Physicochemical properties and sensory characteristics of sausage formulated with surimi powder

Palestina Santana · Nurul Huda · Tajul Aris Yang

Revised: 30 July 2013 / Accepted: 8 August 2013 / Published online: 15 August 2013
© Association of Food Scientists & Technologists (India) 2013

Abstract The objectives of this study were to determine the physicochemical properties and sensory characteristics of fish sausage made with 100 % threadfin bream (*Nemipterus japonicus*) surimi powder (SP100), a mix of 50 % surimi powder and 50 % frozen surimi (SP50), and a control (100 % frozen surimi). No significant differences in protein content and folding test results ($P>0.05$) were detected among the SP100 and SP50 samples and the control. Gel strength of SP100 was lower ($P>0.05$) than that of the control. The texture profile analysis (TPA) values (hardness, cohesiveness, springiness, and chewiness) of SP100 were significantly lower ($P<0.05$) than those of the control. However, the TPA values of SP100 and SP50 were still within the textural range of Malaysian commercial fish sausages. The water holding capacity, and emulsion stability of SP100 were significantly lower ($P<0.05$) than those of SP50 and the control. Of the cooking properties measured, SP100 had lower ($P<0.05$) cooking yield, moisture retention, and fat retention than the control. Quantitative descriptive analysis (QDA) performed by 12 trained panelists showed that sensory characteristic (hardness, cohesiveness, springiness, and chewiness) scores of SP100 were lower than those of SP50 and the control. The use of surimi powder in fish sausage did not differ with that of control in the term of color, odor, or oiliness scored by panelists. The drying process impacted the texture properties of surimi when it was used in fish sausage. However, the use of surimi powder in fish sausage formulation is still accepted since the TPA values of SP100 and SP50 were still within the textural range of Malaysian commercial fish sausages.

Keywords Fish protein · Sausage · Surimi powder · Physicochemical properties · Sensory characteristics

P. Santana · N. Huda (✉) · T. A. Yang
Fish and Meat Processing Laboratory, Food Technology Programme,
School of Industrial Technology, Universiti Sains Malaysia,
Minden 11800, Penang, Malaysia
e-mail: nrlhd@usm.my

Introduction

Surimi is defined as concentrated myofibrillar protein extracted from fish flesh by washing minced meat and mixing it with a cryoprotectant (Okada 1992). This mixture is then frozen and stored at -25°C or below (Matsumoto and Noguchi 1992). Surimi is used in a variety of seafood products, such as the traditional Japanese *kamaboko*. Since last three decades, the surimi industry has expanded from Japan into the United States, Korea, and Southeast Asia (Park and Lin 2005).

Surimi still needs to be kept in -25°C or below during shipping (Toyoda et al. 1992). This frozen condition of storage and distribution costs are high. In addition, surimi also has moisture content up to 83 % which needs high cost for handling, distribution, and space to store (Parvathy and Sajan 2011). Meanwhile, surimi powder (the dried form of surimi) does not require frozen storage, which lowers the distribution and storage costs relative to frozen surimi. Surimi powder also offers advantages such as ease of handling and the ability to be used in dry mix applications (Niki et al. 1992).

The physicochemical properties of surimi powder have been investigated previously, as has optimization of the drying process (Niki et al. 1992; Huda et al. 2001a; Shaviklo et al. 2010b). The nutritional value and physicochemical properties of surimi powder make it ideal for producing formulated seafood and other food products (Park and Lin 2005). Since the 1990s, researchers have focused on the application of surimi powder in food products, including rice-fish snacks (Gogoi et al. 1996), fish crackers (Huda et al. 2001b), fish balls (Huda et al. 2003), corn-fish snacks (Shaviklo et al. 2010a), and fish cutlet mixes (Shaviklo et al. 2011).

