INTRODUCTION

Current trends in functional foods have led to various studies relating to incorporating functional ingredients into meat products. Most of them are nonmeat-based ingredients. Proteins from soybean are commonly used in processed meat products due to their low cost and functional properties. Soy proteins are known for water-binding, fat-binding, and supporting high emulsion stability (Chin et al., 2000); hence, soy protein isolates (SPI) and concentrates are widely used in the preparation of chopped meats (Gordon and Barbut, 1991). However, addition of SPI occasionally gives less desirable palatability and allergen issue to meat products (Ho et al., 1997), and hence there are regulations to restrict their use in meat products. The role of proteins is very important in any meat product because sensory properties can be significantly affected by slight alterations in the protein formulation (Claus et al., 1990). If the lean meat content in meat products is low, then the meat proteins will be insufficient to stabilize the emulsion and the gel formation during heating may be affected, leading to problems in product quality. Appearance of cooked meat is often influenced by meat source, pH, packaging conditions, fat content, and also other added ingredients (King and Whyte, 2006). The most important pigment responsible for meat color is myoglobin. Heating causes denaturation of the globin, which determines the color of cooked meat. Addition of soy protein did not affect the color of the cooked meat products (Lytras et al., 1999).

Currently, mechanically separated poultry meat (MSPM), which contains 13% to 15% protein (Hrynets et al., 2010), is used to prepare gel-type products. High fat and hemoglobin content along with undesirable texture of MSPM are drawbacks for its usage in these...
products. To overcome these problems and to use the low-value MSPM in further processed meat products, the best alternative is to extract myofibrillar proteins (Betti and Fletcher, 2005) using pH-shift technology. The objective of this study was to find the potential application of PPI prepared from mechanically separated turkey meat (MSTM). By replacing lean meat with PPI, the total fat content of the final product can be reduced and by replacing SPI the source of allergen can be eliminated. The study includes incorporation of the PPI in turkey bologna either to replace soy protein or lean meat and to evaluate the physicochemical characteristics of the prepared turkey bologna.

MATERIALS AND METHODS

Materials and Experimental Treatments

Frozen boneless skinless turkey thigh meat was purchased from Lilydale, Edmonton, AB, Canada, and delivered to the Food Processing Development Centre (Alberta Agriculture and Rural Development, Leduc, AB, Canada). Poultry protein isolate was prepared from MSTM according to the established protocol (Hrynets et al., 2010). Briefly, MSTM was homogenized with cold water/ice mixture (1:5 wt/vol) and allowed to stand for 30 min. Further, the proteins in the homogenate were made soluble by the addition of 2 M HCl (pH 2.5). The solubilized proteins were then isoelectrically precipitated at pH 5.2. The precipitated proteins were later adjusted to pH 6.2. Large-scale protein extractions were carried out in the pilot plant of Food Processing Development Centre. The SPI was included as an example of a protein ingredient currently used by the meat industry.

Preparation of Low-Fat Turkey Bologna

Turkey thigh meat was thawed in a 4°C cooler for 24 h and was ground through a 3-mm plate (model AW114, K&G Wetter, Mississauga, ON, Canada). Samples were taken from each batch of ground meat, and proximate composition was determined using a Foss FoodScan analyzer (FoodScan Lab, Type 78800, Foss, Hillerød, Denmark). Meat protein was adjusted to a constant level of 11% (minimum) in all formulations by adding water and shredded ice. The required quantities of ground turkey meat, spices, ice/water, with/without PPI or SPI, were combined, mixed at slow speed without vacuum for 4 min, and then mixed at high speed under vacuum (~0.8 bar) for 2 min in a 30-L bowl. The bologna sausages were thermally processed in a smokehouse (Maurer & Söhne, Insel Reichenau, Germany) to a final internal temperature of 74°C. The product was then cooled in running water until the core temperature reached 30°C and stored at 1°C until analyzed. An internal temperature was measured using a HH23 Microprocessor thermometer (Omega Engineering Inc., Stamford, CT) with copper constantan thermocouples inserted in the geometrical center of the sausages.

