Food Sci. Biotechnol. Vol. 18, No. 1, pp. 36 ~ 42 (2009)

Food Science and Biotechnology

Physicochemical, Textural, and Sensory Properties of Low-fat/reduced-salt Sausages as Affected by Salt Levels and Different Type and Level of Milk Proteins

Hong Chul Lee and Koo Bok Chin*

Department of Animal Science and Biotechnology Research Institute, Chonnam National University, Gwangju 500-757, Korea

Abstract This study was performed to develop low-fat/reduced-salt sausages (LFRSS; <3% fat and <1.5% salt) containing milk protein (whey protein concentrate, WPC, or sodium caseinate, SC) that showed the similar cooking yield and textural characteristics to those of regular-fat/salt sausage control (RFC; 20% fat and 1.5% salt) or low-fat sausage control (LFC; <3% fat and 1.5% salt). Low-fat sausages (LFS) were formulated with a 2.5% fat replacer (*konjac* flour:carrageenan:soy protein isolate=1:1:3) and various salt levels (0.75, 1.0, 1.25, and 1.5%). LFS had differences in color and expressible moisture (EM, %) values as compared to those of RFC. A minimum salt level of 1% and addition of nonmeat proteins were required to manufacture LFRSS that have similar characteristics to those of RFC. However, LFS with 2% milk proteins reduced the hardness and gumminess as compared to LFC. These results indicated that 1% milk protein in combined with 1% salt was a proper level for manufacturing of LFRSS.

Keywords: low-fat/reduced-salt sausage, milk protein, texture profile analysis, sensory evaluation

Introduction

Healthier meat and meat products could be manufactured with reduced fat and salt in combination with the addition of functional ingredients. These products might be used to prevent or treat certain diseases, as well as to provide valuable nutrients (1). Since the consumption of meat products was affected by the incorporation of non-meat ingredients, meat producers have tried to avoid the addition of chemical ingredients to meat products.

Both fat and salt, which are normally added to meat products during manufacturing, contribute to product quality in terms of the flavor and texture of meat products. Salt has been used to decrease cooking loss and firmness in frankfurters (2). Increased sodium level (0-3%) reduced total plate counts (TPC) and pH in various meat products (3). Although fat is needed to provide flavor, texture, and essential fatty acids to meat products, excessive fat and salt in the diet may lead to certain diseases, such as hypertension or coronary heart disease (4). The Korean National Health and Nutrition Survey reported that Koreans consume more sodium than residents of other countries such as the USA, Japan, and Europe (5). Thus, American Heart Association dietary guidelines recommend for meat producers to process meat products with reduced salt level (4).

On the other hand, a reduced salt level was found to affect the functional and textural properties of ground meat (beef+pork) patties (6). Matulis *et al.* (7) suggested that frankfurter hardness was affected by salt concentration, and a salt level more than 1.5% was required for the manufacture of frankfurters to have an appropriate texture. Based on the previous studies, functional ingredients and processing technologies should be applied to reduced salt products to improve their functional and textural characteristics.

Thus, the objectives of this study were to manufacture low-fat sausages with reduced salt levels in combination with milk proteins and to select the best combination of low-fat/reduced-salt sausages (<3% fat and <1.5% salt) with different milk proteins showing similar characteristics to those of their regular-fat/salt counterparts.

*Corresponding author: Tel: +82-62-530-2121; Fax: +82-62-530-2129
E-mail: kbchin@chonnam.ac.kr
Received March 20, 2008; Revised July 12, 2008;
Accepted August 5, 2008

Materials and Methods

Processing and preparation of reduced-salt comminuted sausages All visible fats and connective tissues were trimmed from pork hams which were slaughtered at approximately 110 kg (hog, grade A) as a live animal (6 month) at a retail meat market and stored at refrigerator for about 1 day, and pork back fats were purchased from a local meat market and were stored at −18°C until used.

Low-fat (LFS; <3% fat) and regular-fat/salt sausages (RFS; 20% fat and 1.5% salt) were manufactured according to the method of Chin *et al.* (8) and followed by formulation shown in Table 1. Ground meats were chopped for 30 sec using a silent cutter (K-15; Talsa, Xirivella, EU) in order to obtain cuts of a uniform size. To extract the salt soluble proteins, refined salt, sodium nitrite, sodium erythorbate, and a half volume of ice water were added to the meat, and then chopped for 1 min. Seasonings and remaining ice water were added, and the meat batter was homogenized for 1.5 min continuously mixed for 30 sec at high speed. The meat batter was vacuum-packaged, stuffed into cellulose casing (32 mm), smoked, and cooked to an internal temperature of 71°C in a smokehouse (Nu-Vu, ES-13; Food System, Menominee, MI, USA). After cooking, the sausages were chilled, vacuum-packaged, and stored in a refrigerator until analyzed.

