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ARTICLE

# Quality Properties of Sausages Made with Replacement of Pork with Corn Starch, Chicken Breast and Surimi during Refrigerated Storage

Hyun-Woo Seo, Geun-Ho Kang, Soo-Hyun Cho, Hoa Van Ba, and Pil-Nam Seong*
*National Institute of Animal Science, RDA, Wanju 55365, Korea*

**Abstract**

This effect of replacing pork with corn starch, chicken breast and surimi on the chemical composition, physical, texture and sensory properties of sausage were investigated during storage. Five treatments of sausage such as; T1 (10:0:0, %), T2 (10:5:0, %), T3 (10:10:5, %), T4 (10:15:10, %) and T5 (10:20:15, %) were prepared with replacement of pork with corn starch, chicken breast and surimi. The sausage made with pork meat served as control (C). The sausage in the control had higher moisture and fat contents, but lower protein content than the treatments ($p$<0.05). The sausages in the T2 and T5 had decreased pH values after 3 wk storage ($p$<0.05). The lightness value was lowest in the T3, while the yellowness values were lowest in the T5 during the storage. The TBARS (2-thiobarbituric acid reactive substance) values were lowest in the control in all storage times ($p$<0.05). However, the sausage in the control had higher VBN (volatile basic nitrogen) value than the treatments during the 1 wk storage ($p$<0.05). All treatments had significantly higher hardness, cohesiveness, springiness, gumminess and chewiness values ($p$<0.05) than the control. The results indicated that corn starch, chicken breast and surimi can used as a pork replacer, that it also improves the physicochemical and texture properties of pork sausages.

**Keywords:** replacement, surimi, chicken breast, starch, sausage

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## Introduction

The increasing demand for better quality and healthy meat products has stimulated the use of new non-meat components (Aktaş and Gençcelep, 2006). These non-meat components of natural or synthetic origin, known under the name of hydrocolloids or structuring additions, are introduced during processing and preservation of meat products (Baranowska *et al.,* 2004). Direct replacement of fat with non-meat proteins is an attractive avenue in approaching fat reduction due to the excellent functional and nutritional properties of these non-meat proteins. Starches are multifunctional food ingredients, which have many functional applications, including adhesion, binding, emulsion stabilization, gelling and moisture retention (Pietrasik, 1999). Carballo *et al.* (1995) reported that increased levels of starch favorably affected cooking loss and purge loss. Also, modified food starch added in the chopping process of turkey bologna was very effective in reducing cooking loss as well as decreasing purge loss during storage while not increasing product hardness (Dexter *et al.,* 1993).

Muscle protein gelation contributes to desirable texture and fat-water emulsion stabilization in processed meats. Skinless poultry meat contains more protein, less fat, and less cholesterol than red meat (Hu, 2005; Ressurreccion, 2004). Its protein is of excellent nutritional quality, and it contains all of the essential amino acids for human consumption (Varnam and Sutherland, 1995). Poultry meat processors will meet this demand by producing reduced fat poultry and poultry meat products. Chicken is now being used to manufacture many processed meat products that traditionally have been made from pork. Furthermore, the manufacture of poultry meat products usually costs less than that of similar beef and pork products (Guerrero-Legarreta and Hui, 2010).

Surimi is light in color, has a bland odour, low in fat and high in myofibrillar protein and extremely functional due to the unique gelling properties of these myofibrillar proteins and these qualities make surimi an ideal functional ingredient for fabricating new food products (Lanier, 2000; Lee, 1986). Surimi is considered an intermediate product as it is usually further processed into various other products. Recently, the use of animal species for

*Corresponding author: Pil-Nam Seong, National Institute of Animal Science, Wanju 55365, Korea. Tel: +82-63-238-7352, Fax: +82-63-238-7397, E-mail: spn2002@korea.kr

manufacturing surimi-like material has increased (Antonomanolaki *et al.,* 1999; Jin *et al.,* 2007).

The aim of this study was to evaluate the effect of replacement of pork meat with surimi, chicken breast and corn starch on the quality properties of sausages during cold storage.

