. Sodium lactate at an incorporation level of 3.3% to sausage formulation had an antilisterial effect similar to those of 0.05–1.0% of PS or SB and delayed the lag phase for the growth of *Listeria monocytogenes* at least 2 weeks, compared with the control.

Keywords: Sodium lactate; Comminuted sausage; Shelf-life; *Listeria monocytogenes*

1. Introduction

Chemical preservatives, such as potassium sorbate (PS) and sodium benzoate (SB), have been used to extend the shelf-life of processed meats in some Asian countries including South Korea. However, use of these preservatives may cause outbreaks of allergies or side effects in consumers if they consumed more than certain amounts in their foods. Currently, consumers prefer to take "healthier foods" which are low-fat, low-sodium, functional food products. These foods will require a reduction in the use of chemical preservatives, and more use of natural ingredients in the processing of food products. Thus, many studies have been performed to develop natural ingredients for use as antioxidants or antibacterial agents in the food systems.

Sodium lactate (SL), produced by microbial fermentation, is the sodium salt of natural lactic acid (L+) and is a normal component of muscle tissue. It has been used to control the growth of certain microorganisms during storage, as well as for improving the flavor and processing yields of meat products. In addition, SL has been reported to have an antibacterial effect on some pathogens, such as, *Clostridium botulinum* and *Listeria monocytogenes,* which gave severe problems in the meat products. Anderas, Milkoswski, and Cereveny (1987) reported that *Clostridium botulinum* in fish, chicken and poultry meats was inhibited with the addition of SL (60%) at the levels of 1.5–3.5%. The production of toxin produced by *Clostridium botulinum* in turkey meats was delayed with the addition of SL, as well (Maas, Glass, & Doyle, 1989). Subsequently, Lamkey, Leak, Tuley, Johnson, and West (1991) concluded that SL inhibited the microbial growth, resulting in extension of the shelf-life by more than 2 weeks, as compared to the control. Three to 4% SL in cooked beef limited

* Corresponding author. Tel.: +82-62-530-2121; fax: +82-62-530-2129.

E-mail address: kbchin@chonnam.ac.kr (K.B. Chin).

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the proliferation of *S. typhimurium*, *L. monocytogens* and *E. coli* 0157:H7, as compared to the control or 2% addition of SL (Miller & Acuff, 1994). Maca, Miller, Binger, Lucia, and Acuff (1999) reported that 3% SL could be added in vacuum packaged beef top rounds as an antioxidant and color stabilizer for cooked beef system. In comminuted meat products, frankfurters containing 3.3% SL had lower ($P<0.05$) microbial counts for lactic acid bacteria than those of a control (Murano & Rust, 1995). Low-fat frankfurters containing 2% SL extended shelf-life up to 6 weeks, as compared to 3 and 4 weeks shelf-life for low- or regular-fat controls, respectively (Bloukas, Paneras, & Fournitizis, 1997).

Based on previous studies, it may be possible to substitute the chemical preservatives with SL in comminuted meat products, which will satisfy consumer needs. However, studies on antibacterial effect of incorporation of SL to comminuted sausages are limited as compared to those on PS or SB, which have been used at the different levels for the extension of shelf-life in processed meat products. Thus, the objectives of this study were to investigate the potential use of sodium lactate to replace these preservatives in comminuted sausages and to characterize the physico-chemical, textural and microbial changes resulting from the use of SL in the products.

2. Materials and methods

2.1. Preparation/processing of frankfurter

Fresh pork ham muscles and pork fat trimmings were purchased from a retail meat market, trimmed free of fat and ground through a 0.32 cm (lean) and 0.48 cm (fat) plate of the grinder (Crypto Peerless Ltd., EF-20, England), respectively. Raw meat materials were vacuum packaged and frozen at −20 °C prior to use. Proximate composition of trimmed pork hams and fats was determined to formulate regular-fat (~15%) frankfurters used in this study. The treatment combinations, non-meat ingredients and the compositions of raw meat materials are listed in Tables 1–3.

