

# Textural, Color, and Sensory Properties of Bologna Containing Various Levels of Washed Chicken Skin<sup>1</sup>

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**ABSTRACT** Poultry skin was washed in sodium bicarbonate (0.5%) solution in a pilot plant facility to remove fat from skin. Composition of the washed product was determined and its functional properties were determined in a bologna product at the levels of 0, 10, and 20%. Washing reduced fat, and increased total protein and moisture in skin. Collagen content was significantly increased and water- and salt-soluble protein in washed skin were significantly decreased compared to unwashed skin ( $P < 0.05$ ). With reference to emulsion stability, skin content did not affect fat or gel-water losses and lowered solids loss when compared to bologna with 0% skin ( $P < 0.05$ ). Kramer Shear peak

force was not significantly different for bologna at each treatment level. Total energy was higher for bologna with 0% skin ( $P < 0.05$ ). Skin addition did not affect compression measurements of hardness, springiness, cohesiveness, and chewiness when compared to bologna with 0% skin. The addition of skin resulted in a lighter ( $L$ ), less red ( $a_L$ ), and less yellow ( $b_L$ ) product according to HunterLab color analysis ( $P < 0.05$ ). Consumer panelists rated bologna with 10% skin highest in texture, flavor, and texture and appearance acceptability ( $P < 0.05$ ). Washed chicken skin may have potential as a low cost, low fat ingredient for emulsified meat products.

(*Key words*: texture, bologna, washed by-products, chicken, skin)

1996 Poultry Science 75:1047-1055

## INTRODUCTION

Growth in further processed poultry products has increased steadily within the past few years. In 1993, 59.3% of the chicken broilers were marketed as parts or cut-up meat and in 1995 22% of the households are purchasing skinless boneless breast (Industry Survey Report, 1993; Amey, 1995). Continual market increases in further processed poultry has resulted in an oversupply of chicken skin. Acton and Dick (1978) reported that industry is continually searching and investigating performance of poultry skin as an ingredient in processed meat products. Chicken skin, however, is high in fat (35 to 40%), with its major protein being collagen (Satterlee *et al.*, 1971). High collagen tissues in emulsified meat products are important in stabilizing emulsions and providing textural properties in hamburgers, sausages, and frankfurters (Bailey and Light, 1989; Whiting, 1989). Due to its amino acid content, collagen is 60% hydrophobic. During thermal processing of meat products at temperatures of 60 to 65 C, collagen fibers begin to shrink, denature, and gelatinize, enabling fibers to encapsulate fat (Whiting, 1989). However, shrinking and subsequent cooling of the fibers allows the release

of fat. High collagen meats added to sausage products have been reported to lower emulsion stability leaving a grainy texture in the cooked meat. Several authors have reported that due to its high collagen and lipid content, chicken skin addition at levels of 20% or more was detrimental to textural quality and yield of processed meat products (Acton and Dick, 1978; Buyck *et al.*, 1982; Swatland and Barbut, 1991). Acton and Dick (1978) reported that increases in fat content due to chicken skin addition resulted in greater cooking losses in poultry meat loaves. Products containing elevated levels of fat would lose more moisture during cooking because fat does not bind water (Buyck *et al.*, 1982). Swatland and Barbut (1991) found skin added at levels of 20% showed pronounced losses in gel strength, cook loss, and an increased lipid fraction in the cook loss in muscle-skin slurries. Reducing the fat content may offer improved functionality of skin, in turn, allowing greater use as an ingredient in meat products, especially low fat products.

Various authors have utilized aqueous washings to reduce the fat and color pigments in mechanically deboned poultry meat (MDPM) (Hernandez *et al.*, 1986; Ball, 1988; Dawson *et al.*, 1988, 1989; Elkhalfi *et al.*, 1988; Lin and Chen, 1989; Yang and Froning, 1992; Shahidi *et al.*, 1992; Wimmer *et al.*, 1993). Most investigators found that using low ionic strength solutions containing NaCl, NaHCO<sub>3</sub>, or phosphate buffers at pH 8.0 were effective in removing lipid and color from meat. Application of aqueous washing to reduce skin fat and concentrate the proteins may have potential.

Received for publication November 13, 1995.

Accepted for publication April 5, 1996.

<sup>1</sup>This manuscript has been assigned Journal Series No. 11333, Agricultural Research Division, University of Nebraska.

The objectives of this study were to develop a washed by-product from chicken skin using a pilot plant washing procedure as a means to reduce fat content of skin. The washed skin was incorporated in a bologna product and its functional and sensory properties were measured.