## Materials and Methods

### Preparation of products

The formulations of sausages with replacements of pork with either corn starch or chicken breast and surimi are summarized in Table 1. Fresh pork ham, pork back-fat and chicken breast were obtained from a local commercial processor (Korea) after 24 h postmortem. The meats were trimmed off of all connective tissue and visible fats and then were chopped through a 3 mm plate using a silent chopper (Model 7548, Biro MFG. Co., USA). For each treatment, the chopped lean meat was placed in a bowl cutter (CR-40, Mainca, Spain), chopped for about 10 s at low speed, and then the mixture of ingredients and replacing materials were gradually added while chopping. The meat mixture was chopped for further 1 min at high speed and then about one-third of ice-water was added and the batter was continuously chopped for 2 min at high speed. After that, the pork back-fat was added and the rest of ice water was gradually added, the batter was then chopped at high speed for further 5 min. The temperature of batter was maintained below 10°C during preparation. After chopping, the meat batter was immediately stuffed into 28-mm diameter collagen casings (Naturin Viscofan Co., Spain) using a vacuum stuffer (Model VF610, Handtmann Co., Germany). Finally, the sausages were placed in a smokehouse and cooked until the core temperature reached at 70°C. After cooking, the cooked sausages were immediately soaked in cold water to cool and left to drain the water. Thereafter, the samples were placed in polyethylene/polyamide bags and finally assigned into 5 different storage periods; 1, 2, 3, 4 and 5 wk and kept at 4°C.

### Proximate composition

The moisture, protein, fat and collagen contents of sausages were analyzed using a Food Scan™ Lab 78810 (Foss Tecator Co., Ltd., DK), according to the method of the Association of Official Analytical Chemists (AOAC, 2000).

### Color measurement

Color was determined at 4 defined areas on the cut surface of each sausage sample using a Minolta Chroma Meter CR-400 (Minolta Camera Co., Ltd., Japan) that was standardized with a white plate (Y=86.3, X=0.3165 and y=0.3242). Color was expressed according to the Commission International de l'Eclairage (CIE, 1978) system and reported as CIE $L^*$ (lightness), CIE $a^*$ (redness), CIE $b^*$ (yellowness).

### pH measurement

The pH values of sausage samples were determined in

**Table 1. Formulation of sausage**

| Ingredients (%) | Treatments[1) | | | | | |
|---|---|---|---|---|---|---|
| | C | T1 | T2 | T3 | T4 | T5 |
| Pork | 85 | 75 | 70 | 60 | 50 | 40 |
| Corn starch | - | 10 | 10 | 10 | 10 | 10 |
| Chicken breast | - | - | - | 5 | 10 | 15 |
| Surimi | - | - | 5 | 10 | 15 | 20 |
| Back fat | 12 | 12 | 12 | 12 | 12 | 12 |
| Phosphate | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Salt | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| Sugar | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| L-ascorbic acid | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Erythorbic acid | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| L-Glutamate | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Pepper | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Garlic powder | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |

[1)]C, control; T1, replacement of pork with 10% corn starch; T2, replacement of pork with 10% corn starch, 5% surimi; T3, replacement of pork with 10% corn starch, 5% chicken breast, 10% surimi; T4, replacement of pork with 10% corn starch, 10% chicken breast, 15% surimi; T5, replacement of pork with 10% corn starch, 15% chicken breast, 20% surimi.

triplicates using a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland). The pH was measured after homogenizing 3 g of each sample with 27 mL of distilled water for 30 s using a homogenizer.

**Texture analysis**

The texture properties of the sausages were analyzed using a puncture probe (7 mm diameter) attached to a texture Analyzer (Model 4465, Instron Corp, UK). For texture analysis, the sample from each treatment was cut into 2.5 cm long pieces; the cube was axially compressed twice until reaching each time 80% of its initial height. The speed of load cell was set at 120 mm/min and the following parameters were calculated: hardness (kg), springiness (mm) and cohesiveness (kg*mm), gumminess (kg) and chewiness (kg*mm).

**Lipid oxidation**

The content of thiobarbituric acid reactive substances (TBARS) was determined to evaluate the lipid oxidation level of sausages during storage, using the method described by Pikul *et al.* (1989). TBARS concentrations were calculated by multiplying the absorbance by a constant coefficient of 5.5 which obtained from standard curves and known dilutions (0.1-0.8 μM) of 1,1,3,3 tetramethoxypropane. The TBARS value was expressed as mg malonaldehyde/kg (MA/kg) of sample.