Frozen pork ham muscles were thawed at 2 °C for 24 h and chopped for 30 s in a silent cutter (Crypto Peerless Ltd., K55, France) to reduce the particle size. Salt, sodium nitrite, sodium erythorbate, sodium lactate (SL, 60%, Purac Inc., The Netherlands), seasonings and half of ice water were then added and chopped for 2 min to extract the salt soluble proteins. Flavorants and remaining ice water were then added and the meat batter homogenized until the temperature reached 15–16 °C. The raw meat batter was vacuum packaged to remove the air bubbles and stuffed into polyvinyldiene chloride (PVDC, 7325B, 40 micron gauge, 46 mm, Japan) film with a hand stuffer (Manica, TP-10, Italy), cooked to an internal temperature of 71.7 °C in water bath and chilled immediately in an ice bath.

Table 1
Frankfurter model system formulations

Treatments	Meats (%)	NMI[a] (%)	AW[b] (%)	Preservatives (%)	Total (%)
Control	70	10	20.00	0	100
Treat 1	70	10	19.95	0.05% (PS)[c]	100
Treat 2	70	10	19.90	0.1% (PS)	100
Treat 3	70	10	19.95	0.05% (SB)[d]	100
Treat 4	70	10	19.90	0.1% (SB)	100
Treat 5	70	10	16.70	3.3% (SL)[e]	100

[a] NMI = non meat ingredients.
[b] AW = added water.
[c] (PS), potassium sorbate.
[d] (SB), sodium benzoate.
[e] (SL), sodium lactate solution (60%).

Table 2
Non-meat ingredients for emulsified-sausage products

Non-meat ingredients	Amount (%)
Salt[a]	1.534 (0.234)[a]
Glucose	1.00
Sugar	2.00
Non-fat dry milk	1.00
Hydrolyzed milk protein	1.00
Sodium tripolyphosphate	0.40
Corn starch	2.00
Spices	1.00
Sodium erythorbate	0.05
Salt/sodium nitrite	0.25 (0.016)
Total	10.00

[a] Salt content(%) from cure blend (prague powder).

Table 3
Mean values for pH and proximate composition of raw meat (pork ham)

		pH	Moisture (%)	Fat (%)	Protein (%)
Lean	Mean	5.93	76.9	2.38	20.7
	S.D.	0.08	2.50	0.86	1.22
Back Fat	Mean	6.83	17.9	83.5	1.85
	S.D.	0.16	3.32	1.11	1.02

2.2. Inoculation of a pathogen (Listeria monocytogenes) into regular-fat frankfurters

To prepare the inoculation, an aliquot of *Listeria monocytogenes* strain (ATCC, 43256) was placed in 9 ml of tryptic soy broth (TSB) with 1 ml being transferred every 2 days to a fresh 9 ml TSB and incubated for 24 h at 37 °C. Several dilutions were then prepared in sterilized water to obtain a final concentration of 10^3 colony

forming units (cfu) per gram of sausage sample. After inoculation, the sausages were vacuum packaged (TAEVAC 600MX, Yoiwang-city, Kyungki-do, Korea) into Cryovac coextruded film (7325B, Sealed Air Korea Inc, Seoul, Korea) at ~20 mmHg and stored at 4 °C(±1) for the analysis each week up to 8-weeks of storage.

2.3. Analytical measurements

Analytical measurements for the evaluation of the products are listed below. pH, water activity, microbial counts, thiobarbituric acid reacting substances (TBARS), Hunter color values and volatile basic nitrogen (VBN) were measured at 1-week interval up to 4 weeks and 2-week interval thereafter until 8 weeks of refrigerated storage.

2.3.1. pH, water activity and proximate composition

pH values of cooked sausage were measured by blending 10 g of a finely homogenized sample with 90 ml of double-distilled (dd) water. Sausage samples were blended in a food processor and pH values were determined with a standardized combination electrode attached to a digital pH meter (Mettler-Toledo, model 340, Schwarzenbach, Switzerland). Water activity (a_w) of sausage products was measured using Novasina hygrometer (EEJA-3, Switzerland). Chemical composition, moisture, fat, crude protein (%) were determined by AOAC (1995) methods.