Following overnight storage, each chilled meat chub was removed from its casing and weighed to determine cook yield. Overall cook yield was calculated as a percentage of raw stuffed weight before cooking. One chub per formulation was prepared as 3-mm slices (Weber Maschinenbau GmbH, Neubrandenburg, Germany) that were vacuum packed (10 slices per package) in high-barrier, mylar/polyethylene pouches (Ulma TF-Supra packaging machine, CyE.S. Coop Ltd., Onati, Spain). Required samples were stored at refrigerated

Table 1. Low-fat turkey bologna batter formulation for 10 kg of batter

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Control-1</th>
<th>2.0% SPI</th>
<th>1.5% PPI</th>
<th>2.0% PPI</th>
<th>Control-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turkey meat</td>
<td>5.500</td>
<td>5.500</td>
<td>5.500</td>
<td>5.500</td>
<td>6.500</td>
</tr>
<tr>
<td>SPI</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>PPI</td>
<td>—</td>
<td>—</td>
<td>2.683</td>
<td>3.578</td>
<td>—</td>
</tr>
<tr>
<td>Bologna seasoning</td>
<td>0.887</td>
<td>0.887</td>
<td>0.887</td>
<td>0.887</td>
<td>0.887</td>
</tr>
<tr>
<td>Water/ice (1:1)</td>
<td>3.613</td>
<td>3.391</td>
<td>0.930</td>
<td>0.035</td>
<td>2.613</td>
</tr>
</tbody>
</table>

1All weights given are in kilograms. SPI: soy protein isolate; PPI: poultry protein isolate; Control-1 = control bologna containing 11% meat protein; Control-2 = bologna formulated to contain 13% meat protein. The weight of SPI and 2% PPI used were equivalent to 2% protein content, and the weight used for 1.5% PPI was equivalent to 1.5% protein content.
condition for storage studies. The remainder was vacuum packaged whole, and the samples were stored at 1°C until sampling for instrumental evaluations.

**Batter Analysis**

**Back-Extrusion Test.** Approximately 30 g of batter was loaded into each of three 50-mL beakers. The samples were back-extruded using a metal plunger mounted into the chuck attachment of the Instron Universal Testing System (model 5565, Instron Corporation, Burlington, ON, Canada). The peak force (N) to push the plunger into the sample was recorded and considered as a measure of the batter resistance to flow.

**pH.** The pH value of treatment batters was determined by homogenizing a 3-g sample with 30 mL of distilled water. The pH value of the homogenate was measured using a UB-10 Ultra Basic pH meter (Denver Instrument pH meter, New York, NY).

**Cooked Product Characteristics**

**Proximate Composition of Low-Fat Turkey Bologna.** Moisture, fat, and ash content of turkey bologna were determined as described in AOAC International methodology (AOAC International, 2000). Protein content was determined using a TruSpec CN carbon/nitrogen determinator (Leco Corp., St. Joseph, MI) and multiplying nitrogen content by a factor of 6.25. The ratio between moisture and protein (MPR) has also been calculated.

**Gel Strength.** Gel strength of turkey bologna was conducted by the method of Nowsad et al. (2000). Gels in cylindrical shapes (3.0 cm height, 4.0 cm diameter) were cut off from the turkey bologna meat chub and used for measuring gel strength. The samples were tested at a speed of 5 mm/s using the texture profile analyzer (TA-XT Express, Stable Micro Systems Ltd.) equipped with a ball probe (1.27 cm diameter) in cycle test mode. Gel strength was expressed independently as breaking strength (g) and deformation (cm).