Table 1. The formulation of regular- and low-fat sausages with various salt levels or different type and level of milk protein

Treatments[1)]	CTL	LFS (Experiment 1)				LFRSS (Experiment 2)			
		Salt level (0.75-1.5%)				Salt 1% with different milk proteins			
Ingredients	(RFC)	0.75	1	1.25	1.5 (LFC)	WP1	WP2	SC1	SC2
Pork lean	**55**	**55**	**55**	**55**	**55**	**55**	**55**	**55**	**55**
Pork fat	**20**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Ice water	**19.1**	**36.6**	**36.6**	**36.6**	**36.6**	**36.6**	**36.6**	**36.6**	**36.6**
Non-meat Ingredients	**7.4**	**9.15**	**9.4**	**9.65**	**9.9**	**10.4**	**11.4**	**10.4**	**11.4**
- Fat replacers[2)]	0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
- Refined salt (NaCl>88%)	1.3	0.55	0.8	1.05	1.3	0.8	0.8	0.8	0.8
- Sugar	1	1	1	1	1	1	1	1	1
- Corn syrup	1	1	1	1	1	1	1	1	1
- Sodium tripolyphosphate	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
- Non-fat dry milk	1	1	1	1	1	1	1	1	1
- Maltodextrin	1	1	1	1	1	1	1	1	1
- Hydrolyzed milk protein	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
- Spices #5	1	1	1	1	1	1	1	1	1
- Sodium erythorbate	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
- Cure blend (salt and 156 ppm $NaNO_2$)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
- Whey protein concentrates	0	0	0	0	0	1	2	0	0
- Sodium caseinate	0	0	0	0	0	0	0	1	2
Total	**101.5**	**100.75**	**101.0**	**101.25**	**101.5**	**102**	**103**	**102**	**103**

[1)]CTL, regular-fat/salt sausage control (RFC; fat 20% and salt 1.5%); LFS (low-fat sausages, fat<3%): salt 0.75, 1, 1.25, and 1.5% (LFC); LFRSS (low-fat/reduced-salt sausages, fat<3% and salt 1%): WP1, whey protein concentrate (WPC) 1%; WP2, WPC 2%; SC1, sodium caseinate (SC) 1%; SC2, SC 2%. [2)]Fat replacers: *konjac* flour, carrageenan, and soy protein isolate at the ratio of 1:1:3.

LFS were manufactured with various salt levels (0.75, 1.0, 1.25, and 1.5%) or the selected optimum salt level combined with various levels of milk proteins [whey protein concentrates (WPC) or sodium caseinate (SC): 1 or 2%; Sung Poong Corp., Seoul, Korea] (Table 1) and the product characteristics of the sausages (LFRSS) were evaluated as compared to those of the RFS (20% fat and 1.5% salt).

pH and proximate analysis pH values were measured by using a pH meter (MP 120; Mettler-Toledo, Schwarzenbach, Switzerland). Proximate compositions were determined according to the methods of AOAC (9). Moisture was measured by the drying method, fat contents by the Soxhlet method, and protein contents by Kjeldahl nitrogen determination.

Cooking loss and expressible moisture Cooking loss (CL, %) was determined in terms of the differences in weight before and after cooking. Approximately 1.5 g of sausage samples wrapped with filter papers (110 mm, Whatman #3; Whatman Intl. Ltd., Maidstone, England) was centrifuged at 1,000×g for 15 min using a modified method of Jauregui *et al.* (10). Expressible moisture (EM, %) values were calculated as the differences in weight separated from total sample to filter paper after centrifugation.

Hunter color values (L, a, and b) Color values of sausages were measured by calculating the mean with the results for 4 different locations on the sausage surface using a chroma meter (CR-10; Minolta, Osaka, Japan). Mean data were expressed by Hunter L (lightness), a (redness), and b (yellowness) values compared to the standardized plate of L=91.1, a=1.28, b=−1.54.

Sensory evaluation Seven untrained sensory panels were evaluated for the color, flavor, texture, and overall acceptance using 8-point hedonic scales to evaluate the consumer trends. The scale was followed: from 1 (most like) to 8 (most dislike).

