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The effects of tapioca, wheat, sago and potato flours on the physicochemical and sensory properties of duck sausage

[1,2]Muthia, D., [1,]*Nurul, H. and [1]Noryati, I.

[1]Fish and Meat Processing Laboratory,
Food Technology Program, School of Industrial Technology,
Universiti Sains Malaysia, 11800 Minden, Pulau Pinang, Malaysia
[2]Agriculture Polytechnic, Animal Husbandry Faculty,
University of Andalas, West Sumatera, Indonesia

Abstract: This study evaluated the effects of different flours (tapioca, wheat, sago and potato) on the physicochemical properties of duck sausage. The examined physicochemical properties included proximate composition, cooking yield, color (lightness, redness and yellowness), folding, texture profile (hardness, elasticity, cohesiveness, gumminess and chewiness) and sensory properties. The study found that different flours have no effect on the cooking yield of duck sausage. The tapioca formulation showed a mid-range lightness value, folding score and textural properties. Duck sausages made with wheat flour had higher protein content and lightness value and a harder texture. Sausages made with potato flour had a darker color, the lowest folding scores and a softer texture. The addition of sago flour resulted in a higher folding score, greater elasticity and increased overall acceptability of sausage due to higher scores for texture and juiciness. These results show that the properties of duck sausage are influenced by the type of flour used.

Keywords: duck meat, sausages, physicochemical properties, sensory properties

Introduction

Duck meat is a poultry product that, unlike chicken meat, has not yet been developed as a primary food for human consumption in certain society. Several studies have examined the characteristics of duck meat. Soncin et al. (2007) conducted research on the volatile fraction of raw pork, duck and goose meat in order to characterize each species, examine the significance of the results and predict the acceptability of meat. Liu et al. (2007) have studied changes in taste compounds of duck during processing, and Wołoszyn et al. (2009) studied the influence of genotype on duck meat color. Little research, however, examines the utilization of duck meat in ready-to-eat products.

One ready-to-eat product that can be produced from duck meat is sausage. Research on value-added products made from duck meat has been conducted by Bhattacharyya et al. (2007). These researchers determined the quality characteristics of chicken and spent duck sausages and compared them to the characteristics of prepared spent hen chicken and broiler chicken. Despite the comparative differences among these sausages, spent duck meat can produce nutritionally sound and acceptable sausage with characteristic parameters that are within the range of standard values.

The use of non-meat components such as starches can stimulate better-quality and healthier meat products. Baranowska et al. (2004) explains that these non-meat components of natural or synthetic origin, also known as hydrocolloids or structuring additions, are introduced during the processing and preservation of meat products. Starches are multifunctional food ingredients. They have many functional applications, including adhesion, binding, emulsion stabilization, gelling, and moisture retention (Pietrasik, 1999). Giese (1995) stated that starches could be used as “binders” to increase the emulsion characteristics of the sausage product. On the other hand, starches can act as “fillers” that bind water and fat by means of physical entrapment (Heinz and Hautzinger, 2007).

A large amount of research has examined the use of starch to increase the acceptability and quality of meat products (Hughes et al. 1997; Yang et al. 2001; Dzudie et al. 2002; Serdaroğlu et al. 2005; Aktaş and Genccelep, 2006; Ahamed et al. 2007; Nisar et al. 2009). In comminuted meat products, potato starches are recommended to increase cooking yield or reduce loss from cooking, to improve texture and to extend

*Corresponding author.
Email: *nrlhd@usm.my*
Tel: +604-6532112 ; Fax: +604-6573678

shelf life (Murphy, 2000). Potato and tapioca starch have long been used by meat processors during the preparation of sausages and other meat products (Hughes et al., 1997; Ruban et al. 2008). Modified starches are also used as binders to maintain juiciness and tenderness in low-fat meat products (Claus and Hunt, 1991). In addition, modified starch can improve textural quality and reduce purge accumulation in low-fat bologna. The aim of this study was to determine the effects of the incorporation of tapioca, wheat, sago and potato flours on the physicochemical properties of duck sausages.