**Expressible Moisture.** The expressible moisture content of turkey bologna samples was determined using a texture profile analyzer (TA-XT Express, Stable Micro Systems Ltd., Surrey, UK). A known quantity of sample (approximately 300 mg) was placed on a preweighed filter paper and sandwiched between 2 glass plates. Using the texture profile analyzer under adhesive test mode, the sample was tested with a target force of 1,000 g. The hold time for the test was 2 min, which was sufficient to express the water content of the sample. The filter paper along with the absorbed water was immediately weighed after the test. Expressible moisture was measured as the quantity of water released per gram of meat and was expressed in percentage.

**Product Characteristics During Refrigerated Storage**

**Color.** A Minolta CR-400 (Konica Minolta Sensing Americas Inc., Ramsey, NJ) colorimeter using illuminant D55 as the light source was used to assess the color (Commission Internationale d’Eclairage L* a* b*) of turkey bologna during dark storage in refrigerated condition. The packages were cut opened, and turkey bologna was exposed to light just before taking the readings. The products were evaluated for color after overnight refrigerated storage and were designated as 0 wk. Further the products were evaluated during refrigerated storage on a weekly basis for 5 wk.

**Purge Loss.** Purge accumulation from preweighed, cooked sliced product was determined on vacuum-packaged bags of each treatment. After packaging (described above), the bags were stored at refrigerated temperature (4°C) for either 3 or 5 wk. Purge loss was determined by reweighing blotted slices from the packages following each storage interval, and was expressed as a percentage of the initial slice weight.

**TBA Reactive Substances.** Lipid oxidation of turkey bologna during refrigerated storage was measured using the induced TBA reactive substances (TBARS) test as described by Kornbrust and Mavis (1980). About 3 g of the sample was homogenized (Fisher Scientific, Powder Gen 1000S1, Schwerte, Germany) with 27 mL of 1.15% KCl solution for 1 min at setting 3. An aliquot of 200 µL of the homogenate was mixed with 1,000 µL of 80 mM Tris-maleate buffer (pH 7.4), 400 µL of 2.5 mM ascorbic acid, and 400 µL of 50 µM ferrous sulfate and incubated at 37°C. Samples were removed at 0 and 2.5 h incubation, followed by addition of 4 mL of TBA-TCA-HCl solution [26 mM TBA, 0.92 M TCA (trichloroacetic acid), and 0.8 mM HCl]. Further, the test tubes were placed in boiling water for 15 min. The samples were allowed to cool at room temperature and absorbance was taken at 532 nm against the blank containing all the reagents except the protein homogenate. The TBARS concentration was calculated using the extinction coefficient of E532 = 1.56 × 10² M⁻¹ cm⁻¹ and expressed as nanomoles of malondialdehyde (MDA) per gram of product.

**Statistical Analysis**

Each experiment and each assay were done at least in triplicate. Reported results represent an average of each experimental assay. All data were subjected to ANOVA using the GLM procedure of SAS (SAS, 2006). Differences between means were determined using Tukey’s honestly significant difference test and were reported as significant at the $P < 0.05$ level.

**RESULTS AND DISCUSSION**

**Batter Analysis**

**Batter Strength Using Back-Extrusion Test.** Batter strength estimated using the back-extrusion test is given in Table 2. Batter strength of control-1 was found to be significantly lower than all other treatments. The lower batter strength of control-1 might be due to the
lower protein content in the treatment or due to higher water content (Table 3). Hamm (1975) suggested that the interaction between particle surfaces will be reduced due to increased water content, which results in lowering the viscosity of liquid phase. There was no significant difference in batter strength between control-2 and treatment with 2% PPI. Batter strength of treatment containing SPI was not different from that of 1.5% PPI samples but lower than that recorded for control-2 and treatment containing SPI.