2.3.2. Cooking loss and water holding capacity. Cooking losses (CL,%) were calculated as the percent weight difference of the meat batter mass before and after cooking at 71.7 °C, as described in Chin, Keeton, Longnecker, and Lamkey (1998). Water-holding capacity (WHC) was measured by centrifugation, according to the modified method of Jauregui, Regenstein, and Baker (1981). Approximately 1.5 g of each cooked sausage was wrapped with dried filter paper (Whatman no. 3) and weighed. After centrifugation at 3000 rpm for 15 min, expressible moisture (EM,%) calculated as weight difference between the total sample weight and sample weight.

2.3.3. Chemical deterioration. Test for TBARS was performed to determine the degree of lipid oxidation, according to the method of Ziper and Watt (1962). The test was performed every-week up to 4 weeks and every 2-weeks thereafter up to 8 weeks of storage, and expressed as TBARS (mg malonaldehyde/ kg). Volatile basic nitrogen (mg%) test was performed to determine the extent of protein deterioration during refrigerated storage. VBN was measured by the modified micro diffusion assay, according to the method from Pearson (1968).

$$\mathrm{VBN(mg\%)} = \frac{(a-b)\times(f\times 0.02N\times 14.007\times 100\times 100)}{S}$$

where, a = titer for sample, b = titer for blank, f = factor of reagent, N = normality, S = sample weight (g).

2.3.4. Color values (Hunter L, a, b*)*. Color values were measured using a Chrom Meter (CR-200, Minolta Corporation, Ramsey, NJ), which was standardized using as white blank, and samples were measured with in five different locations across the cut surface. The results were expressed as Hunter L (lightness), a (redness), b (yellowness) values.

2.3.5. Texture profile analysis (TPA). Sausage samples were cut into cylinder (1.3 cm thick, 1 cm diameter) and subjected to two cycle compression test and analyzed with a texture meter (TA-XT2, Stable micro system, England). Ten samples per treatment were compressed to 75% of their height through a two-cycle compression described by Bourne (1978). A flat plate attached to a 5 kg load cell was compressed twice at the test speed of 120 mm/min. Work performance on the sample and the TPA parameters were as follows: fracturability (g) was the force at the first significant break in the curve, the peak force during the initial compression was expressed as hardness (first compression, g); Springiness (cm) was determined as the height that the sample recovered during the time elapsed between the end of first compression and the start of second compression: cohesiveness was calculated as the ratio of the area under the second compression curve to the area under the first compression curve; gumminess was calculated as the product of hardness times and cohesiveness; and the chewiness was calculated as the products of gumminess and springiness.

2.3.6. Microbial determination. Sausages (each 25 g) inoculated with 10^3 cfu/g of *Listeria monocytogenes* (LM) were opened every week up to 4 weeks and every 2 weeks thereafter up to 8 weeks of storage, and homogenized in 225 ml of sterilized double-distilled water. The mixtures were plated on aerobic plate counts (APC) for total bacteria, tryptic soy agar (TSA) for *Listeria monocytogenes* (LM) and violet-red bile agar (VRB) for *Enterobacteriaceae* determination. Colonies were counted after incubation at 37 °C for 48 h and data were expressed as $\log_{10}$ colony forming units (cfu)/g.

2.4. Statistical analysis

The experiment was performed in triplicates and data were analyzed by analysis of variance (ANOVA) in 4 (treatments) × 6 (storage times) factorial design with a control using the general linear model (GLM) procedure

of the SAS statistical package (1989). Also ANOVA for a 4 × 6 factorial design was performed to determine whether the interactions between treatment and storage time were significant ($P<0.05$). If the significant interactions were observed ($P<0.05$), mean separation procedure was accomplish with pool means using Duncan's mean comparisons. In addition, the microbial counts were separated out by treatment within storage time to determine the differences in the growth rate of *Listeria monocytogenes* among treatments.