## MATERIALS AND METHODS

Fresh chicken skin from 6- to 8-wk-old fryers was received from a local commercial source. The skin was removed from the birds 3 to 4 d after slaughter, packaged in a polyethylene packaging film, and held at  $-23$  C for approximately 7 d. A separate shipment was used for each of three 60-lb lots. The skin was mixed in a mixer<sup>2</sup> with a liquid antioxidant (Sustane HW-4, blend of 20% BHA, 20% BHT), 60% vegetable oil as a carrier.<sup>3</sup> The amount of antioxidant was added to skin at 0.02% (200 ppm) of total fat content of skin. The skin from each lot (replicate) was placed in a single layer on separate metal trays and blast frozen at  $-23$  C until hard (1.5 to 2 h). The skin was then tempered for 30 min, in a cold room (4 C) and ground in a Hobart meat grinder<sup>4</sup> with a 0.5-in plate. The ground skin was refrozen overnight (16 h) at  $-23$  C, tempered under the same conditions, manually broken apart, and further ground in a bowl chopper.<sup>4</sup> The ground particles of skin were free-flowing. The skin was packaged in polyethylene film and held at  $-23$  C until washing (2 to 4 d).

### Pilot Plant Washing and Centrifugation

The three lots of flaked raw skin were each washed separately in the commercial pilot plant of the University of Nebraska Food Processing Center. Approximately 60 lb of flaked skin were mixed<sup>5</sup> in a 60-gal Groen Kettle<sup>6</sup> for approximately 30 to 40 min in a 0.5%  $\text{NaHCO}_3$  solution.<sup>7</sup> Steam was injected as needed into the slurry during mixing to maintain a constant temperature of 45 C prior to entering the centrifuge. Temperature was continuously monitored using a thermocouple. The mixture was centrifuged in a high-speed centrifuge Type SA 7-06-076<sup>8</sup> at  $11,500 \times g$ . Flow rate was maintained at 1920 mL/min. Temperature of the outflow was 53.6 C. The pellet was collected at the solids discharge site and was filtered through two to four layers of cheesecloth. The pellet yield for this process was 34%, which is calculated as a percentage of the unprocessed skin. The pellet was frozen at  $-23$  C for 4 d prior to its use as an ingredient in bologna product.

### Proximate Composition and pH

Moisture, total protein, and ash of the unwashed flaked, washed skin, raw bologna batter, and cooked bologna were determined according to the methods of the Association of Official Analytical Chemists (AOAC, 1990). Moisture content was measured in a convection oven at 100 C for 18 h. Total lipid was determined for each sample using a Soxtec<sup>9</sup> fat analyzer (Foster and Gonzales, 1992) with chloroform and methanol as solvents. Total protein (nitrogen conversion = 6.25) was determined by the Kjeldahl method using a block digester.<sup>9</sup> Proximate analyses and pH were performed in triplicate on each replicate (a total of nine samples for all replicates) and expressed on a wet basis. The pH of the washed skin and bologna were also taken by mixing approximately 25 g of skin or bologna with 75 mL of distilled water and agitated for 15 min on a shaker table. The pH of the slurry was taken with a pH meter (Digital ionalyzer/501).<sup>10</sup>

### Collagen Determination

Two 50-g aliquots of skin were collected from each of the three unwashed lots and each of the sodium bicarbonate washed lots. Fat was removed from the aliquots three consecutive times in chloroform and methanol (2:1) (vol/vol). The solvent to solid ratio remained at 5:1. The defatted samples were dried in a vacuum oven at 40 C for 4 to 6 h. Following drying, a 1-g sample was hydrolyzed in 5 mL of 7N sulfuric acid for 16 to 18 h at 105 C. The hydrolyzate was filtered through Whatman No. 541 paper and adjusted to 100 mL with distilled water. From this dilution, 1 mL was further diluted to 500 mL (1:499). Collagen was determined by hydroxyproline analysis according to the method of Kolar (1990). Hydroxyproline content was converted to collagen using a factor of 7.57 (Satterlee *et al.*, 1971). Collagen values were expressed in milligrams collagen per gram protein.

### Water-Soluble and Salt-Soluble Protein

Salt-soluble proteins and water-soluble proteins in the unwashed skin and in skin washed in sodium bicarbonate were determined according to a modification of the procedure by Yang and Froning (1992). Potassium iodide was used to extract the proteins in place of KCl. Two 2-g samples of washed or unwashed skin taken from each lot were suspended in 20 mL of 0.6 M KI-0.05 M Tris buffer solution (pH 8.1). The mixture was agitated for 16 h at 4 C. The mixture was then centrifuged at  $12,000 \times g$  for 40 min. The supernatant was collected and filtered with glass wool. The supernatant was then diluted with distilled water to an ionic strength of 50 mM KI-Tris buffer solution and stored at 4 C for 24 h. This mixture was then centrifuged at  $11,500 \times g$  for 20 min. The supernatant was

<sup>2</sup>Leland Detroit Manufacturing Co., Detroit, MI 48210.