**Cooking Yield.** Cooking yield is important to the manufacturer for economic reasons; changes in cooking yield will cause changes in composition of finished products, which affects their palatability (Pietrasik, 1999). Results showed that there was no significant difference in cooking yield between treatments with PPI and control-2 (Table 3), indicating that turkey meat can be substituted with PPI without having a deteriorating effect on cook yield; however, cooking yield of control-1 and SPI was lower. A previous study showed that addition of 2% SPI did not reduce cooking loss (Claus and Hunt, 1991). Jones and Mandigo (1982) demonstrated that cooking yield is influenced by protein-fat-water ratios, pH, batter microstructure, preblending, ingredients, and salt concentration resulting in fat and water release. Cooking yield of SPI was lower than 2% PPI but not different from the 1.5% PPI treatment. This showed that to maintain the same cook yield only 1.5% PPI is needed instead of 2% of SPI addition. Loss in cooking yield in the present study for all the treatments was less than 6%. Cooking losses of greater than 6% for a bologna-type product would generally be considered high (Claus et al., 1990).

**Proximate Composition of Low-Fat Turkey Bologna.** Proximate composition of the prepared turkey bologna is given in Table 3. Moisture content of the products varied between 72 and 76%. Because the formulation was based on the protein content, the final weight was adjusted using water. Protein content of the final products showed that the products met the Canadian requirement of minimum 11% protein. According to Shand (1999), the MPR of comminuted meat products with conventional fat content varies between 3.5 and 5.0 and that of products with lower fat content varies between 5.0 and 7.2. The MPR of the turkey bologna in this study showed that products are in the range of low-fat products (Table 3). This is further evident from the fat content, which was lower compared with high-fat (22% fat content) bologna (Pietrasik and Janz, 2010). The lower fat content in turkey bologna is due to the lower fat content in turkey thigh meat (~7%). There was no significant difference in the ash content of various treatments.

**Gel Strength.** Gel strength analysis is a good indicator of elasticity of food products. Gel strength of turkey bologna was expressed separately as breaking strength and deformation (Table 4). Breaking strength of SPI was significantly ($P < 0.05$) higher than both PPI treatments and control-1 but not different from control-2. The harder texture of gels with SPI could be attributed to greater moisture release during cooking. Increased hardness of reduced-fat meat batters due to SPI addition has been reported by Lin and Mei (2000). Youssef and Barbut (2011) suggested that addition of nonmeat proteins influences the gel formation by modifying the building blocks of the system and also by the possible

### Table 3. Cooking yield and proximate composition of turkey bologna

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cooking yield (%)</th>
<th>Moisture content (%)</th>
<th>Protein content (%)</th>
<th>Fat content (%)</th>
<th>Ash content (%)</th>
<th>MPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-1</td>
<td>95.44 ± 0.32$^c$</td>
<td>76.39 ± 1.80$^a$</td>
<td>11.51 ± 0.37$^c$</td>
<td>3.96 ± 0.04$^b$</td>
<td>3.00 ± 0.14</td>
<td>6.64</td>
</tr>
<tr>
<td>SPI</td>
<td>95.65 ± 0.34$^{bc}$</td>
<td>74.08 ± 1.60$^{bc}$</td>
<td>13.62 ± 0.26$^a$</td>
<td>3.97 ± 0.15$^b$</td>
<td>3.21 ± 0.18</td>
<td>5.44</td>
</tr>
<tr>
<td>1.5% PPI</td>
<td>96.23 ± 0.40$^{abc}$</td>
<td>73.68 ± 1.37$^{bc}$</td>
<td>12.52 ± 0.13$^b$</td>
<td>3.94 ± 0.02$^b$</td>
<td>3.15 ± 0.18</td>
<td>5.88</td>
</tr>
<tr>
<td>2% PPI</td>
<td>96.25 ± 0.44$^{a}$</td>
<td>72.25 ± 1.34$^{a}$</td>
<td>13.37 ± 0.20$^a$</td>
<td>3.90 ± 0.42$^{ab}$</td>
<td>3.25 ± 0.17</td>
<td>5.40</td>
</tr>
<tr>
<td>Control-2</td>
<td>96.45 ± 0.48$^a$</td>
<td>74.87 ± 0.14$^{ab}$</td>
<td>13.42 ± 0.05$^a$</td>
<td>4.73 ± 0.03$^b$</td>
<td>3.10 ± 0.11</td>
<td>5.58</td>
</tr>
</tbody>
</table>