3. Results and discussion

Since no interactions ($P>0.05$) were observed between treatment (preservatives) and storage time except for the microbial counts, physico-chemical and textural data were pooled over treatments or storage times to test the main effect (Tables 4 and 5). However, microbial data were separated out by treatments within storage time or by storage days within a treatment because interactions between treatment and storage time were significant ($P<0.05$; Table 6).

3.1. pH, water activity, and proximate composition

The effects of 3.3% SL on chemical composition, pH and water activity (a_w) of regular-fat frankfurters were evaluated and compared with sausages containing PS and SB with different levels (0.05–0.10%), and a control. pH and a_w values of sausages in all treatments were 6.10–6.13 and 0.936–0.941, respectively, and these parameters were not affected ($P>0.05$) by various preservatives (Table 4). These results for pH determination confirmed a previous study, which reported that the level of SL did not affect pH values of low-fat (9% fat) frankfurters (Bloukas et al., 1997). Lin and Lin (2002) did not find any differences in pH values of low-fat Chinese-style sausages between the addition of 3% SL and a control (no SL addition) during storage. The addition of 3.3% SL (60% solution) to the sausage formulations equals to approximately 2% of pure SL (100%) and was not significantly different from a control (Table 4). However, previous studies have shown addition of 2–3% SL lowered a_w values ($P<0.05$) in cooked meat products or vacuum-packaged coarse liver pate, respectively (Debevere, 1989; Hammer and Wirth, 1985). Shelef and Yang (1991) suggested that foods containing

Table 4
Physico-chemical, textural and microbiological properties of frankfurters manufactured with various preservatives

Treatments[a]	CTL	Potassiun sorbate (%)		Sodium benzoate (%)		SL (%)
Parameters[b]		0.05	0.1	0.05	0.1	3.3
pH	6.11	6.11	6.13	6.10	6.10	6.13
Water activity	0.940	0.940	0.940	0.940	0.941	0.936
Moisture	63.8	63.8	62.8	63.7	64.1	61.9
Fat	15.4	16.4	16.9	16.9	15.7	16.7
Protein	13.2	12.8	12.3	12.9	12.5	11.9
CL (%)	1.47	1.68	1.31	1.88	1.66	1.80
EM (%)	27.6	28.3	26.5	28.3	26.9	26.2
Total bacteria	4.16a	3.65b	3.34 c	3.33 c	3.31 c	3.30 c
LM	4.09a	3.60 b	3.35 bc	3.34 bc	3.28 c	3.26c
TBARS	0.125 a	0.104 ab	0.104 ab	0.090 bc	0.074 cd	0.062d
VBN	4.99	4.98	4.86	4.68	4.98	4.74
Hunter *L*	72.2 ab	72.6 ab	72.4 ab	72.3 ab	73.0 a	71.4 b
Hunter *a*	11.9	11.7	10.2	12.0	11.6	12.2
Hunter *b*	9.02	9.17	9.61	9.47	9.28	9.15
Hardness	2974	2946	2934	2983	3247	3309
Cohesivness	0.19	0.19	0.20	0.18	0.20	0.19
Springiness	0.55	0.51	0.55	0.50	0.55	0.48
Gumminess	563	576	576	541	624	599
Chewines	245	236	252	197	266	229

Means with same row having same letter (a–d) are not different ($P>0.05$). Data were pooled over the storage time.

[a] Treatment: CTL, no preservative; SL, 3.3% Sodium lactate (SL, 60%).

[b] Paramters: CL, cooking loss(%); EM, expressible moisture (%); LM, *Listeria monocytogenes* (Log_{10} cfu/g); TBARS, Thiobarbituric acid reacting substances (mg malonaldehyde/100 g); VBN, volatile basic nitrogen (mg%).