<sup>3</sup>Universal Oil Products Co., Des Plaines, IL 60017-5017.

<sup>4</sup>Hobart Manufacturing Co., Troy, OH 45374.

<sup>5</sup>Baldor Industrial Motor, Fort Smith, AK 72902.

<sup>6</sup>Groen Kettle, Elk Grove, IL 60007.

<sup>7</sup>Arm and Hammer, Princeton, NJ 08543-5297.

<sup>8</sup>Westfalia Separator, 4740 Oelde 1, Germany.

<sup>9</sup>Tecator, Hoganas Sweden.

<sup>10</sup>Orion Research Inc., Boston, MA 02129.

TABLE 2. Smokehouse thermal processing schedule

Variable	Step 1	Step 2	Step 3	Step 4	Step 5
Dry bulb, C	54	66	77	50	50
Wet bulb, C	41	52	66	36	36
Relative humidity, %	50	50	50	50	50
Time, h	0.5	2	1.75 <sup>1</sup>	0.25 <sup>2</sup>	0.17 <sup>3</sup>

<sup>1</sup>Product taken to internal temperature of 66 C.

<sup>2</sup>Shower cycle.

<sup>3</sup>Blower to dry product.

collected and assayed for water-soluble protein utilizing the bicinchoninic acid (BCA) Protein Assay Kit<sup>11</sup> using BSA as a standard (Pierce, 1993). The pellet was dissolved in 3 mL of 0.6 M KI-0.05 M Tris buffer and the protein was determined by the Biuret method (Gornall *et al.*, 1949). The protein dissolved in 0.6 M KI-0.05 M Tris was taken as salt-soluble protein. The amount of water-soluble proteins and salt-soluble proteins were based on the amount of protein (milligrams per milliliter) detected from BCA Protein Assay and the Biuret test. Water-soluble proteins and salt-soluble protein extracted were expressed in milligrams per gram protein.

## SDS-PAGE

The dissolved salt soluble protein was prepared for SDS-PAGE. The SDS-PAGE was performed at 200 V until the dye front migrated to the end of gel according to the procedure of Laemmli (1970) using a Bio-Rad Mini-Protean II electrophoresis cell.<sup>12</sup> The separating gel and stacking gel were 10 and 3.75% polyacrylamide, respectively. Twenty micrograms of protein was loaded per each lane. The protein was stained with 0.1% Coomassie Brilliant Blue R-250 solution and destained with 7.5% methanol/5% glacial acetic acid solution. A broad range (6 to 200 kDa) molecular weight marker was loaded concurrently with the samples.

## Product Manufacture

Beef trimmings (<10% fat) were fabricated from "A" maturity carcasses that were slaughtered commercially. Pork trimmings were obtained from market weight hogs (gilts and barrows) slaughtered at the Loeffel Meat Laboratory of the University of Nebraska, Animal Science Department. These raw materials were stored frozen and tempered to -3 C for 3 to 4 d, trimmed of excess fat and ground semi-frozen (-2 to -4 C) through a 0.5-in plate in a meat grinder<sup>3</sup> before proximate analysis could be obtained on these raw materials. They were stored at 3 C until bologna manufacture.

A bologna formulation (Table 1; Mandigo, unpublished data) was based on the proximate composition values of three replicates (lots) of skin at three skin levels (0, 10, and 20% of meat block). The three levels of skin were incorporated in the formulation to partially replace the beef in bologna sausage. The amount of water was standardized for each treatment/replication based on moisture levels from the three lots of skin, and beef. Therefore, only beef, skin, and added water amounts varied between 0, 10, and 20% bologna batches. This methodology isolated the effect of skin on bologna.

Replicates were processed separately in a random order. The bologna ingredients were added in the following order: meat block (beef, washed skin, and pork) water, salt, cure, seasonings, dextrose, and sodium erythorbate. They were mixed for 3 min in a mixer<sup>1</sup> and processed once through an emulsion mill (Hobart Micro-Cut MCV 12).<sup>3</sup> The meat batter was vacuum stuffed (Vemag Robot 1000 DC Vacuum Stuffer)<sup>13</sup> into 50-mm fibrous casings. Bologna was thermally processed to an internal temperature of 65 C (150 F) in an Alkar single truck smokehouse<sup>14</sup> according to Table 2. Product temperature was monitored with a smokehouse computer probe verified with an external thermometer. Following 24 h of chilling at 4 C, the bologna was vacuum packaged<sup>15</sup> and stored at 2 C for 6 d until further testing.