Materials and Methods

Raw material

Duck carcasses were purchased from a local farm in Kedah Malaysia and transported in an ice box to FIKA Food Sdn. Bhd. Pulau Pinang, Malaysia, where they were mechanically deboned. After deboning, all samples were formed into 20 kg blocks, frozen at –30°C and transported in an ice box to the Fish and Meat Processing Laboratory of Food Technology Programme, Universiti Sains Malaysia. The blocks were cut into pieces of approximately 1 kg and stored at −18°C until processing. Flour and all other ingredients were obtained from a local market in Penang, Malaysia.

Sausage formulation

The mechanically deboned duck meat (MDDM) was used as 65% of the formulation. Four treatment formulations of sausages were prepared using 4% tapioca, wheat, sago or potato flour. Other ingredients included palm oil (6%), egg white powder (0.75%), cold water (14.25%), salt (2.43%), sugar (1%), monosodium glutamate (0.05%), and spices (5.52%).

Sausage preparation

Frozen MDDM was cut into small pieces and mixed (Robot Coupe Blixer 3, France) with all other ingredients for about 5 min. The sausage butters were stuffed into artificial casing and formed into links 15 cm in length using a mechanical sausage-filler. The sausages were steamed at 65^{o}C for 30 min and then at 85-90^{o}C for 2 hours until their internal temperature reached 70^{o}C. They were cooled in cool water (10-15^{o}C) for 2 min and then stored in a freezer at -18^{o}C before they were analyzed.

Proximate composition

Moisture, crude protein, crude fat, ash and the amount of carbohydrate was determined by subtracting the moisture, fat, protein and ash contents (AOAC, 2000)

Cooking yield

Sausages were thawed at 4^{o}C for 4 hours and were cooked for 4 min on each side. All cooking measurements were replicated five times per treatment. The cooking yield was determined by calculating the weight difference between samples before and after cooking (Serdaroğlu, 2006).

$$\text{Cooking yield (\%)} = \frac{\text{Cooked sausage weight}}{\text{Uncooked sausage weight}} \times 100$$

Texture profile analysis

The textural profiles of duck sausage were conducted with a Stable Micro System TA-XT2i Texture Analyzer. The procedures for operating the Texture Analyzer were stated in the Standard Operating Procedure (SOP). This study compared the texture profile of duck sausages obtained from various treatments. The following parameters were determined: hardness (kg) is the resistance at maximum compression of first bite to deform the sample; cohesiveness is the positive force ratio of the second compression area to the first compression area (A2/A1); elasticity (mm) or springiness (mm) is the distance that the sample recovered its height between the first and second compressions; gumminess (kg) is the multiply of hardness and cohesiveness and chewiness (kg mm) is the multiply of gumminess and elasticity (Bourne, 1978; Klettner, 1989; Yetim et al. 2006). All texture profiles were replicated five times per treatment.

Color analysis

Color was measured on five raw sausages of each formulation using a calorimeter (Minolta CM 300m, Japan). Color coordinate values (L*, a*, and b*) were recorded. The equipment was standardized with a white color standard. The analysis was repeated on each sample five times.

Folding test

The folding test was carried out according to the method described by Lanier (1992). The duck sausage samples were cut into 3 mm thick rounds from the middle of the sausage. A numerical score was given according to the conventional scale as follows: AA (5)=no crack showing after folding twice, A (4)=no crack showing after folding in half, B (3)=cracks gradually when folded in half, C (2)=cracks immediately when folded in half, and D (1)=breaks by finger pressure. Each of samples were tested five times.

Sensory analysis

Sensory analysis was completed by 25 panelists according to the criteria described by Carpenter et al. (2000). The duck sausage samples were boiled and served warm to the panelists. The sensory attributes evaluated were color, odor, texture, juiciness, oiliness, taste and overall acceptability. These attributes were evaluated using a seven-point hedonic scale (7=like extremely; 1=dislike extremely).

Statistical analysis

All analyses were run in triplicate. The data were analyzed with an analysis of variance (ANOVA, 2000) ($p<0.05$), and the means were separated with Duncan's multiple range tests using Statistical Package for Social Science (SPSS) software version 16.0 (SPSS Inc., Illinois, USA).