**Volatile basic nitrogen (VBN)**

5 g of sausage was extracted by adding 25 mL of distilled water for 30 min. A Conway micro-diffusion cell was used, which was sealed with vaseline. One mL of the extract was added to the lower well, then 1 mL of 0.01 N sulfuric acid ($H_2SO_4$) was added to the central well, followed by adding 1 mL of $K_2CO_3$ saturated solution to the upper well. After 2 h of incubation at 25°C, 20 μL of Brunswik reagent (Daejung Chemicals & Metals Co., Korea) was added to the central well. The mixture was directly titrated with 0.01 N NaOH. As a blank, 1 mL of distilled water was titrated in the same manner. The amount of VBN produced was estimated by equation:

$$\mathrm{VBN} = 0.14 \times \frac{(\mathrm{b(sample)} - \mathrm{a(sample)}) \times \mathrm{f}}{\mathrm{W}} \times 100 \times \mathrm{d}$$

Where a (sample) and b (blank) are the amounts (mL) of 0.01 N NaOH used in the titration, d is 25 (dilution ratio of 25 mL to 1 mL used), W is the sample amount (g), and f is 1.0 (the factor of 0.01 N NaOH).

**Sensory evaluation**

Sensory evaluation of sausages in different treatments at 1 day storage was performed using the method as described by Deda *et al.* (2007) with suitable modifications. Briefly, eight panelists consisted of 2 males and 6 females with an average age of 30-35 years selected from the members of Animal Products Processing Division of the National Institute of Animal Science, Suwon, Korea were used. Before the sensory evaluation, the panelists were trained using commercial sausages for several months (once per every two weeks) to familiarize them with the characteristics to be evaluated. Prior to evaluation, the sensory samples were warmed at room temperature (about 25°C) for 1 h and cut into 1.5 cm long pieces, coded with random numbers. The panelists were laid to seat in private seats under fluorescent lighting and were served with the sensory samples in a random manner. The sensorial characteristics including texture, flavor, taste and overall acceptability specifically selected for frankfurters evaluation (Choe *et al.,* 2013; Ozvural and Vural, 2011) were used. The samples were evaluated for the aforementioned sensorial traits using a 7-point scale (1 point = extremely undesirable, 7 point = extremely desirable) as described by Meilgaard *et al.* (1991). The panelists were asked to refresh their mouth with the drinking distilled water and salt-free crackers between samples. All sensory sessions were carried out in the sensory panel booth room equipped with white lighting at a constant temperature (20°C).

**Statistic analysis**

The data were subjected to statistical analysis using the Statistic Analysis System (SAS) package (SAS Institute, USA, 2008). All data were analyzed by the General Linear Model procedure considering treatment and storage time as the main effects. Means were compared using Duncan's Multiple Range Test. Significant differences ($p<0.05$) between mean values of quintuplicate samples were determined for the proximate composition, meat color, pH, TBARS, VBN and texture. Significant differences ($p<0.05$) between sensory evaluations were determined (N=8).

## Results and Discussion

**Proximate composition of pork sausages**

As expected, the treatments differed significantly with respect to their levels of moisture, protein, fat and collagen contents are presented in Table 2. The moisture content was higher in the control than in the all treatments (68.44 vs. 62.98-64.12%, $p<0.05$). All treatments had a

**Table 2. Proximate composition (%) of replacing pork with corn starch, chicken breast, surimi of pork sausages**

| Treatments[1)] | Moisture (%) | Protein (%) | Fat (%) | Collagen (%) |
|---|---|---|---|---|
| C | $68.44^{A}$ | $17.53^{E}$ | $11.27^{A}$ | $1.69^{B}$ |
| T1 | $63.26^{D}$ | $22.55^{A}$ | $10.73^{B}$ | $1.78^{B}$ |
| T2 | $63.22^{DE}$ | $22.34^{B}$ | $10.80^{B}$ | $2.32^{A}$ |
| T3 | $62.98^{E}$ | $22.35^{B}$ | $10.40^{C}$ | $1.88^{B}$ |
| T4 | $63.60^{C}$ | $21.95^{C}$ | $9.88^{D}$ | $1.67^{B}$ |
| T5 | $64.12^{B}$ | $21.48^{D}$ | $9.34^{E}$ | $1.75^{B}$ |
| SEM | 0.35 | 0.33 | 0.12 | 0.06 |