## Emulsion Stability and Textural Methods

Emulsion stability tests were completed on 5 samples from each replicate (a total of 15 samples) immediately

TABLE 1. Bologna formulations

Ingredients	Percentage skin level		
	0%	10%	20%
Beef (90/10), kg	3.6	2.7	1.8
Skin, kg	0.0	0.91	1.8
Pork (70/30), kg	5.4	5.4	5.4
Water, <sup>1</sup> kg	2.0	1.9	1.8
Salt, kg	0.2	0.2	0.2
Cure (6.25% NO <sub>2</sub> ), g	22.4	22.4	22.4
Seasonings, g	45.6	45.6	45.6
Dextrose, g	45.6	45.6	45.6
Sodium, g	4.8	4.8	4.8
Erythorbate (550 ppm), g			

<sup>1</sup>Based on moisture for beef (66.72%) and skin (Lot 1, 75.33%; Lot 2, 77.86%; Lot 3, 80.08%).

<sup>11</sup>Pierce Chemical Co., Rockford, IL 61105.

<sup>12</sup>Bio-Rad Laboratories, Hercules, CA 94547.

<sup>13</sup>Robert Reiser and Co., Canton, MA 02021.

<sup>14</sup>Alkar, Lodi, WI 53555.

<sup>15</sup>Kramer Grebe, Germany.

after processing according to the method of Townsend *et al.* (1968).

Cook loss was determined as the amount of fluid (fat, gel-water, and solids) released from three 35-g batter samples in polycarbonate tubes during cooking in the same conditions described above.

Bologna sticks were sliced 3 mm thick and 5 cm in diameter and vacuum packaged prior to testing. Samples were stored at 4 C for 4 d prior to testing. Samples were tempered for 15 to 20 min at room temperature, as the weights (grams) of five samples from separate bologna sticks were taken per replicate (a total of 15 samples). An Instron Universal Testing Instrument (Model 1123)<sup>16</sup> equipped with a Kramer Shear device was used to measure peak force (kilograms; point of inflection in curve; Voisey, 1977) and area under the curve (AUC; squared centimeters) on bologna slices. Samples were centered in the Kramer Shear box and sheared across the bologna stock. The settings for the Instron were set as follows: full scale load 5 kg; cross head speed 100 mm/min, chart speed 200 mm/min; load cell 500 kg. The peak force (Newtons per gram) and total energy (Joules per gram) were calculated.

Double compression testing was performed on the bologna using an Instron machine (Bourne, 1978). The bologna was sliced 3.2 cm thick and at 5 cm in diameter. Bologna slices were tempered at room temperature for 15 to 20 min as the weights of five samples from each treatment-replication combination were taken. The samples were placed parallel to a round compression stand measuring 14 cm in diameter and compressed to 25% of their original height (75% compression) twice to determine the textural parameters according to Bourne (1978). The parameters of hardness (Newtons per gram), chewiness (Newtons  $\times$  meters per gram), cohesiveness (no units), and springiness (millimeters) were calculated from the force deformation curve (Bourne, 1978). Instron settings were set as follows: full scale load 20 kg, cross head speed 50 mm/min; chart speed 100 mm/min; load cell 2,500 kg.

### HunterLab Color Analysis

Hunter L,  $a_L$ , and  $b_L$  values of sliced bologna (center of freshly sliced 3-mm thick bologna) were evaluated with HunterLab tristimulus colorimeter (Model D25M-9 Optical Head).<sup>17</sup> Five readings of Hunter L,  $a_L$ , and  $b_L$  were taken for each treatment-replication combination. The instrument was standardized with a white plate standard ( $L = 95.47$ ,  $a = -0.6$ , and  $b = 0.4$ ).

### Consumer Sensory Panel Evaluation

Following 6 d of storage at 2 C, a consumer taste panel was held for 3 consecutive d in the sensory evaluation laboratory at the University of Nebraska-Lincoln Animal Science Department. Panelists ( $n = 30$ ) were comprised mainly of undergraduate and graduate students, and staff of the Animal Science Department, most of whom had participated in previous consumer panels. Each treatment-replication combination was served on 1 d. Each panelist was, therefore, given six samples each day, one at a time, that were evaluated on separate sheets. A 9-point hedonic scale (9-like extremely, 1-dislike extremely) was used to evaluate the following attributes (Bourne, 1978): appearance, texture, flavor, and overall acceptability. Panelists were given water and unsalted crackers to consume between samples. Panelists were instructed to expectorate samples after sensory evaluation.