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

$^b$ Results are presented as mean values ($n = 3$) ± SD. SPI: soy protein isolate; PPI: poultry protein isolate; MPR: moisture-to-protein ratio; control-1: control bologna containing 11% meat protein; control-2: bologna formulated to contain 13% meat protein.
interactions between meat and nonmeat proteins. Replacing of 2% meat protein with PPI did not alter the breaking strength of turkey bologna. Control-1 showed the lowest breaking strength, which directly links with its lower batter strength. Water-binding ability of proteins also contributes to the formation of an elastic gel (Barbut, 1993). The lower water binding ability of control-1 (as revealed by cooking yield) might be due to the lower protein content of the sample. The important factors influencing gel-forming ability are pH, protein solubility, and the type of extractable proteins (Lanier, 1986). There was no difference in deformation among all the treatments.

**Expressible Moisture.** Expressible moisture indicates meat texture, tenderness, and juiciness and denotes the ability of meat to hold water (Mallikarjunan and Hung, 1997). Analysis of expressible moisture revealed no significant difference between any of the treatments (Table 4).

**Product Characteristics of Low-Fat Turkey Bologna During Refrigerated Storage**

**Color Characteristics.** Changes in color characteristics (L*, a*, b*) of turkey bologna as a function of refrigerated storage is given in Table 5. There was no significant (P > 0.05) interaction between treatments and storage time for any of the instrumental color parameters, indicating that color stability was not negatively affected by addition of PPI or SPI. The L* values showed that products with 1.5% PPI appeared to be lightest and were not different from samples containing 2% PPI and control with 11% meat protein. Lightness values for control-2 appeared to be significantly lower compared with all other treatments. This darker color of control-2 might be due to higher amount of pigments due to higher percentages of added thigh meat. In this study, all treatments except control-2 had similar lean meat content and were expected to have the same myoglobin content. Trespalacios and Pla (2007) stated that the color of comminuted products is mostly influenced by nonmeat ingredients added. Trespalacios and Pla (2007) stated that the color of comminuted products is mostly influenced by nonmeat ingredients when the myoglobin content is kept constant. Products with SPI were lighter than control-2 but darker than control-1 and 1.5% PPI samples. However, an earlier study showed that the addition of soy protein concentrate in ground beef products did not significantly influence its color characteristics (Pietrasik and Duda, 2000). The L* values showed significant reduction after 2 wk of storage onward. During storage of meat products, color of the products may turn to brown, causing reduction in L* values, which is mainly due to oxidation of pigments. The rate of color change is dependent on the total amount of oxygen available for reaction (Saguy and Karel, 1980) and on the temperature of product storage (Labuza, 1980).

The product with a lower L* value showed a higher a* value (Table 5); control-2 had higher a* value compared with other treatments, indicating more redness, and this may be due to higher pigment content that could be due to the higher percentage of thigh meat used. There was no difference in a* values of products prepared with PPI or SPI. During storage, a* values were significant higher compared with fresh samples (0 wk) until 3 wk of storage; however, the magnitude of differences was small and would normally be considered to be of little or no practical importance. Samples stored 4 to 5 wk did not differ from fresh (0 wk).

The color of meat products also varies with the type of nonmeat ingredients added. Akesowan (2008) noticed that addition of 1.5 and 2% SPI significantly decreased a* values and increased b* values, causing the light pork sausages to be less red and more yellow (Akesowan, 2008). Similar observations were also noticed in this study with the addition of 2% SPI compared with control-2.