Texture profile analysis (TPA) TPA of the sausage samples were performed by TPA using the Instron Universal Testing Machine (Model 3344; Canton, MA, USA) according to the method of Bourne (11). After equilibrium with room temperature (25°C), sausage samples (1.25 cm diameter) were compressed to 75% of their original height with 500-N load cell at a cross speed of 300 mm/min. TPA values were expressed in terms of hardness (gf), springiness (cm), gumminess, chewiness, and cohesiveness of low-fat and regular-fat sausages.

Statistical analysis Experiment 1 was performed in triplicate, and data were analyzed by one-way analysis (salt level) of variance (ANOVA) using SPSS software 12.0 (12) for windows (SPSS Inc., Chicago, IL, USA) with a significance level of 0.05%. Data for experiment 2 were analyzed by two-way ANOVA and interaction between the type and level of milk protein was assessed. If the interactions between the level and type of milk protein

were not significant ($p>0.05$), data were analyzed by main factor combinations using Duncan's multiple comparison test. Dunnett's T-test was used to compare the RFC (20% fat and 1.5% salt) with each LFS (<3% fat) treatment (1.5 and 1.0% salt level).

Results and Discussion

Physicochemical, textural, and sensory properties of LFS with reduced salt levels (experiment 1) pH values of LFS (<3% fat) were 5.79-5.82 (Table 2). The fat content (%) of LFS was less than 3%, and thus, more than 20% of the fat was removed from the RFC (20% fat and 1.5% salt). LFS had higher moisture and lower fat content than RFS. Salt level did not affect pH values or chemical composition (Table 2). Yang *et al.* (13) manufactured low-fat frankfurters with several binders and fat substitutes, and reported that the moisture content (%) of low-fat (10%) frankfurters, ranging from 70.7 to 74.6% was higher than that of regular-fat controls (22%), ranging from 61.5 to 62.7%. Additionally, low-fat frankfurters manufactured with isolated soy protein, modified waxy maize starch, and isolated muscle protein had similar sensory and texture properties to those of regular-fat products.

The LFS tended to be darker and less yellow ($p<0.05$) or similar to those of RFC (Table 2). These results could partially be attributed to the reduced fat levels in LFS. However, the LFS showed no differences in Hunter color values with the reduced salt levels. Yang *et al.* (13) reported that sausages with reduced fat levels were darker and less yellow than their regular-fat counterpart. In their study, the Hunter L, a, and b values of regular-fat sausage versus low-fat sausage were 58.1-62.0, 13.7-15.1, and 8.1-8.3 vs. 54.4-60.4, 14.5-15.3, and 7.4-8.3, respectively. The addition of several binders and fat substitutes also did not cause a change in Hunter color values in LFS. Su *et al.* (14) reported that Hunter L values of low-fat sausage (1.5% salt) did not change with increased salt level (1.5 vs. 2.5%). In addition, incorporation of non-meat protein, a pre-emulsified fat (PEF) in frankfurters had no effect on Hunter a and b values. Frankfurters with PEF had lower Hunter L values than their meat counterparts, except for a few cases. Thus, reduction of sodium chloride in emulsified sausages did not affect color of meat products.

RFC had less expressible moisture (EM, %) than LFS (Fig. 1A, $p<0.05$), as expected. This resulted from the strong binding of the emulsion and lower moisture (%) of RFC. However, an increased salt level did not affect the EM of LFS. These results were not in agreement with the previous results indicating that both salt content and pH affected the water holding capacity in cooked sausage. In their research, water holding capacity was significantly affected by the pH of raw materials in combination with sodium chloride (15). Conversely, cooking losses (CL, %) did not differ, regardless of fat and salt levels (Fig. 1B). Park *et al.* (16) reported that regular-fat sausage did not differ in cooking loss of low-fat sausage with chitosans during refrigerated storage. Yang *et al.* (13) also reported that low-fat frankfurters showed no differences in cooking loss, regardless of the type of fat replacer added. Based on these previous results, cooking losses (%) were not significantly affected by salt and fat levels.