### Statistical Analyses

Treatments for the washed and unwashed skin analysis were assigned to a 2 (unwashed, 0.5% NaHCO<sub>3</sub> washed)  $\times$  3 (Lots 1, 2, 3) complete factorial design (Steel and Torrie, 1980). Batter and bologna treatments were assigned to a 3 (skin levels-0, 10, and 20%)  $\times$  3 (Lots 1, 2, 3) complete factorial design (Steel and Torrie, 1980). The data were analyzed using the General Linear Models Procedure of SAS<sup>®</sup> (SAS Institute, 1991). A split-plot design was used with lots as the main effects and treatments as the split-plot effects. Main effects and split-plot effects were reported significantly different at  $P < 0.05$ . Individual mean differences were determined using least squares mean analysis. The statistical design was used in order to minimize effects of variation between lots. Each lot served as blocking criterion.

## RESULTS AND DISCUSSION

### Proximate Composition

Proximate composition values for the raw materials are found in Table 3. The unwashed skin values are relatively close to those of Swatland and Barbut (1991). The composition of raw chicken skin will vary according to age, and source of skin. Smolinska *et al.* (1988) reported protein levels for skin to be 12.2%, whereas Essary and Young (1977) found broiler skin to be 28.9% protein. The primary objective during pilot plant washing was to lower fat content in skin. Bench studies on washing skin in 0.5% NaHCO<sub>3</sub> (pH 7.9) and 0.1 M NaCl (pH 7.0) solutions proved to be effective in significantly reducing fat, increasing moisture and protein according to Froning and Bonifer (1994).

### Collagen, Water-Soluble Protein, and Salt-Soluble Protein

The collagen, water-soluble protein, and salt-soluble protein content are found in Table 4. The amount of

<sup>16</sup>Instron Corp., Canton, MA 02021.

<sup>17</sup>Hunter Associates Inc., Fairfax, VA 22090.

TABLE 3. Raw material proximate composition<sup>1</sup>

Ingredients	Fat	Protein	Moisture		Ash
			Ash		
(%)					
Beef (90/10) <sup>2</sup>	12.86 ± 0.49	19.81 ± 2.15	66.72 ± 0.01	0.73 ± 0.19	
Pork (70/30) <sup>3</sup>	24.47 ± 1.25	16.13 ± 0.39	58.86 ± 0.28	0.87 ± 0.29	
Unwashed skin <sup>4</sup>	41.34 ± 3.66	8.38 ± 0.71	45.88 ± 0.82	0.48 ± 0.10	
Washed skin	9.95 ± 0.94	11.02 ± 0.69	77.76 ± 0.79	0.32 ± 0.05	

<sup>1</sup>Three lots (replicates) each determined in triplicate (nine samples for all replicates).

<sup>2</sup>Beef trimmings fabricated from "A" maturity carcasses.

<sup>3</sup>Pork trimmings obtained from market weight hogs.

<sup>4</sup>Chicken skin from 6- to 8-wk-old fryers washed in aqueous NaHCO<sub>3</sub> solution.

collagen found in unwashed skin was 40.1 mg/g skin (not reported in table). This value is considerably greater than collagen content determined by Satterlee *et al.* (1971), and Swatland and Barbut (1991) (29.5 mg/g skin and 30.45 mg/g skin). The strain and diet of broilers may affect the fat content of skin, which indirectly may dilute the protein content (Becker, 1983). Collagen content was significantly higher ( $P < 0.05$ ) in washed skin compared to unwashed. The temperature of the slurry during washing and centrifugation reached 53 C. Collagen begins to denature at 60 C (Whiting, 1989) and likely was not prone to loss during skin processing (Whiting, 1989). Other studies also have shown increased collagen levels due to washing (Yang and Froning, 1992; Wimmer *et al.*, 1993).

The amount of water-soluble protein in washed skin (16.05 mg/g protein) was significantly lower ( $P < 0.05$ ) than that in unwashed skin (72.61 mg/g protein). Washing with sodium bicarbonate removed a significant portion of the water-soluble proteins. According to several bench studies, washing in 0.5% sodium bicarbonate proved to be most effective in removing water-soluble proteins contained in MDCM based on Hunter color values and hemoprotein analysis (Dawson *et al.*, 1989; Shahidi *et al.*, 1992; Yang and Froning, 1992). Pilot-plant washing significantly ( $P < 0.05$ ) lowered extractable salt-soluble protein fraction remaining in washed skin. Salt-soluble protein content for unwashed and washed skin was 92.7 mg/g protein, and 56.2 mg/g protein, respectively (Table 4). Prior to entering the centrifuge, temperature of the slurry was maintained at 45 C. The temperature of the mixture following centrifugation reached 53 C. At 50 C salt-soluble (myofibrillar) and sarcoplasmic proteins denature, coagulate, and shrink transversely (Whiting, 1989). Therefore, exposure of the mixture to temperatures above 50 C likely resulted in partial loss of functionality of salt-soluble protein fraction in skin.