The products containing protein isolates were significantly (P < 0.05) more yellow compared with the control samples as evidenced by b* values (Table 5). Soy protein isolate was reported to impart a yellowish color in meat products (Akesowan, 2008). In marinated meat products when citric acid was used, yellowness increased (Onene et al., 2004). The addition of citric acid during the preparation of PPI might influence the yellowness of the meat products containing PPI. There was no significant difference in b* values of products as a function of storage.

**Purge Loss.** Purge loss indicates the inability of proteins to hold water within a product. There was no significant difference in purge loss values as a function of storage; however, the values were significantly different for various treatments. Purge loss was significantly (P < 0.05) higher for control-1 samples compared with

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**Table 4.** Expressible moisture and gel strength parameters of turkey bologna1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Expressible moisture (%)</th>
<th>Breaking strength (g)</th>
<th>Deformation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-1</td>
<td>5.06 ± 1.41</td>
<td>1,305.8 ± 105.8d</td>
<td>13.8 ± 1.4</td>
</tr>
<tr>
<td>SPI</td>
<td>3.85 ± 1.21</td>
<td>1,971.9 ± 155.5a</td>
<td>13.4 ± 1.0</td>
</tr>
<tr>
<td>1.5% PPI</td>
<td>4.25 ± 1.28</td>
<td>1,633.7 ± 215.3b</td>
<td>13.5 ± 1.1</td>
</tr>
<tr>
<td>2% PPI</td>
<td>3.77 ± 0.77</td>
<td>1,737.9 ± 121.7bc</td>
<td>13.5 ± 1.4</td>
</tr>
<tr>
<td>Control-2</td>
<td>4.31 ± 0.95</td>
<td>1,877.4 ± 144.2ab</td>
<td>12.7 ± 0.8</td>
</tr>
</tbody>
</table>

**Note:** a–dMeans within column with no common superscript differ significantly (P < 0.05).

1Results are presented as mean values (n = 3) ± SD. SPI: soy protein isolate; PPI: poultry protein isolate; control-1: control bologna containing 11% meat protein; control-2: bologna formulated to contain 13% meat protein.
This higher purge loss of control-1 might be due to the high added water content, as suggested by Claus et al. (1990). Shand (2000) noticed a significant correlation between purge and moisture content or batter viscosity. High purge loss would be very unappealing to consumers, and the liquid within the package would shorten shelf-life of the product (Shand, 2000). Purge loss values of 2% PPI, SPI, and control-2 samples were not significantly different. Claus and Hunt (1991) also noticed no effect on purge loss by addition of 2% SPI during bologna preparation. Purge loss value of 1.5% PPI indicated that addition of 1.5% PPI is required to have similar purge loss values as SPI and control sample with 13% protein content.

**TBARS Value.** The most common form of chemical spoilage in meat products is due to oxidative rancidity (Kanner, 1994). The values for lipid oxidation levels at 0 min incubation were too low (0.01 to 0.04 nmol of malondialdehyde/gram of meat) to make any conclusion. Hence lipid oxidation was induced for 2.5 h of incubation at 37°C. Control-2 samples were highly susceptible to lipid oxidation throughout the storage period compared with treatments containing protein isolates (Figure 2). The highest levels of lipid oxidation were shown in the control-2 samples as indicated by higher levels of MDA. This might be due to the high content of fat from turkey thigh meat because meat addition was higher for control-2. In general, there was a decreasing trend for lipid oxidation during refrigerated storage. This might be due to the depletion of oxygen available within the package because the products were vacuum packed. Nolan et al. (1989) also noticed less oxidation in vacuum-packed turkey meat compared with other packaging treatments. Other influential factors can enhance lipid oxidation only when oxygen has free access to the stored meat products (Ahn et al., 1993).