$^{A-E}$Means with different superscript in the same column significantly differ at $p<0.05$.
[1)]C, control; T1, replacement of pork with 10% corn starch; T2, replacement of pork with 10% corn starch, 5% surimi; T3, replacement of pork with 10% corn starch, 5% chicken breast, 10% surimi; T4, replacement of pork with 10% corn starch, 10% chicken breast, 15% surimi; T5, replacement of pork with 10% corn starch, 15% chicken breast, 20% surimi.

significantly higher protein than the control (21.48-22.55 vs. 17.53%, $p<0.05$). In the case of fat content, the T3 had the lowest content (9.34%), with the content of protein and fat decreasing with the increase in the percentage of chicken breast and surimi ($p<0.05$). The T2 had significantly higher collagen content (2.32%) than the other treatments ($p<0.05$). Corn starch is reduced the moisture and fat contents of the sausage (68.44 vs. 63.26 and 11.27 vs. 10.73% in the control and T1, respectively; $p<0.05$). This may be as a result of the low moisture and fat contents, typically 11.6% moisture, 0.35% total lipid content, 0.18% ash content and 26.6% amylose content, present in commercial native corn starch (Qiu *et al*., 2015).

**Color and pH of pork sausages**

The color and pH values of sausages in the control and treatments at different storage times are presented in Table 3. The pH values were significantly lower in the control than in the treatments during the first 4 wk of storage ($p<0.05$). Storage time significantly ($p<0.05$) reduced the pH values of sausages formulated of replacing pork with chicken breast and surimi levels. While, the control sausage remained their values stable during storage times. All treatment sausages increased in pH with increased chicken breast and surimi levels after 2 wk refrigerated storage time. Similarly Deda *et al.* (2007) showed that storage time reduced the pH values of frankfurters made with various tomato paste levels due to the increase of lactic acid bacteria. Honikel (1987) reported that pH had a profound effect on physical properties such as the water-holding capacity, tenderness and color of meat. Usually, a high pH is closely related to high shear force or gel strength in meat products. Therefore, pH was found to have effect on the texture properties in any replacing pork with corn starch, chicken breast and surimi sausages was increased hardness, cohesiveness, springiness, gumminess and chewiness in the present study.

Sausages in control had a significantly higher lightness and redness values than the all treatments during storage time ($p<0.05$). The lightness was lowest from 1 to 4 wk in T3 ($p<0.05$). All sausages were increase lightness during storage at 3 wk. The yellowness was lowest in the T5 throughout the storage time ($p<0.05$). Surimi-like material has typically high whiteness and lightness values due to the removal of pigments, including myoglobin (Jin *et al.,* 2007). Therefore, replacing pork with corn starch, chicken breast and surimi sausages was increased lightness value, but decreased redness value in the present study.

**Shelf-life stability**

The TBARS and VBN values of sausages are presented in Table 4. The TBARS values of sausage in the control were significantly lower than that of treatments (T1-T5) during storage ($p<0.05$). The replace of pork with chicken at the all levels (T3-T5) did not affect ($p>0.05$) the TBARS values of sausages except for at 5 wk of storage. In addition, sausages are in the 3rd and the 4th wk has the highest TBARS value. Mcmillin *et al.* (1991) reported that such a phenomenon of TBARS value which increased firstly then decreased lately was probably related to the reason that velocity of fat being oxidized into malonaldehyde was slower than that of malonaldehyde being oxidized or polymerized into other products. This may be due to the different phospholipid contents between the formulations as well as altered protein make-up. Lipid oxidation in muscle systems is initiated at the membrane level in the intracellular phospholipid fractions (Gray *et al.,* 1996). Ockerman (1985) indicated that TBARS value were usually below 0.7-1.0 mg malonaldehyde/kg meat. Ockerman and Kesh (1982) also reported that taste with fat oxidation of acid deterioration would be affected in sensory evaluation tests when reaching above 1.0 mg mal-