Results and Discussion

Proximate composition

Table 1 presents the moisture, protein, fat, ash and carbohydrate content of the duck sausages. The use of different flours did not significantly affect the moisture or ash content of duck sausage. However, protein content was higher in duck sausage made with wheat flour than in those made with other flours. Previous research has reported that the protein content of wheat flour is higher than that of tapioca, sago, and potato flours (Matsunaga et al. 2003; Jobling, 2004; Aktas and Gençcelep, 2006; Anjum et al. 2008). It is generally known that flour is not a good source of fat. The fat content of the duck sausages examined in this study resulted from fat in the duck meat and the addition of palm oil during sausage preparation.

Bhattacharyya et al. (2007) reported that following chemical composition of spent-duck sausages: 57% moisture, 21% protein and 18% fat. The lower moisture content and higher fat content reported in their study results from the higher amount of vegetable fat (20%) and lower amount of water (10%) added during sausage preparation. Another factor contributing to the lower moisture content and higher protein and fat contents is the age of the animals used for sausage preparation (Bhattacharyya et al. 2007). Spent–ducks are usually slaughtered around the age of 18-24 months, while meat-type ducks are slaughtered around the age of 3-4 months. Lawrie (1998) stated that the meat of older animals will have a lower moisture content and a higher fat content than the meat of younger animals. Although the sausages in this study had different moisture, protein and fat contents, its proximate composition is within the range of the proximate composition of 10 commercial chicken sausages in Malaysia. Huda et al. (2009) reported that the proximate composition of Malaysian commercial chicken sausages is as follows: 58.49 - 68.85% moisture content, 7.03 - 14.14% protein content, 4.91 - 18.48% fat content, 2.17 – 3.30 % ash content and 6.69 – 21.59% carbohydrate content.

Color, cooking yield and folding test

Table 2 shows the color attributes of the duck sausages. Color appearance is one of the main physical attributes that determines the consumer acceptability of sausage products. Color is described as coordinates as lightness (L*), redness (a*) and yellowness (b*). Color was significantly affected ($p<0.05$) by the additional of various flours in the duck sausage

Table 1. Proximate composition of duck sausages with different type of flours

Treatments	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	CHO (%)
Tapioca	65.62 ± 0.04^{a}	14.24 ± 0.12^{a}	12.61 ± 0.57^{a}	2.38 ± 0.02^{c}	5.13 ± 0.11^{c}
Wheat	65.68 ± 0.12^{a}	15.77 ± 0.03^{b}	13.57 ± 0.56^{b}	2.19 ± 0.02^{b}	2.77 ± 0.20^{a}
Sago	65.33 ± 0.35^{a}	14.53 ± 0.16^{a}	12.58 ± 0.10^{a}	2.24 ± 0.02^{b}	5.31 ± 0.29^{d}
Potato	65.66 ± 0.08^{a}	14.68 ± 0.03^{a}	13.43 ± 0.09^{b}	2.09 ± 0.01^{a}	4.15 ± 0.05^{b}

* Data presented in means ± sd. Different letters in the same column indicate significant differences ($p<0.05$).

Table 2. Color properti es of duck sausages with different type of flours

Treatments	Color		
	L*	a*	b*
Tapioca	58.1 ± 0.3^{ab}	9.4 ± 0.03^{c}	19.5 ± 0.03^{b}
Wheat	58.3 ± 0.07^{b}	8.8 ± 0.1^{b}	19.4 ± 0.1^{ab}
Sago	57.6 ± 0.1^{a}	8.3 ± 0.07^{a}	19.1 ± 0.03^{a}
Potato	57.4 ± 0.04^{a}	9.1 ± 0.1^{b}	19.9 ± 0.03^{c}

* Data presented in means ± sd. Different letters in the same column indicate significant differences (p<0.05).

Table 3. Cooking yield and folding test of duck sausages with different type of flours

Treatments	Cooking Yield (%)	Folding Test
Tapioca	96.59 ± 1.2^{a}	4.4 ± 0.5^{b}
Wheat	95.79 ± 0.9^{a}	4.0 ± 0.0^{a}
Sago	96.93 ± 0.3^{a}	4.6 ± 0.54^{b}
Potato	96.98 ± 0.5^{a}	3.6 ± 0.54^{a}

Data presented in means ± sd. Different letters in the same column indicate significant differences (p<0.05)