### SDS-PAGE

The significant decrease in salt extractable protein due to pilot plant washing is reflected in the SDS-PAGE gel patterns (Figure 1) in salt extractable protein remaining in NaHCO<sub>3</sub> washed and unwashed skin. We can speculate that the principal salt-soluble proteins in the washed skin were likely to be found in the region of myosin (200 kDa),

M-protein (165 kDa), and C-protein (135 to 140 kDa). These proteins could also be proteolytic breakdown products of myosin that would produce a fragment of 150 kDa (Yates *et al.*, 1983; Pearson and Young, 1989). As seen in Figure 1, band intensities in the myosin 200 kDa and also in the region between 31 and 45 kDa appear less intense in the washed skin fraction than in the unwashed fraction. During washing and centrifugation, a washing out effect of high molecular and low molecular weight salt-soluble proteins in chicken skin occurred. Exposure of skin to temperatures of 45 to 53 C may have increased

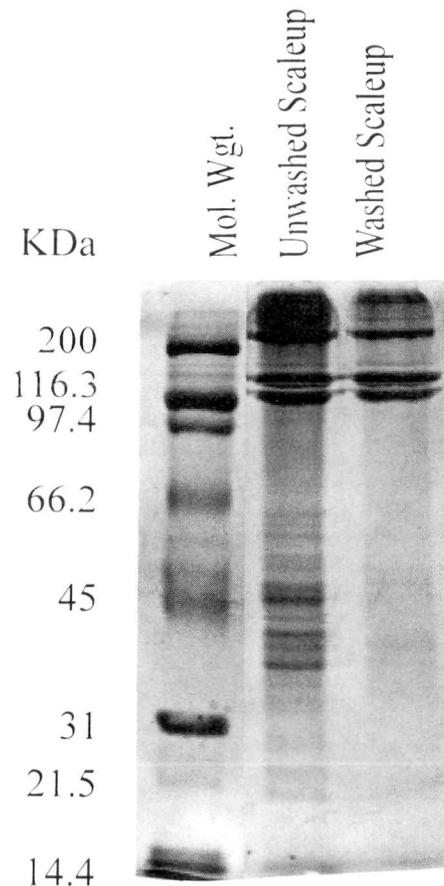


FIGURE 1. The SDS-PAGE patterns of salt-extractable protein of washed and unwashed skin from scale-up.

TABLE 4. Collagen content, salt-soluble, and water-soluble protein analysis on unwashed and washed skin<sup>1,4</sup>

Treatment	Collagen <sup>2,3</sup>	Salt-soluble protein <sup>2</sup>		Water-soluble <sup>2</sup> protein
		(mg/g protein)		
Unwashed	479.26 ± 17.72 <sup>b</sup>	92.70 ± 2.35 <sup>a</sup>	72.62 ± 2.43 <sup>a</sup>	
Washed	665.35 ± 17.72 <sup>a</sup>	56.20 ± 5.21 <sup>b</sup>	16.05 ± 2.43 <sup>b</sup>	

<sup>a,b</sup>Means within the same column with no common superscript differ significantly ( $P < 0.05$ ).

<sup>1</sup>Means ± SEM.

<sup>2</sup>t test of means ± SEM.

<sup>3</sup>Determined by hydroxyproline analysis (7.57 as conversion factor).

<sup>4</sup>Skin pH = 8.55.

solubility of salt-soluble proteins. Yates *et al.* (1983) found that after incubating bovine muscles at 37 C, breakdown in myosin and troponin-T was evident. Comparisons were made between SDS-PAGE gels of myofibrils incubated at 37, and at 4 C. Band patterns and intensities revealed that there was a substantial decrease and breakdown of myosin with nearly complete loss of troponin-T.

### Emulsion Stability and Cooking Loss

Fat, gel loss, and total cooking losses were not significantly different due to level of skin in bologna ( $P < 0.05$ ; Table 5). Loss of proteinaceous solids was greater in the control batters than in batters containing 10 and 20% washed skin ( $P < 0.05$ ). This loss may have been due to the slightly higher fat content of control batter. Eilert *et al.* (1993a) reported that proteinaceous solids and smoke-house batter stability losses were higher with increased fat. A concern and a limiting factor in using connective tissues as meat replacements would be dilution of the principle water-binding and gel-forming protein myosin (Kerney *et al.*, 1986). Washed skin added at 10 to 20% levels was not detrimental to the emulsion stability of the meat matrix in bologna. Washed skin was high in collagen and hence the effect of collagen on the meat emulsion should be emphasized (665.35 mg/g protein; Table 4). Collagen fibers become an integral component of the meat emulsion when temperatures reach approximately 60 C (Whiting, 1989). Above 60 C, collagen melts and loses its strength. Collagen is mainly hydrophobic and encapsulates fat as it denatures and shrinks (Bailey and Light, 1989; Whiting, 1989). However, during cooling, collagen