Table 5
Physico-chemical, textural and microbiological properties of frankfurters as affected by storage times (weeks)

Parameter[a]	Storage times (weeks)						
	0	1	2	3	4	6	8
pH	6.15 a	6.16 a	6.13 ab	6.16a	6.06 bc	6.05 c	6.08 abc
Water activity	0.941	0.941	0.939	0.938	0.939	0.939	0.939
EM(%)	28.1 ab	28.4 ab	26.1 ab	25.9 b	28.8 ab	29.3 a	29.2 a
Total bacteria	3.38b	3.43b	3.46b	3.35b	3.23b	3.25 b	3.95a
LM	3.36	3.39	3.50	3.44	3.45	3.67	3.70
TBARS	0.05 c	0.09 b	0.08 b	0.10 b	0.10 b	0.10 b	0.15 a
VBN	3.63 c	4.68 b	4.79 b	5.10 ab	4.82 b	5.37 ab	5.87 a
Hunter L	73.2 a	72.1ab	72.7ab	71.5 b	72.7 ab	71.1 ab	71.9 ab
Hunter a	12.0	12.0	10.9	11.5	11.5	11.5	11.7
Hunter b	8.79 cd	8.50 d	8.83 cd	9.71b	9.38 bc	9.51 bc	10.8a
Hardness	3757 a	3186 ab	3003ab	2978ab	2994 ab	2107 b	2602b
Cohesivness	0.19	0.19	0.20	0.19	0.19	0.20	0.20
Springiness	0.59 a	0.54ab	0.50 bc	0.46c	0.47 c	0.48 c	0.52 bc
Gumminess	716 a	595 ab	585 ab	536 b	555 b	525 b	501 b
Chewiness	331	255	217	197	205	185	239

Means with same row having same letter (a–d) are not different ($P > 0.05$). Data were pooled over various preservatives.
[a] Parameter; same as in Table 4.

higher moisture content (%), such as comminuted beef and chicken, did not significantly affect a_w by the addition of SL, as compared to those containing less water. During 8 weeks of refrigerated storage, pH values pooled over treatments tended to decrease, resulting in the differences in pH value at 4 weeks from that of initial storage, however, a_w values were not changed with storage time (Table 5). Our results indicated that storage time had effect on pH, but no effect on a_w values. These confirmed results of Bloukas et al. (1997) who reported that pH was affected by storage time, but not affected by the addition of SL.

Mean values for moisture, fat and protein contents (%) of comminuted sausages were in the range of 61–64, 15–17, 12–14%, respectively. The typical moisture, fat and protein contents of emulsified sausage products sold in Gwangju, Korea, varied 55–65, 10–25, and 7–15%, respectively (Chung & Chin, 2002). Bloukas et al. (1997) manufactured low-fat (~9%) and regular-fat (~25%) beef sausages, and reported the moisture, fat, protein and ash contents (%) of regular-and low-fat frankfurter to be 58, 25, 11, 2.90%, and 70, 10, 13, 2.97%, respectively. Thus, regular-fat (~25%) sausages in their study had higher fat contents than those of our study (15–17%). Currently, Korean consumers are interested in high-quality meat products, which have higher meats with low-fat and low-salt contents and no or least amounts of chemical preservatives, if possible. Thus, many researches have been attempting to develop "healthier meat products" that manufactured without or least amounts of these preservatives or with at least natural preservatives to meet their demands. SL would be a potential substitute for conventional chemical preservatives because it is derived from lactic acid, naturally present in the animal tissue.

3.2. Cooking loss and expressible moisture

After cooking to an internal temperature of 71.7 °C in a water bath, cooking loss (CL,%) and expressible moisture (EM,%) were measured, as showed in Table 4. Mean values for CL in all treatments varied from 1 to 2% and no differences in CL values were observed ($P > 0.05$) among the treatments (Table 4). CL values of treatments cooked in a water bath may not be directly comparable with those of actual smokehouse cooking because the latter would be more extreme condition. Bloukas et al. (1997) reported that if the beef sausages were cooked in boiling water for 2 min, CL was determined less than 1%, however, approximately 17–20% of processing loss was found under the cooking in a smokehouse. A previous study showed that low-fat bologna cooked in a water bath had 1–2% CLs, however, approximately 9–10% CLs were observed in an actual smokehouse cooking (Chin, Keeton, Miller, Longnecker, & Lamkey, 2000). Preservatives had no effect on EM values ($P > 0.05$) among treatments, but, EM values were slightly affected ($P < 0.05$) by storage time (Table 5), resulting in difference of EM values (%) pooled over the treatments at week 3 from ($P < 0.05$) those at weeks 6 and 8 (Table 5). This result might be

partially due to the protein deterioration with an increases in storage time, which results in lower water holding capacity.