Although no differences in textural properties were observed between the regular- and low-fat treatments (Table 3), LFS containing 1.0% salt or higher had similar hardness values to those of low-fat control (LFC; <3% fat and 1.5% salt). In this study, the salt level did not significantly affect the textural properties of LFS, because the addition of a fat replacer (*konjac* flour-carrageenan-soy protein isolate) in LFS might compensate for the textural defects in the case of reduced salt level (1). Luruena-Martinez *et al.* (17) also reported that low-fat frankfurters (9 and 12% fat) manufactured with locust bean/xanthan gum had similar hardness, springiness, chewiness, and gumminess as compared to the regular-fat counterpart (20% fat). Choi and Chin (18) concluded that the low-fat sausage manufactured with various fat replacers had similar textural characteristics to those of regular-fat counterparts. Xiong *et al.* (19) also reported that sausages manufactured with low-salt (1%) and fat (4%) showed weak binding, resulting in lower hardness. However, this value was improved by the incorporation of ι-carrageenan (0.5%) into the sausages, resulting in higher binding capacity.

Table 2. pH, proximate composition, and color values of low-fat sausage as compared to those of regular-fat/salt counterparts

Treatments[1)]	RFC	LFS with various salt levels (%)			
		0.75	1.0	1.25	1.5 (LFC)
pH	5.82±0.03[2)]	5.79±0.08	5.81±0.04	5.82±0.08	5.80±0.09
Moisture (%)	58.6±3.06^{b}	75.8±1.92^{a}	75.7±0.02^{a}	76.6±1.47^{a}	76.2±1.83^{a}
Fat (%)	21.7±2.83^{a}	0.43±0.01^{b}	0.32±0.01^{b}	0.23±0.01^{b}	0.66±0.01^{b}
Protein (%)	13.8±0.98	14.8±0.89	14.4±0.96	14.3±0.99	14.1±0.27
Hunter color[3)]					
L	59.2±2.06^{a}	54.9±1.96^{b}	56.2±1.75^{ab}	52.9±1.78^{b}	56.0±2.76^{ab}
a	17.8±1.29	17.8±1.61	15.9±1.35	17.7±4.56	15.2±2.80
b	19.8±1.83^{a}	17.1±0.92^{ab}	16.4±0.57^{b}	16.8±2.59^{ab}	15.5±1.70^{b}

[1)]RFC, regular-fat/salt counterpart (fat 20% and salt 1.5%); LFS, low-fat sausages (fat<3%) with various salt levels (0.75, 1.0, 1.25, and 1.5%).
[2)]All values are the mean±SD; [a-b]Means having different superscript within same row are significantly different ($p<0.05$)
[3)]L=lightness, a=redness, b=yellowness.

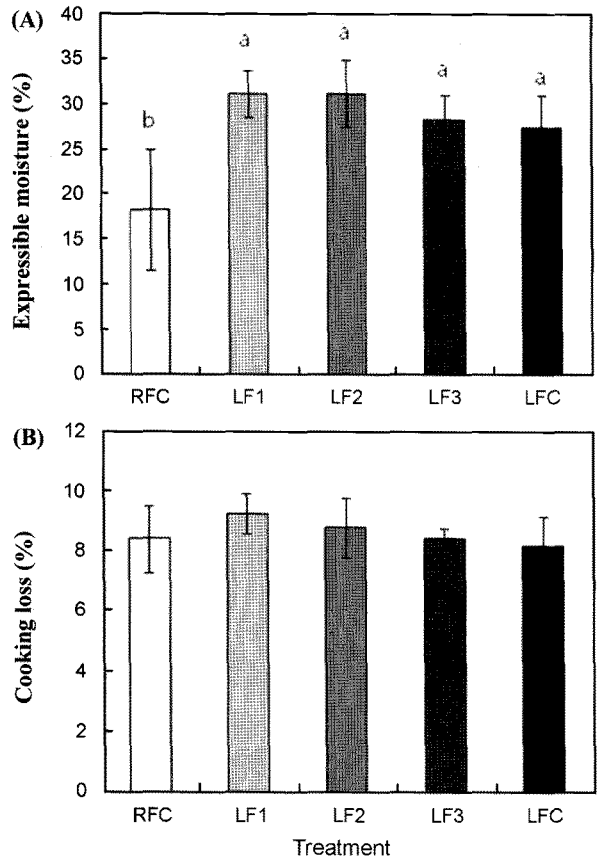

Fig. 1. Functional properties of low-fat sausages manufactured with various salt levels as compared to those of regular-fat/salt counterpart (A) expressible moisture (B) cooking loss (experiment 1). RFC, regular-fat/salt counterpart (fat 20% and salt 1.5%); LFS, low-fat sausages containing various salt levels (LF1: salt 0.75%, LF2: salt 1.0%, LF3: salt 1.25%, and LFC: salt 1.5%). [a-b]Means having different superscript are significantly different ($p<0.05$).