**Table 3. Changes in the pH and color of replacing pork with corn starch, chicken breast, surimi of pork sausage during storages time at 4ºC**

| Treatments[1)] | | Storage (wk) | | | | | SEM |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| pH | C | 6.19$^{Bb}$ | 6.31$^{Ea}$ | 6.05$^{Ec}$ | 6.29$^{Da}$ | 6.19$^{Db}$ | 0.03 |
| | T1 | 6.52$^{Aa}$ | 6.38$^{Dab}$ | 6.19$^{Dbc}$ | 6.39$^{Cab}$ | 6.09$^{Ec}$ | 0.05 |
| | T2 | 6.46$^{Ab}$ | 6.45$^{Cb}$ | 6.54$^{Ca}$ | 6.48$^{Bb}$ | 6.32$^{Cc}$ | 0.02 |
| | T3 | 6.5$^{Ac}$ | 6.51$^{Bc}$ | 6.59$^{Ba}$ | 6.54$^{Ab}$ | 6.55$^{Ab}$ | 0.01 |
| | T4 | 6.54$^{Ab}$ | 6.54$^{Bb}$ | 6.66$^{Aa}$ | 6.53$^{ABb}$ | 6.55$^{Ab}$ | 0.01 |
| | T5 | 6.60$^{Aab}$ | 6.61$^{Aab}$ | 6.65$^{Aa}$ | 6.57$^{Ab}$ | 6.48$^{Bc}$ | 0.02 |
| | SEM | 0.04 | 0.02 | 0.06 | 0.03 | 0.04 | |
| L* (lightness) | C | 68.65$^{Ac}$ | 69.40$^{Ab}$ | 70.59$^{Aa}$ | 67.78$^{Ad}$ | 68.72$^{Ac}$ | 1.07 |
| | T1 | 65.06$^{Cb}$ | 65.21$^{Eb}$ | 66.53$^{Da}$ | 63.98$^{Dc}$ | 65.50$^{Cb}$ | 1.01 |
| | T2 | 65.43$^{Cb}$ | 65.81$^{Db}$ | 66.66$^{Da}$ | 63.77$^{DEd}$ | 64.79$^{Dc}$ | 1.09 |
| | T3 | 64.06$^{Dc}$ | 65.14$^{Eb}$ | 66.51$^{Da}$ | 63.51$^{Ed}$ | 64.98$^{CDb}$ | 1.17 |
| | T4 | 65.53$^{Cc}$ | 67.15$^{Cb}$ | 68.09$^{Ca}$ | 65.35$^{Cc}$ | 66.79$^{Bb}$ | 1.15 |
| | T5 | 65.54$^{Bc}$ | 67.79$^{Bb}$ | 68.63$^{Ba}$ | 66.41$^{Bc}$ | 67.12$^{Bbc}$ | 1.22 |
| | SEM | 0.22 | 0.22 | 0.21 | 0.22 | 0.20 | |
| a* (redness) | C | 6.90$^{Aa}$ | 6.45$^{Ab}$ | 6.80$^{Aa}$ | 5.46$^{Ad}$ | 5.92$^{Ac}$ | 0.59 |
| | T1 | 6.07$^{Ba}$ | 5.80$^{Bb}$ | 5.85$^{Bb}$ | 4.87$^{Bd}$ | 5.34$^{Bc}$ | 0.47 |
| | T2 | 5.15$^{Cb}$ | 5.13$^{Cb}$ | 5.45$^{Ca}$ | 4.57$^{Cd}$ | 4.93$^{Cc}$ | 0.35 |
| | T3 | 5.05$^{CDc}$ | 5.62$^{Ba}$ | 5.68$^{Ba}$ | 4.64$^{Cd}$ | 5.37$^{Bb}$ | 0.43 |
| | T4 | 4.78$^{Ec}$ | 5.20$^{Ca}$ | 5.32$^{Ca}$ | 4.20$^{Dd}$ | 5.03$^{Cb}$ | 0.43 |
| | T5 | 4.89$^{DEb}$ | 5.13$^{Ca}$ | 5.15$^{Ca}$ | 4.10$^{Dc}$ | 4.94$^{Cb}$ | 0.43 |
| | SEM | 0.11 | 0.07 | 0.08 | 0.07 | 0.05 | |
| b* (yellowness) | C | 9.54$^{Cb}$ | 10.00$^{Ca}$ | 10.11$^{Ba}$ | 9.94$^{Da}$ | 10.09$^{Ca}$ | 0.28 |
| | T1 | 9.87$^{ABd}$ | 10.31$^{Bc}$ | 10.55$^{Ab}$ | 10.92$^{Aa}$ | 11.13$^{Aa}$ | 0.51 |
| | T2 | 10.06$^{Ad}$ | 10.91$^{Aa}$ | 10.52$^{Ac}$ | 10.71$^{Bb}$ | 10.73$^{Bb}$ | 0.34 |
| | T3 | 9.93$^{ABc}$ | 10.01$^{Cbc}$ | 9.80$^{Cc}$ | 10.30$^{Cab}$ | 10.58$^{Ba}$ | 0.41 |
| | T4 | 9.69$^{BCc}$ | 10.02$^{Cb}$ | 9.48$^{Dc}$ | 10.20$^{Cb}$ | 10.55$^{Ba}$ | 0.47 |
| | T5 | 8.90$^{Dc}$ | 9.45$^{Db}$ | 9.42$^{Dc}$ | 9.66$^{Eb}$ | 9.83$^{Ca}$ | 0.36 |
| | SEM | 0.06 | 0.07 | 0.07 | 0.06 | 0.07 | |