3.3. Thiobarbituric acid reacting substance and volatile basic nitrogen determination

When sodium benzoate and sodium lactate were incorporated in the sausage formulation, TBARS values were lower ($P<0.05$) than the those obtained from the control (Table 4). Storage time had an effect ($P<0.05$) on TBARS, resulting in higher values with increased storage time (Table 5). These results confirmed those of Bloukas et al. (1997), who reported that the TBA values were affected by both level of SL and storage period.

Mean values for volatile basic nitrogen (VBN) were not affected ($P>0.05$) by various preservatives, however, they tended to increase with increased storage time (Tables 4 and 5). Results from our study were not confirmed with Lin and Lin (2002), who reported that Chinese-style sausages containing SL had lower than those with other ingredients, such as potassium sorbate (0.2%) and trisodium phosphate (TSP, 0.2%) during storage. They also suggested that higher VBN values for TSP were associated with the higher microbial counts among treatments.

3.4. Hunter color values

No differences in Hunter color values were observed, except for few cases (0.1% SB vs. 3.3% SL; Table 4). Storage time had an effect ($P<0.05$) on lightness and yellowness of sausages (Table 5), resulting in decreased lightness and increased yellowness values ($P<0.05$) with increased storage time with few exceptions. Contrary to our results, a previous study reported that color values of frankfurters were not affected by storage time and SL treatments (Bloukas et al., 1997). These color differences might not be significant because of small magnitude of differences in lightness and yellowness values, even though results from our study showed slight differences in Hunter color values, not only among treatments, but also during storage time.

3.5. Texture profile analysis

Textural profile analysis (TPA) values of sausages manufactured with various preservatives are shown in Table 4. Our results showed that any preservatives did not affect ($P>0.05$) TPA values of the sausage products (Table 4). These results are in agreement with those of Bloukas et al. (1997), who reported that the increased level of SL had not effect on product hardness and cohesiveness in both regular-fat and low-fat (9%) sausages. However, storage time affected textural properties most (Table 5). Sausages with or without preservatives became weaker in TPA hardness at week 6 and less springy at 2 weeks of refrigerated storage. The decreases in TPA hardness, springiness and gumminess values may be partially due to decreases in water holding capacity (increased EM) or increases in purge accumulation during storage.

3.6. Shelf-life effect (microbial change)

Because interactions between treatment (preservatives and their level) and storage time were significant

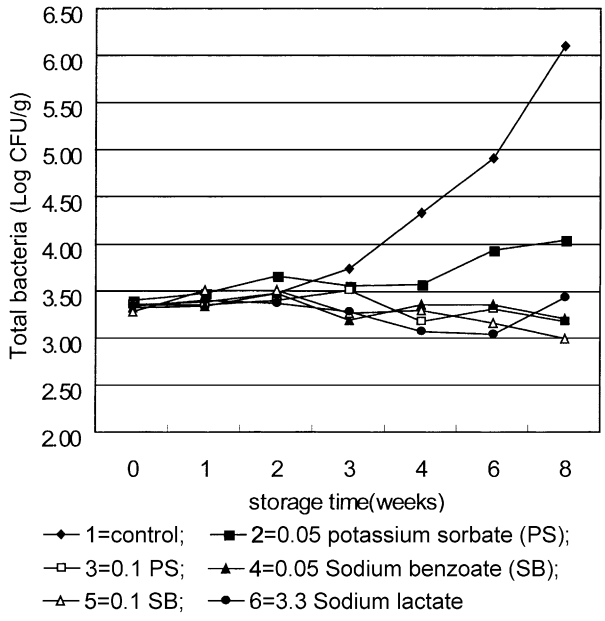

Fig. 1. Changes of total bacterial counts of regular-fat sausages as affected by preservatives during refrigerated storage.