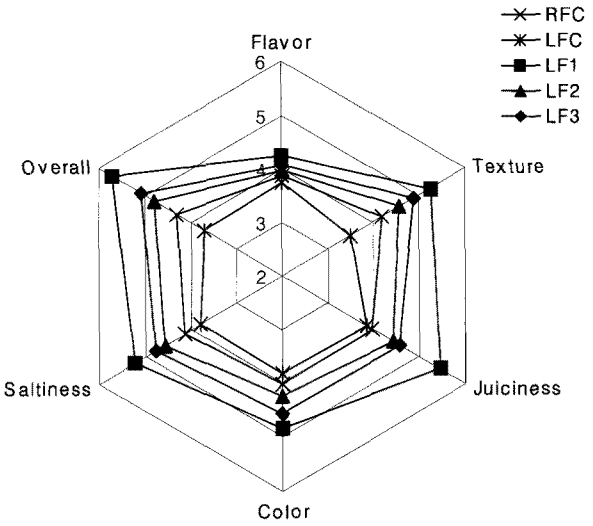

Fig. 2. Sensory evaluation of low-fat sausages with various salt levels as compared to that of regular-fat/salt counterpart (experiment 1). RFC, regular-fat/salt counterpart (fat 20% and salt 1.5%); LFS, low-fat sausages containing various salt levels (LF1: salt 0.75%, LF2: salt 1.0%, LF3: salt 1.25%, and LFC: salt 1.5%).

Sensory data show that panelists preferred regular salt treatments (1.5%) rather than the lower-salt (<1.5%) counterparts (Fig. 2). As a result, LFC showed similar or better sensory results to those of RFC. Meat products with 1.25% salt might be classified as low-salt products and was required to mimic the saltiness of regular-fat products (20). The LFC had also similar sensory flavor, color, and saltiness values to those of RFC, while those with 0.75% salt did not have acceptable overall acceptability. These results also supported that LFS containing 1.0% or higher salt should be required to satisfy the consumer, because these sausages were found to have better textural and sensory properties in this study. However, Matulis *et al.* (7) reported that, in a sensory evaluation, cohesiveness and juiciness were found to be enhanced by the addition of 1.5% salt. Also, Ruusunen *et al.* (21) reported the lowest salt content of ham was 1.7% salt to maintain the saltiness similar to that of normal cooked ham containing 2 or 2.3% salt. These results suggested that functional non-meat ingredients need to be added during the manufacturing of low-fat/reduced-salt sausages (<3% fat and <1.5% salt) to compensate for the functional and textural defects.

Physicochemical and textural properties of LFRSS with milk proteins (1.0% salt, experiment 2) Experiment 2 was performed to select the LFRSS (<3% fat and <1.5%

Table 3. Textural properties of low-fat sausages manufactured with various salt levels as compared to those of regular-fat/salt counterpart

Treatments[1)]	Regular-fat/ salt sausages (RFC)	Low-fat sausages (LFS) with various salt levels			
		0.75	1.0	1.25	1.5 (LFC)
Hardness (gf)	5,635±1330[2)]	3,407±951	4,104±801	3,922±1676	4,133±1744
Springiness (cm)	0.30±0.03	0.25±0.05	0.25±0.05	0.26±0.04	0.30±0.02
Cohesiveness	0.22±0.04	0.19±0.02	0.19±0.03	0.20±0.02	0.24±0.02
Gumminess	1,240±129	676±278	773±193	809±490	929±433
Chewiness	392±89	195±102	187±95	240±177	296±158

[1)]Treatments: RFC, regular-fat/salt counterpart (fat 20% and salt 1.5%); LFS, low-fat sausages (fat<3%) with various salt levels (0.75, 1.0, 1.25, and 1.5%).
[2)]All values are mean±SD.