[A-E]Means with different superscript in the same column significantly differ at $p<0.05$.
[a-d]Means with different superscript in the same row significantly differ at $p<0.05$.
[1)]C, control; T1, replacement of pork with 10% corn starch; T2, replacement of pork with 10% corn starch, 5% surimi; T3, replacement of pork with 10% corn starch, 5% chicken breast, 10% surimi; T4, replacement of pork with 10% corn starch, 10% chicken breast, 15% surimi; T5, replacement of pork with 10% corn starch, 15% chicken breast, 20% surimi.

onaldehyde/kg meat. In present study, the sausages in the treatment had TBARS values (1.08-1.76 mg malonaldehyde/kg product) higher than the value of 1 mg malonaldehyde/kg. Lipid oxidation products may be responsible for the development of unpleasant aromas and flavors in sausage (Bhattacharyya *et al.,* 2007).

The increased amount of VBN is the result of decomposition of protein by microorganisms during storage, therefore the VBN level can be an index of meat product freshness. At wk 1, the control samples had significantly ($p<0.05$) higher VBN value (14.92 mg%), compared with those of treatment samples (8.51-13.36 mg%). The VBN value in the T2 was lowest during storage. In addition, sausages are in the 3rd and the 4th wk has the highest VBN value. The VBN is related to bacterial activities (Banwart, 1981) and protein breakdown (Eagan *et al.,* 1981). Formation of volatile compounds associated with the growth of microorganisms during storage causes an increase in the VBN level (Jay, 1992).

**Texture profile of pork sausages**

The texture characteristics of sausages are presented in Table 5. When fat content is reduced by increasing the proportion of added water and keeping the amount of protein essentially constant, low-fat products can be obtained with less hardness (Bloukas and Paneras, 1993; Cavestanty *et al.,* 1994; Carballo *et al.,* 1995; Colmenero *et al.,* 1995; Gregg *et al.,* 1993). Therefore, the protein content appears to play a major role in the firmness of the finished product. All treatments had significantly higher hardness, cohesiveness, springiness, gumminess and chewiness values ($p<0.05$) than control samples. No signifi-

**Table 4. Changes in the TBARS and VBN of replacing pork with corn starch, chicken breast, surimi of pork sausages during storage time at 4°C**