was gelatinized and fat was expelled from its shrunken fibers. This procedure results in fat coalescence, gel pockets, and poor textural properties of meat products. Hoogenkamp (1992) reported that the amount of gel, solid, and fat losses indicated how successful the meat matrix was for entrapment of fat and water that determined extent of how successful the meat matrix for entrapment of fat and water and determined extent of product cook loss. Acton and Dick (1978) reported that fat losses significantly increased when levels of 30, 40, and 50% skin were added to poultry meat loaves. The authors attributed fat loss to increasing levels of skin addition. Buyck *et al.* (1982) also reported that cooking loss was higher for chicken patties containing 30% skin and fat compared to the other formulations. Swatland and Barbut (1991) reported percentage skin to be positively correlated with cooking loss and lipid fraction in cooking loss. They also believed within the range of 0 to 20% there would likely be a noticeable effect of skin content on total cooking losses.

### Bologna Composition and Characteristics

As mentioned earlier, some variation in bologna proximate composition was due to some differences in beef and washed skin composition. Except for varying skin, beef, and water addition, each formula was treated the same. There were no differences in ash and fat content for any of the treatments (Table 6). Moisture content was higher in bologna containing 20% washed skin than that observed in the control bologna ( $P < 0.05$ ), but 10% treatments did not differ from the control and 20%

TABLE 5. Emulsion stability and cooking loss for bologna batters containing 0, 10, and 20% washed skin

Treatment	Components released			
	Fat	Gel-Water	Solids	Total cook loss
	(mL/100 g)			(mL/100 g)
0% skin	0.62 ± 0.11	11.96 ± 0.73	0.59 ± 0.06 <sup>a</sup>	13.18 ± 0.83
10% skin	0.58 ± 0.10	11.04 ± 0.64	0.30 ± 0.05 <sup>b</sup>	11.87 ± 0.72
20% skin	0.50 ± 0.10	10.25 ± 0.69	0.35 ± 0.06 <sup>b</sup>	11.11 ± 0.78

<sup>a,b</sup>Means ± SEM within the same column with no common superscript differ significantly ( $P < 0.05$ ).

TABLE 6. Proximate composition and pH of bologna containing 0, 10, and 20% washed skin<sup>1,2</sup>

Treatment	Ash	Moisture	Protein	Fat	pH
0% skin	2.90 ± 0.03	64.17 ± 0.23 <sup>b</sup>	16.20 ± 0.12 <sup>a</sup>	16.12 ± 0.30	5.74 ± 0.07
10% skin	2.84 ± 0.03	64.83 ± 0.22 <sup>ab</sup>	15.75 ± 0.12 <sup>b</sup>	16.22 ± 0.30	5.68 ± 0.06
20% skin	2.94 ± 0.04	65.36 ± 0.22 <sup>a</sup>	14.77 ± 0.11 <sup>c</sup>	15.92 ± 0.30	5.82 ± 0.06

<sup>a-c</sup>Means within the same column with no common superscript differ significantly ( $P < 0.05$ ).

<sup>1</sup>Means ± SEM.

<sup>2</sup>Calculated on wet basis.

treatments. Skin addition affected total protein content of bologna ( $P < 0.05$ ; Table 6). Protein content was lowest in bologna with 20% washed skin. As washed skin replacement of meat increased, total protein content in the meat was decreased. Muellenet *et al.* (1994) reported that sarcoplasmic and myofibrillar proteins in meat decreased as collagen replacement of meat increased. Washed skin was higher in moisture and lower in total protein than beef (Table 3), possibly contributing to the above compositional differences. Although formulations were calculated on an equal proximate composition basis, apparently some variation occurred in the final bologna composition (Table 6).

Washed skin did not affect pH of bologna when compared to all beef bologna (Table 6). The pH of the washed skin was 8.55 prior to addition to bologna formulation, but final product pH was not altered when compared to controls.

Kramer Shear peak force, hardness, springiness, cohesiveness, and chewiness were not affected by washed skin addition (data not presented). However, total energy in Joules per gram  $\times 10^{-2}$  was significantly higher in the control bologna ( $1.13 \pm 0.03$ ) than in product containing 10% ( $1.01 \pm 0.03$ ) and 20% ( $0.95 \pm 0.03$ ) washed skin ( $P < 0.05$ ). This result may have been caused by a stronger gel matrix of the control bologna due to the greater proportion of myofibrillar proteins. Some authors reported no significant differences in shear force due to additions of skin (Acton and Dick, 1978; Smolinska *et al.*, 1988). Studies have found chicken skin addition to formulas increased hardness and chewiness in emulsified meat products (Baker *et al.*, 1969; Buyck *et al.*, 1982). Similar findings were also reported for beef connective tissue addition (Rao and Henrickson, 1983; and Eilert *et al.*, 1993b).