Table 4. Texture profile analysis of duck sausages with different type of flours

Texture parameter	Tapioca	Wheat	Sago	Potato
Hardness (kg)	4.35 ± 0.15^{a}	5.77 ± 011^{c}	5.16 ± 0.06^{b}	4.22 ± 0.11^{a}
Elasticity (mm)	14.18 ± 0.15^{a}	14.22 ± 0.08^{a}	16.12 ± 0.09^{b}	14.03 ± 0.07^{a}
Cohesiveness	0.23 ±0.02^{a}	0.24 ± 0.02^{a}	0.24 ±0.02^{a}	0.22 ± 0.02^{a}
Gumminess (kg)	1.00 ± 0.05^{a}	1.38 ± 0.14^{b}	1.24 ± 0.11^{b}	0.92 ± 0.06^{a}
Chewiness (kg mm)	14.16 ± 0.89^{a}	19.58 ± 1.72^{b}	19.98 ± 1.78^{b}	13.01 ± 0.89^{a}

* Data presented in means ± sd. Different letters in the same rows indicate significant differences (p<0.05).

formulations. Tapioca and wheat flours produced sausage with a higher L* value than sago and potato flours. These results are similar to those reported by Yetim et al. (2006), who showed that increasing the concentration of wheat flour increased the L* value of the sausages. When the a* value of the duck sausage was examined, samples with tapioca flour showed the highest value (9.4), followed by samples with potato (9.1), wheat (8.8) and sago (8.3) flours. The highest b* values were found in the samples made with potato flour (19.9). The results of the color analysis in this study are within the color range of the commercial chicken sausages in Malaysia. Huda et al. (2009) reported that the L*, a* and b* values of commercial chicken sausage were 44.42-65.54, 6.51-22.11 and 16.10-31.80, respectively. The slightly lower L* value of duck sausages compared to the average L* value of chicken sausages is related to the original form of duck meat. Duck meat has a darker color than chicken meat due to its higher myoglobin and fat content. This is because the ducks' muscles require more oxygen, and the oxygen is delivered to those muscles by the red cells in the blood. One of the proteins in meat, myoglobin, holds oxygen in the muscle and gives the meat a darker color (USDA, 2010).

Table 3 shows the cooking yields of the duck sausages. There were no significant differences ($p>0.05$) in cooking yield among the four treatments. The yields in this study were higher than those of the spent-duck sausages studied by Bhattacharyya et al. (2007). Although that study reported yields of 83-85%, the age of the animal will influence the properties of the final product. However, the results of this study are almost identical to those reported by Garcia-Garcia and Totosaus (2007) who found that the cooking yield of low-sodium sausages formulated with locust bean gum, potato starch and k-carrageenan was within the range of 96.86-97.00%. The cooking yields found in this study are slightly lower than the cooking yields for commercial chicken sausages in Malaysia. Huda et al. (2009) reported that the range of cooking yields for commercial chicken sausage was 99.17 – 102.46%.

Table 3 shows the results of the folding test, a simple and fast method of predicting the textural quality of gel composite products such as sausages and meatballs. The folding test scores in this study ranged from 3.60 - 4.60. Higher folding test scores resulted from the duck sausage formulated with sago flour; formulations with tapioca, wheat and potato flour showed decreasing folding test scores. The potato duck sausage had a lower folding test score because of its softer texture. This is correlated with the lower hardness value of the potato duck sausage (Table 4). The folding test scores in this study are slightly lower than those of commercial chicken sausages in Malaysia. Huda et al. (2009) reported that the folding test score range of commercial chicken sausage was 4.20 – 5.00.

Texture profiles analysis

The texture profile analysis is shown in Table 4; significance differences ($p<0.05$) were found among the samples for all parameters except cohesiveness. Texture profiles are affected by many processing factors such as the type and amount of ingredients, additives, heat treatment and equipment used (Yetim, 2000). Hardness is the most important quality parameter when evaluating the textural properties of sausages (Klettner, 1993). The highest hardness value was produced by wheat flour, followed by