| Treatments[1)] | | Storage (wk) | | | | | SEM |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| TBARS (mgMA/kg) | C | $0.78^{Ca}$ | $0.78^{Ba}$ | $0.46^{Cb}$ | $0.69^{Cab}$ | $0.57^{Cab}$ | 0.04 |
| | T1 | $1.66^{Aab}$ | $1.44^{Abc}$ | $1.33^{Ac}$ | $1.76^{Aa}$ | $1.27^{ABc}$ | 0.05 |
| | T2 | $1.58^{ABa}$ | $1.44^{Aab}$ | $1.38^{Aab}$ | $1.59^{ABa}$ | $1.31^{ABb}$ | 0.04 |
| | T3 | $1.36^{Ba}$ | $1.37^{Aa}$ | $1.19^{Bb}$ | $1.4^{Ba}$ | $1.31^{ABa}$ | 0.02 |
| | T4 | $1.38^{ABa}$ | $1.45^{Aa}$ | $1.08^{Bc}$ | $1.42^{Ba}$ | $1.23^{Bb}$ | 0.03 |
| | T5 | $1.45^{ABa}$ | $1.4^{Aa}$ | $1.13^{Bb}$ | $1.43^{Ba}$ | $1.34^{Aa}$ | 0.03 |
| | SEM | 0.06 | 0.05 | 0.06 | 0.07 | 0.05 | |
| VBN (mg%) | C | $14.92^{Ab}$ | $13.91^{ABb}$ | $16.84^{Aa}$ | $14.46^{Bb}$ | $14.18^{Ab}$ | 0.33 |
| | T1 | $13.36^{Bc}$ | $12.91^{BCc}$ | $15.65^{ABa}$ | $14.64^{Bb}$ | $14.92^{Ab}$ | 0.28 |
| | T2 | $8.51^{Dc}$ | $12.08^{Cb}$ | $10.8^{Db}$ | $14.55^{Ba}$ | $12.08^{Bb}$ | 0.57 |
| | T3 | $11.99^{Cc}$ | $13.36^{ABb}$ | $12.81^{Cbc}$ | $14.28^{Ba}$ | $12.35^{Bc}$ | 0.24 |
| | T4 | $12.08^{Cc}$ | $14.28^{Ab}$ | $12.45^{Cc}$ | $16.11^{Aa}$ | $12.54^{Bc}$ | 0.44 |
| | T5 | $12.44^{Cc}$ | $13.91^{ABb}$ | $14.73^{Bb}$ | $15.92^{Aa}$ | $14.55^{Ab}$ | 0.32 |
| | SEM | 0.48 | 0.21 | 0.53 | 0.22 | 0.32 | |

[A-D]Means with different superscript in the same column significantly differ at $p<0.05$.
[a-c]Means with different superscript in the same row significantly differ at $p<0.05$.
[1)]C, control; T1, replacement of pork with 10% corn starch; T2, replacement of pork with 10% corn starch, 5% surimi; T3, replacement of pork with 10% corn starch, 5% chicken breast, 10% surimi; T4, replacement of pork with 10% corn starch, 10% chicken breast, 15% surimi; T5, replacement of pork with 10% corn starch, 15% chicken breast, 20% surimi.

**Table 5. Texture profile analysis of replacing pork with corn starch, chicken breast, surimi of pork sausages**

| Treatments[1)] | Haedness (kg) | Cohesiveness (mm) | Springiness (kg*mm) | Gumminess (kg) | Chewiness (kg*mm) |
|---|---|---|---|---|---|
| C | $0.70^{B}$ | $0.97^{B}$ | $16.70^{C}$ | $0.67^{B}$ | $11.18^{B}$ |
| T1 | $1.11^{A}$ | $1.58^{A}$ | $18.37^{AB}$ | $1.76^{A}$ | $32.30^{A}$ |
| T2 | $1.07^{A}$ | $1.60^{A}$ | $18.25^{AB}$ | $1.72^{A}$ | $31.40^{A}$ |
| T3 | $1.06^{A}$ | $1.61^{A}$ | $18.57^{A}$ | $1.70^{A}$ | $31.61^{A}$ |
| T4 | $1.06^{A}$ | $1.53^{A}$ | $18.57^{A}$ | $1.62^{A}$ | $30.01^{A}$ |
| T5 | $1.09^{A}$ | $1.69^{A}$ | $18.01^{B}$ | $1.84^{A}$ | $33.21^{A}$ |
| SEM | 0.02 | 0.05 | 0.1 | 0.07 | 1.25 |

[A-C]Means with different superscript in the same column significantly differ at $p<0.05$.
[1)]C, control; T1, replacement of pork with 10% corn starch; T2, replacement of pork with 10% corn starch, 5% surimi; T3, replacement of pork with 10% corn starch, 5% chicken breast, 10% surimi; T4, replacement of pork with 10% corn starch, 10% chicken breast, 15% surimi; T5, replacement of pork with 10% corn starch, 15% chicken breast, 20% surimi.

cant differences were observed between treatments with respect to hardness, cohesiveness, springiness, gumminess and chewiness. Thus, the treatment samples had a harder texture than the control samples.