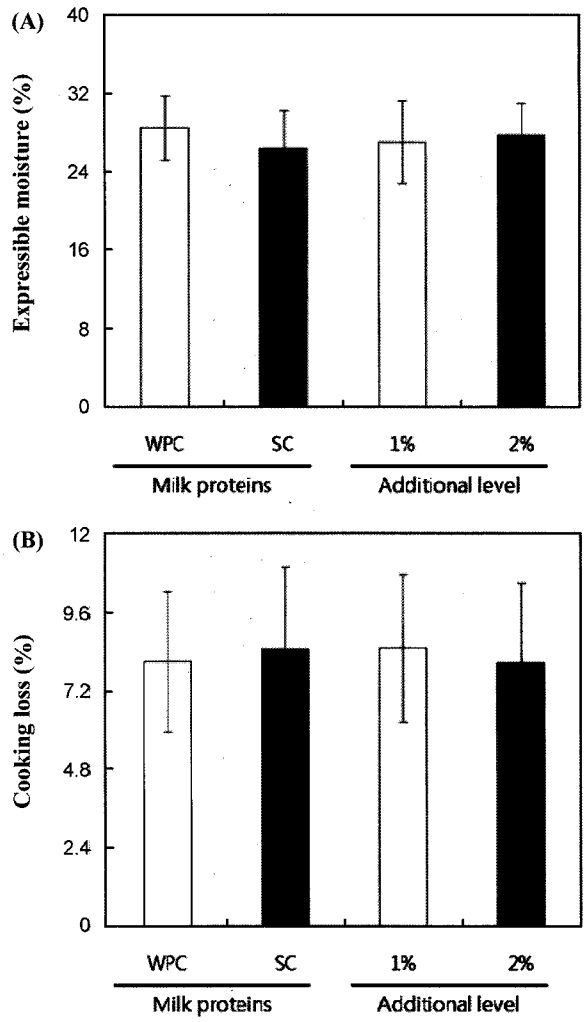

Fig. 3. Functional properties of low-fat/reduced-salt sausages (LFRSS; <3% fat and 1.0% salt) formulated with milk proteins affected by levels of milk proteins (A) expressible moisture (B) cooking loss (experiment 2). Milk protein: WPC= whey protein concentrate, SC=sodium caseinate; addition level: milk protein 1 or 2%.

salt) showing similar product qualities to those of regular-fat/salt and low-fat controls (RFC and LFC; 1.5% salt). Milk proteins, such as SC and WPC, were added to the initial mixture of sausages to maintain proper textral and functional properties.

The Dunnett's T-test was performed to compare the RFC (20% fat and 1.5% salt) with each LFS treatment (1.5 and 1.0% salt levels). pH values of LFS and RFC were 5.92-5.98. Moisture and fat contents of RFC were different from those of their LFS (Table 4). The Hunter L values of LFS were not different from those of RFC, except when treated with 1% SC (Table 4). Based on these results, sausages containing 1% salt were similar to those with 1.5% salt. Barbut (22) reported that regular whey did not improve cooking loss, even though modified whey improved cooking loss in chicken meat batter. Additionally, Smith and Rose (23) suggested that an optimum balance of NaCl and sodium tripolyphosphate should be selected in order to attain the maximum functional properties of WPC. In this study, the addition of excessive milk proteins (2%) into the meat batter reduced hardness and gumminess (Table 5). Thus, a level of 1% rather than 2% of milk proteins would be a proper amount to incorporate into LFS.

Since no interaction was observed between the type and level of milk protein, data were pooled and listed in Table 6 and 7. There were no significant differences in pH values, chemical compositions, and physicochemical and most textural properties (Table 6 and 7). However, LFS with 2% milk protein were less chewy than 1% counterpart ($p<0.05$, Table 7). Rhee (24) reported that an increased level of SC (0-3%) reduced the springiness in emulsified sausages. Previous studies reported that sausages containing a higher level of SC, ranging from 0 to 6%, were harder, less juicy, and more elastic, when exposed to rising temperatures during chopping of the batter (2).

In conclusion, a salt level of 1% might be the minimum level that should be used in the manufacture of LFS. Reduced chewiness values were observed with increased levels of milk proteins. Thus, the salt level of LFS (<3% fat) could be reduced from 1.5 to 1.0% without quality defects if milk proteins such as, SC or WPC, at the level of 1% were incorporated into the sausages mixture.

Acknowledgments

This work was supported by grant (#R08-2003-000-10568-0) from the basic research program of the Korea Science and Engineering Foundation, Republic of Korea.

Table 4. Dunnett's T-test of physicochemical properties of low-fat/reduced-salt sausages (LFRSS; <3% fat and 1.0% salt) with different type and level of milk proteins as compared to those of regular-fat/salt counterpart