Addition of washed skin affected Hunter L,  $a_L$ , and  $b_L$  values of bologna (Table 7). Hunter L values were significantly higher for 10 and 20% addition than for control bologna ( $P < 0.05$ ). Hunter  $a_L$  values decreased with increasing levels of skin ( $P < 0.05$ ). Hunter yellowness  $b_L$  values were significantly higher for 0 and 10% skin treatments than for control bologna ( $P < 0.05$ ). Addition of increasingly higher levels of skin resulted in lighter bologna because of dilution of myoglobin content in beef. Acton and Dick (1978) reported lower Gardner  $a_L$  values for turkey meat loaves containing higher levels of skin but Gardner L and  $b_L$  values were not influenced by skin content. Rao and Henrickson (1983) noted lower "a" values in bologna (10 and 20% fat levels) containing 20% hide collagen. Eilert *et al.* (1993b) reported lighter, less red frankfurters containing 20, 30, and 40% modified connective tissue (MCT) than at 0 and 10%. Internal color and external color decreased with higher levels of MCT addition. Product with 20, 30, and 40% MCT were more yellow than control samples, which was contrary to our findings.

Consumer panelists did not detect any flavor differences in bologna for any treatment (Table 8). Bologna appearance ratings were higher for the 10% skin level than at 0 and 20% levels ( $P < 0.05$ ). Bologna texture at 10% skin addition was rated highest compared to 0 and 20% skin treatments ( $P < 0.05$ ). Overall acceptability was highest for the control bologna and 10% washed skin level ( $P < 0.05$ ). Consumers rated the bologna containing 10% skin treatment most favorable. Past research has shown that addition of 20% or more skin resulted in undesirable texture in chicken patties and frankfurters (Baker *et al.*, 1969; Buyck *et al.*, 1982). Buyck *et al.* (1982) concluded that additions of 10% skin would not adversely affect textural quality. Our research results showed that consumers

TABLE 7. Hunter L,  $a_L$ , and  $b_L$  values for bologna containing 0, 10, and 20% washed skin<sup>1</sup>

Treatment	Hunter L <sup>2</sup>	Hunter $a_L$ <sup>3</sup>	Hunter $b_L$ <sup>4</sup>
0% skin	53.98 ± 0.26 <sup>b</sup>	10.73 ± 0.21 <sup>a</sup>	8.80 ± 0.09 <sup>a</sup>
10% skin	55.25 ± 0.26 <sup>a</sup>	9.80 ± 0.22 <sup>b</sup>	9.02 ± 0.09 <sup>a</sup>
20% skin	55.94 ± 0.26 <sup>a</sup>	7.90 ± 0.21 <sup>c</sup>	8.54 ± 0.09 <sup>b</sup>

<sup>a-c</sup>Means within the same column with no common superscript differ significantly ( $P < 0.05$ ).

<sup>1</sup>Means ± SEM.

<sup>2</sup>Lightness.

<sup>3</sup>Redness.

<sup>4</sup>Yellowness.

TABLE 8. Sensory evaluation<sup>1</sup> for bologna containing 0, 10, and 20% washed skin

Treatment	Texture	Appearance	Flavor	Overall acceptability
0% skin	5.50 ± 0.07 <sup>b</sup>	5.60 ± 0.10 <sup>a</sup>	5.36 ± 0.13	5.23 ± 0.13 <sup>ab</sup>
10% skin	6.00 ± 0.07 <sup>a</sup>	5.55 ± 0.10 <sup>a</sup>	5.48 ± 0.13	5.47 ± 0.13 <sup>a</sup>
20% skin	5.85 ± 0.07 <sup>a</sup>	4.75 ± 0.10 <sup>b</sup>	5.06 ± 0.13	4.88 ± 0.13 <sup>b</sup>

<sup>a,b</sup>Means ± SEM within the same column with no common superscript differ significantly ( $P < 0.05$ ).

<sup>1</sup>Nine-point hedonic scale (9-like extremely, 1-dislike extremely).

avored bologna containing 10% washed skin over bologna without skin or with 20% added skin. Washed chicken skin (by-product of chicken skin) may offer potential to the poultry industry as a low-cost, low fat ingredient for incorporation in emulsified meat products; however, according to our study, levels over 10% may be detrimental to sensory quality.

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