The sausages made with high starch levels (>5%) had low fat content, more hardness and cohesiveness than the products made with no added starch (Beggs *et al.,* 1997; Pietrasik, 1999). Liu *et al.* (2008) also reported that the sausages with 2 g/100 g modified potato starch significantly improved the flavour and texture. In meat/starch systems, gelatinized starch absorbs more water, but its presence does not cause a chemical interaction between proteins and starch because meat protein begins to denature before starches gelatinize (Li and Yeh, 2002; Li and Yeh, 2003). Aleson-Carbonell *et al.* (2005) suggested that the textural properties of a meat product are determined by the ability of its protein matrix to retain water and bind fat. From the results obtained in the present study and previous studies it can be said that the addition of corn starch can increase the hardness, cohesiveness, gumminess and chewiness of the sausages. The results suggest that the replace pork with corn starch, chicken breast and surimi of pork sausages can improve their texture properties.

### Sensory characteristics of pork sausages

The sensory characteristics of sausages evaluated at 1 d storage are presented in Table 6. There was no difference ($p>0.05$) in color, flavor, texture and overall acceptability score between the control and treatments. The pork sausages replacement of pork with corn starch had higher

**Table 6. Sensory evaluation of replacing pork with corn starch, chicken breast, surimi of pork sausages**

| Treatments[1)] | Color[2)] | Flavor[3)] | Texture[4)] | Overall acceptability[5)] |
|---|---|---|---|---|
| C | 2.86 | 5.86 | 5.00 | 4.42 |
| T1 | 3.14 | 5.00 | 6.43 | 4.14 |
| T2 | 2.86 | 5.00 | 6.57 | 4.57 |
| T3 | 3.57 | 4.71 | 6.29 | 5.14 |
| T4 | 3.15 | 5.00 | 6.14 | 4.14 |
| T5 | 3.29 | 4.86 | 5.71 | 4.43 |
| SEM | 0.2 | 0.23 | 0.21 | 0.18 |

[1)]C, control; T1, replacement of pork with 10% corn starch; T2, replacement of pork with 10% corn starch, 5% surimi; T3, replacement of pork with 10% corn starch, 5% chicken breast, 10% surimi; T4, replacement of pork with 10% corn starch, 10% chicken breast, 15% surimi; T5, replacement of pork with 10% corn starch, 15% chicken breast, 20% surimi.
[2)]Scale: 1 = pale pink; 9 = dark red.
[3)]Scale: 1 = very unacceptable; 9 = very acceptable.
[4)]Scale: 1 = very firm; 9 = very tender.
[5)]Scale: 1 = very unacceptable; 9 = very acceptable.

texture scores than the control. Overall, the texture results showed that the surimi and chicken breast had decreased score (6.43 to 5.71). A slight reduction in flavor scores was observed for the samples replacement of pork with corn starch, chicken breast and surimi, but these did not significantly interfere with the results obtained from the sensory study showing that the samples replacement of pork with corn starch, chicken breast and surimi had no significant ($p$>0.05) effects on the color, flavor, texture and the overall acceptability of the sausages. Other studies (Barbut and Mittal, 1992; Desmond *et al.,* 1998; Mansour and Khalil, 1997) have reported that tenderness and juiciness are increased by additives with starch. However, Berry and Wergin (1993) and Troutt *et al.* (1992) reported lower juiciness scores for meat products containing carbohydrate ingredients. Liu *et al.* (2008) also reported that the sausages with 2 g/100 g modified potato starch significantly improved the flavor and texture.

## Conclusion

The corn starch, chicken breast and surimi can be used as a pork replacer, improving the physicochemical and texture properties of pork sausages. Specifically, pork sausages produced replace with corn starch, chicken breast and surimi had a lower fat content, and exhibited higher protein content, pH and texture properties than control pork sausage. These results may be useful in improve textured properties meat products.

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