Treatments[1)]	Salt 1.5%			Salt 1.0%		
	RFC	LFC	WP 1	WP 2	SC 1	SC 2
pH	5.95±0.10[2)]	5.92±0.08	5.94±0.08	5.97±0.09	5.97±0.10	5.98±0.07
Moisture (%)	58.1±0.67	74.3±0.87*	74.5±1.44*	74.2±1.14*	74.7±1.10*	74.0±1.19*
Fat (%)	20.3±0.92	2.37±0.83*	2.05±0.69*	2.30±0.84*	2.07±0.94*	1.96±0.60*
Hunter L	69.8±3.39	64.7±2.23	64.8±2.65	65.3±1.86	63.6±1.30*	64.3±2.62
Expressible moisture (%)	13.4±2.03	20.1±2.83	28.6±4.07*	28.4±3.36*	25.6±4.80*	27.1±3.58*
Cooking loss (%)	9.19±2.70	9.37±2.50	8.60±2.61	7.62±2.03	8.43±2.45	8.52±3.25

[1)]RFC, regular-fat/salt control (fat 20% and salt 1.5%); LFC, low-fat control (fat<3% and salt 1.5%); LFRSS, low-fat/reduced-salt sausages (<3% fat and 1.0% salt)–WP 1=whey protein concentrate (WPC) 1%, WP 2= WPC 2%, SC 1=sodium caseinate (SC) 1%, SC 2=SC 2%; *$p<0.05$.
[2)]All values are mean±SD.

Table 5. Dunnett's T-test of textural properties of low-fat/reduced-salt sausages (LFRSS) with different type and level of milk proteins as compared to those of regular-fat/salt counterpart

Treatments[1)]	Salt 1.5%		Salt 1%			
	RFC	LFC	WP 1	WP 2	SC 1	SC 2
Hardness (gf)	6,653±1699[2)]	4,437±137	4,573±467	3,861±23*	4,201±366	3,780±791*
Springiness (cm)	0.27±0.02	0.27±0.04	0.25±0.01	0.22±0.03	0.25±0.00	0.22±0.03
Gumminess	1,274±349	954±199	823±108	627±21*	693±145	586±141*
Chewiness	348±132	256±85	203±30	138±23	178±30	122±16
Cohesiveness	0.20±0.01	0.22±0.03	0.19±0.01	0.17±0.01	0.18±0.02	0.16±0.01

[1)]RFC, regular-fat/salt control (fat 20% and salt 1.5%); LFC, low-fat control (fat<3% and salt 1.5%); LFRSS, low-fat/reduced-salt sausages (<3% fat and 1.0% salt)–WP 1=whey protein concentrate (WPC) 1%, WP 2= WPC 2%, SC 1=sodium caseinate (SC) 1%, SC 2=SC 2%; *$p<0.05$.
[2)]All values are mean±SD.

Table 6. pH and proximate compositions of low-fat/reduced-salt sausages (LFRSS) formulated with milk proteins affected by type and level of milk protein

	Milk proteins		Addition level (%)	
	WPC	SC	1%	2%
pH	5.96±0.08[1)]	5.98±0.08	5.96±0.08	5.98±0.07
Moisture (%)	74.4±1.17	74.3±1.10	74.6±1.15	74.1±1.05
Fat (%)	2.17±0.70	2.01±0.71	2.06±0.74	2.13±0.68
Hunter L	65.1±2.07	63.9±1.89	64.2±1.99	64.8±2.11
Hunter a	16.4±4.11	17.6±4.75	17.3±4.14	16.7±4.78
Hunter b	6.13±2.10	4.77±1.97	5.20±1.84	5.70±2.42

LFRSS, <3% fat and 1.0% salt; WPC, whey protein concentrate; SC, sodium caseinate.
[1)]All values are mean±SD.

Table 7. Texture properties of low-fat/reduced-salt sausages (LFRSS) formulated with milk proteins affected by type and level of milk protein

	Milk proteins		Addition level (%)	
	WPC	SC	1%	2%
Hardness	4,217±492[1)]	3,990±559	4,387±404	3,820±459
Springiness	0.24±0.03	0.24±0.02	0.25±0.01	0.22±0.02
Gumminess	725±130	639±132	758±129	606±86
Chewiness	170±43	150±38	190±28[a]	130±19[b]
Cohesiveness	0.18±0.01	0.17±0.01	0.18±0.01	0.16±0.01

LFRRS, <3% fat and 1.0% salt; WPC, whey protein concentrate; SC, sodium caseinate.
[1)]All values are mean±SD; [a-b]Means having different superscript within same row in the same factor (milk proteins or addition level) are significantly different ($p<0.05$).