### Table 5. Changes in color values of turkey bologna during refrigerated storage

<table>
<thead>
<tr>
<th>Item</th>
<th>L* value</th>
<th>a* value</th>
<th>b* value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage (S)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 wk</td>
<td>66.27 ± 1.81a</td>
<td>11.13 ± 0.54c</td>
<td>12.12 ± 1.01</td>
</tr>
<tr>
<td>1 wk</td>
<td>65.48 ± 2.51ab</td>
<td>11.63 ± 0.77a</td>
<td>12.09 ± 0.75</td>
</tr>
<tr>
<td>2 wk</td>
<td>65.12 ± 1.54b</td>
<td>11.52 ± 0.74ab</td>
<td>12.02 ± 0.47</td>
</tr>
<tr>
<td>3 wk</td>
<td>65.14 ± 1.44b</td>
<td>11.41 ± 0.66ab</td>
<td>12.10 ± 0.59</td>
</tr>
<tr>
<td>4 wk</td>
<td>64.99 ± 1.26b</td>
<td>11.39 ± 0.61abc</td>
<td>12.09 ± 0.61</td>
</tr>
<tr>
<td>5 wk</td>
<td>65.22 ± 1.34b</td>
<td>11.32 ± 0.75bc</td>
<td>12.03 ± 0.55</td>
</tr>
<tr>
<td>Treatment (T)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control-1</td>
<td>65.99 ± 2.08a</td>
<td>10.99 ± 0.37c</td>
<td>11.48 ± 0.62b</td>
</tr>
<tr>
<td>SPI</td>
<td>65.12 ± 1.68b</td>
<td>11.14 ± 0.40bc</td>
<td>12.50 ± 0.60a</td>
</tr>
<tr>
<td>1.5% PPI</td>
<td>66.26 ± 1.17a</td>
<td>11.14 ± 0.46bc</td>
<td>12.52 ± 0.46a</td>
</tr>
<tr>
<td>2.0% PPI</td>
<td>65.59 ± 1.62ab</td>
<td>11.32 ± 0.70b</td>
<td>12.38 ± 0.43a</td>
</tr>
<tr>
<td>Control-2</td>
<td>63.88 ± 0.80b</td>
<td>12.39 ± 0.37a</td>
<td>11.51 ± 0.23b</td>
</tr>
</tbody>
</table>

Source of variation (P-value)
- S: 0.0008
- T: <0.0001
- S × T: 0.9311

\(^a-c\) Means within column with no common superscript differ significantly (P < 0.05).

1Results are presented as means ± SD. Total n = 90. SPI: soy protein isolate; PPI: poultry protein isolate; control-1: control bologna containing 11% meat protein; control-2: bologna formulated to contain 13% meat protein.

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**Figure 1.** Purge loss (%) of turkey bologna during refrigerated storage. Control-1: 11% meat protein; SPI: 2% soy protein isolate; PPI: poultry protein isolate; and control-2: 13% meat protein. The experiment was replicated 3 times (n = 3), and the average reading was used to plot the graph. Different letters (a–c) denote statistically significant differences (P < 0.05).

**Figure 2.** Lipid oxidative stability of turkey bologna as a function of ingredients during refrigerated storage measured as induced TBA reactive substances. Control-1: 11% meat protein; SPI: 2% soy protein isolate; PPI: poultry protein isolate; control-2: 13% meat protein. The experiment was replicated 3 times (n = 3), and the average reading was used to plot the graph. MDA = malondialdehyde.
CONCLUSIONS

The study revealed that physicochemical properties of control-1 treatment were inferior to other products. Cooking yield of turkey bologna with PPI and control-2 were higher than that of control-1 and SPI. Samples with PPI and control-1 showed lower L* values compared with SPI and control-2. Protein isolates were found to impart yellowish color to turkey bologna. Products containing protein isolates showed lower susceptibility to lipid oxidation. It can be concluded that PPI can be substituted for SPI or meat protein without negatively affecting the physicochemical characteristics as evident from the data of cooking yield or purge loss. This study also points toward the potential of PPI to be used as a food ingredient and in turn to have better utilization of MST.

ACKNOWLEDGMENTS

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REFERENCES