Table 5. Sensory evaluation of duck sausages with different type of flours

Sensory Parameter	Tapioca	Wheat	Sago	Potato
Color	4.5 ± 1.5^{a}	5.0 ± 1.3^{a}	4.3 ± 1.3^{a}	4.3 ± 1.1^{a}
Odor	5.0 ± 1.2^{ab}	5.2 ± 0.9^{ab}	4.7 ± 1.4^{a}	5.6 ± 0.5^{b}
Texture	3.1 ± 1.6^{a}	3.6 ± 1.7^{a}	3.7 ± 1.6^{a}	3.8 ± 1.6^{a}
Juiciness	3.8 ± 1.7^{a}	4.1 ± 1.5^{a}	4.4 ± 1.5^{a}	4.3 ± 1.5^{a}
Oiliness	3.6 ± 1.3^{a}	4.4 ± 1.2^{a}	4.4 ± 1.1^{a}	4.2 ± 1.2^{a}
Taste	3.7 ± 1.3^{a}	4.1 ± 1.5^{ab}	4.7 ± 1.2^{b}	4.4 ± 1.2^{ab}
Overall	3.5 ± 1.4^{a}	4.4 ± 1.5^{ab}	4.5 ± 1.2^{b}	4.2 ± 1.4^{ab}

* Data presented in means ± sd. Different letters in the same rows indicate significant differences ($p<0.05$).

sago, tapioca and potato flours. Similar result were reported by Mohamed et al. (1988); in their study, crackers made from wheat flour were harder to break than crackers made from tapioca flour. In the current study, sausage made with sago flour showed higher values of elasticity and chewiness. The greater elasticity of duck sausage made with sago flour is correlated with the higher folding test score of duck sausage made with sago flour.

The different effects of flour types on the textural properties of sausage are related to the amylose and amylopectin content of each flour as well as their granule size. Mohamed et al. (1988) found that the amylose content and granule size of wheat flour is low when compared with sago and tapioca flour. Cheow et al. (2004) reported that the swelling power, solubility and amylase-leaching of wheat flour were much lower than sago and tapioca flour. Flour with a lower swelling power will not trap as much water in the starch molecule. In the case of cracker production, this will produce a lower degree of linear expansion due to the smaller "air cell" formed during the frying process. In the case of sausage, the smaller "water cell" will probably form a harder texture. The effects of this can be seen in the sample made with wheat flour.

Generally, the textural properties of duck-sausages produced during this study are within the range of the textural properties of chicken sausages. Huda et al. (2009) reported that the range of hardness, springiness, cohesiveness, gumminess and chewiness of commercial chicken sausages is 3.84-7.25 kg, 12.79-15.65 mm, 0.25-0.41 ratio, 1.28–2.58 kg, and 16.81-33.01, respectively.

Sensory evaluation

The sensory evaluation result is shown in Table 5. The scores awarded by the panelists during the sensory test were similar. Different types of flours had no significance affect ($p>0.05$) on the acceptability of color, texture, oiliness and juiciness. However, significantly different responses ($p>0.05$) were given for odor, taste and overall acceptability. Duck-sausages formulated with sago flour had slightly higher scores for taste and overall acceptability. A previous study by Yu and Yeang (1993) also indicated that different types of flour (tapioca, potato and corn) have no effect on the color, flavor and overall acceptability of fish balls. Serdaroglu et al. (2005) also reported similar results for the color and flavor acceptability of meatballs prepared with different flours (black-eyed pea, chickpea, lentil and rusk).

In this study, the panelists awarded around neither like nor dislike (4.00) and like slightly (5.00) of sensory scores for all parameters. The mean scores for color, odor, texture, juiciness, oiliness, taste and overall acceptability were 4.52, 5.12, 3.55, 4.15, 4.15, 4.23 and 4.15, respectively. The panelist fail to awarded higher score (like extremely) to the duck-sausage samples. The lower sensory scores in this study are due to the unfamiliarity of panelist with duck-sausages. Bhattacharyya et al. (2007) reported no differences in the sensory scores for broiler chicken-sausage, spent-hen sausage and spent-duck sausage. The entire samples were able to get higher scores on the sensory parameters.

Conclusion

Based on these results, this study shows that the various types of flours produced different physicochemical effects on the duck sausage. The duck sausages formulated with wheat flour had greater proximate composition values and improved color characteristics. However, duck sausage formulated with sago flour had better gelation properties (as seen in the folding test and elasticity scores) and better scores on the sensory evaluation. It is possible to produce duck sausage, but further research is necessary to improve the sensory acceptability of duck sausage.

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