References

1. Jimenez-Colmenero F, Carballo J, Cofrades S. Healthier meat and meat products: Their role as functional foods. Meat Sci. 59: 5-13 (2001)
2. Girard JP, Culioli J, Maillard T, Denoyer C, Touraille C. Influence of technological parameters on the structure of the batter and the texture of frankfurter type sausage. Meat Sci. 27: 13-28 (1990)
3. Brewer MS, Rostogi BK, Argoudelis L, Sprouls GR. Sodium lactate/sodium chloride effects on aerobic plate counts and color of aerobically packaged pork. J. Food Sci. 60: 58-62 (1995)
4. AHA. American Heart Association Guidelines: Revision 2000. Circulation 102: 2284-2299 (2000)
5. KHIDI. Research report: Korean national health and nutrition survey 2001. pp. 511-512. Korea Health Industry Development Institute, Seoul, Korea (2001)
6. Ruusunen M, Vainionpaa J, Lyly M, Lahteenmaki L, Niemisto M, Ahvenainen R, Puolanne E. Reducing the sodium content in meat products: The effect of the formulation in low-sodium ground meat patties. Meat Sci. 69: 53-60 (2005)
7. Matulis RJ, McKeith FK, Sutherland JW, Brewer S. Sensory characteristics of frankfurters as affected by fat, salt, and pH. J. Food Sci. 60: 42-47 (1995)
8. Chin KB, Lee HL, Kook SH, Yoo SS, Chun SS. Evaluation of various combinations of pork lean and water added on the physicochemical, textural, and sensory characteristics of low-fat sausages. Food Sci. Biotechnol. 13: 481-485 (2004)
9. AOAC. Official Methods of Analysis of AOAC Intl. 17th ed. Method. 950.46, 991.36, 981.10. Association of Analytical Chemists. Gaithersburg, MD, USA (2000)
10. Jauregui CA, Regenstein JN, Baker RC. A simple centrifugal method for method for measuring expressible moisture, a water binding property of muscle foods. J. Food Sci. 46: 1271-1273

(1981)
11. Bourne MC. Texture profile analysis. Food Technol. -Chicago 32: 62-66, 72 (1978)
12. SPSS Inc. SPSS 12.0 for windows. Chicago, IL, USA (2003)
13. Yang A, Keeton JT, Beilken SL, Trout GR. Evaluation of some binders and fat substitutes in low-fat frankfurters. J. Food Sci. 66: 1039-1046 (2001)
14. Su YK, Bowers JA, Zayas JF. Physical characteristics and microstructure of reduced-fat frankfurters as affected by salt and emulsified fats stabilized with nonmeat proteins. J. Food Sci. 65: 123-128 (2000)
15. Puolanne E, Ruusunen M, Vainionpaa JI. Combined effects of NaCl and raw meat pH on water-holding in cooked sausage with and without added phosphate. Meat Sci. 58: 1-7 (2001)
16. Park SY, Chin KB, Yoo SS. Flavor compounds and physicochemical properties of low-fat functional sausages manufactured with chitosans during refrigerated storage. Korean J. Food Sci. Anim. Resour. 25: 285-294 (2005)
17. Luruena-Martinez MA, Vivar-Quintana AM, Revilla I. Effect of locust bean/xanthan gum addition and replacement of pork fat with olive oil on the quality characteristics of low-fat frankfurters. Meat Sci. 68: 383-389 (2004)
18. Choi SH, Chin KB. Development of low-fat comminuted sausage manufactured with various fat replacers similar textural characteristics to those with a regular fat counterpart. Korean J. Food Sci. Technol. 34: 577-582 (2002)
19. Xiong YL, Noel DC, Moody WG. Textural and sensory properties of low-fat beef sausages with added water and polysaccharides as affected by pH and salt. J. Food Sci. 64: 550-554 (1999)
20. Ruusunen M, Sarkka-Tirkkonen M, Puolanne E. The effect of salt reduction on taste pleasantness in cooked 'bologna-type' sausages. J. Sensory Stud. 14: 263-270 (1999)
21. Ruusunen M, Sarkka-Tirkkonen M, Puolanne E. Saltiness of coarsely ground cooked ham with reduced salt content. Agr. Food Sci. Finland 10: 27-32 (2001)
22. Barbut S. Effect of caseinate, whey, and milk powders on the texture and microstructure of emulsified chicken meat batters. LWT -Food Sci. Technol. 39: 660-664 (2006)
23. Smith DM, Rose AJ. Properties of chicken salt-soluble protein and whey protein concentrate gels as influenced by sodium tripolyphosphate. Poultry Sci. 74: 169-175 (1995)
24. Rhee SK. Studies on the additional effect of milk casein in processed meat products. Anseong Agr. Junior College, Gyeonggi, Korea. 23: 143-151 (1991)