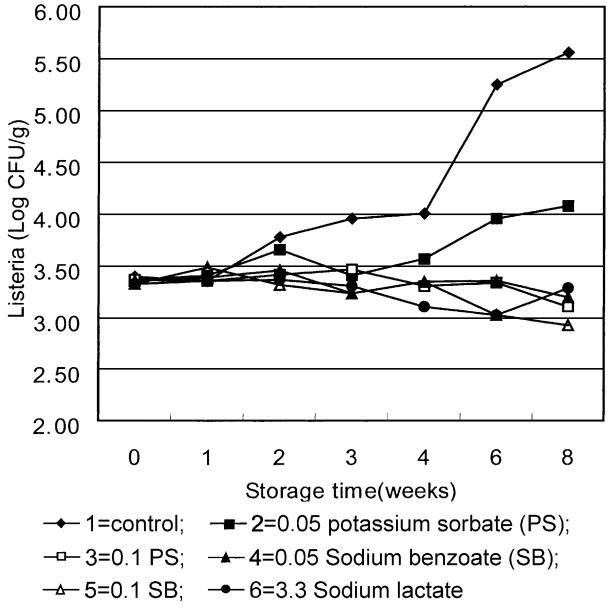

Fig. 2. Changes of micobial counts for inoculated *Listeria monocytogenes* of regular-fat sausages as affected by preservatives during refrigerated storage.

($P<0.05$), microbial data were separated out and analyzed by treatment and storage time. Since LM was inoculated at the level of 10^3 cfu/g in all treatments, we anticipated this to be the predominant flora in the sausages. Thus, aerobic plate counts had a similar trend to LM (Figs. 1 and 2). From 3 to 4 weeks of storage time, treatments containing preservatives started to be lower microbial counts ($P<0.05$) as compared with the control. These results are in agreement with those with Bloukas et al. (1997), who reported that the total plate counts for the control had increased rapidly after 4 weeks storage. Treatments containing 3.3% SL alone had an antilisterial effect similar to those with 0.05–0.1% of PS or SB during storage (Fig. 1). No *Enterobacteriaceae* ($<10^2$ cfu/g) were found in all treatments during or at the end of storage (data not shown). Murano and Rust (1995) reported that SL was an effective antibacterial agent for psychrotrophic bacteria in frankfurters and the addition of starch–soy protein isolate did not increase microbial growth. Results from our study indicated that 3.3% SL alone would be replaced with at least 0.05% of PS or SB for inhibiting LM growth in regular-fat sausages during storage. This will result in delay of lag phase at least a couple of weeks, as compared with the control.

4. Conclusions

Regular-fat frankfurters were manufactured with potassium sorbate (PS) and sodium benzoate (SB) each at 0.05 and 1.0%, and were compared with those containing 3.3% sodium lactate (SL, 60%) or with control (without preservative). When 3.3% SL was added to the sausage formulations, lower TBARS values were found, as compare to control. Storage time was a factor affecting the product quality, resulting in decreases in textural properties. Compared with the control, treatments containing preservatives had lower total bacterial counts after 4 weeks of storage and had lower microbial counts of *Listeria moncytogenes* (LM) reduced by at least 2 log cycle at the end of storage time (8 weeks) by these treatments. Antimicrobial effect were also found similar to either 0.05–1.0% of PS or SB without any deterioration in quality of sausages. Results from our study indicated that SL (60%) at the level of 3.3% had the potential to replace at least 0.05% PS or SB for similar antilisterial effect in frankfurters, and therefore it delayed the lag phase for the growth of LM approximately a couple of weeks, compared with the control. Future studies will be planned to explore the possibility of using reduced levels of SL in combined with other natural ingredients as a replacer for conventional synthetic or chemical preservatives.

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