Fish sausage is a fish product for which gelling properties are important characteristics. Surimi powder has high gel

strength and excellent bending capacity (Niki et al. 1992), thus it may be an ideal raw material for fish sausage. However, the application of surimi powder in fish sausage has not been studied previously. In this study the physicochemical properties and sensory characteristics of fish sausage formulated with threadfin bream fish (*Nemipterus japonicus*) surimi powder were evaluated.

Materials and methods

Surimi powder preparation

Surimi powder was prepared according to the method used by Huda et al. (2001a). Briefly, frozen surimi blocks made from threadfin bream, which contained 6 % sucrose and 0.3 % phosphate as cryoprotectants, were produced by a local surimi manufacturer located in Kedah, Malaysia. The frozen blocks were transported by refrigerated truck to the laboratory and stored at -18°C . Sliced frozen surimi pieces ($20 \times 1 \times 10$ cm) then were freeze-dried (Labconco FreezeDry system, Kansas City, MO, USA) at a pressure of 0.050 mmHg in the chamber at a condensing plate temperature of -40°C for 72 h until the moisture content reached 5 %. Each piece of surimi was milled using a miller (Huitm, Selangor, Malaysia) for 10 s and then sieved using a 28-mm screen mesh. The surimi powder then was vacuum packed (Audionvac VMS 133, Hogeweyselaan, The Netherlands) and kept at 6°C for sausage preparation.

Fish sausage preparation

The materials and preparation procedures used to make fish sausage are described in Dincer and Cakli (2010) and Raju et al. (2003) with slight modification. Three batches of fish sausage were made: sausages formulated with 100 % surimi powder (SP100), sausages made of a mixture of 50 % surimi powder and 50 % frozen surimi (SP50), and control sausages formulated with 100 % frozen surimi. Two 1 kg portions of each batch type were produced. The experiments were replicated twice.

Frozen surimi blocks were thawed overnight at 6°C and then chopped in a cutter mixer (Robot Coupe BLIXER 3, Burgundy, France) with all of the other ingredients listed in Table 1. This material was used to make the control sausages and part of the SP50 sausages. Cold water was added to surimi powder until the moisture content of the rehydrated surimi powder was similar to that of frozen surimi blocks ($\pm 76\%$). Salt was added to the mixture to extract myofibrillar protein, then ice, sugar, spices, cooking oil, and tapioca starch were added (Table 1). For each type of sausage, the mixture was

Table 1 Formulations of fish sausage preparations

Materials	Formula (g/1,000 g)		
	Control	SP50	SP100
Frozen surimi (moisture content 76 %)	650	325	0
Surimi powder (moisture content 5 %)	0	82.1	164.2
Cold water (for rehydrating surimi powder)	0	242.9	485.8
Potato starch	50	50	50
Soy oil	50	50	50
Salt	20	20	20
Sugar	10	10	10
Garlic powder	11	11	11
White pepper powder	7.5	7.5	7.5
Monosodium glutamate	1.5	1.5	1.5
Ice	200	200	200

SP50: formulation of sausage using surimi powder: frozen surimi=50:50;
SP100 formulation of sausage using 100 % surimi powder

stuffed into 2.5 cm diameter casings using a stuffer (Mainca, Barcelona, Spain). Sausages were steamed in a steamer (Kerres CS350, Backnang, Germany) at $90 \pm 3^{\circ}\text{C}$ until their internal temperature reached 75°C (measured using a thermocouple probe) and held for 30 min. The steamed sausages were promptly cooled in ice water for 15 min and then vacuum-packed.

For each sausage type, a ~ 300 g sample of one of the 1 kg portions was directly analyzed for physicochemical properties. The rest of the sample was blast frozen (Irinox, Carbanese, Italy) and stored at -18°C until analyzed for proximate composition, cooking properties, and sensory characteristics. The second 1 kg portion of sausage batter was not stuffed into casing or steamed; it was used to analyze the water holding capacity (WHC) and emulsion stability (= % total expressible fluid/TEF) of the batter.

Proximate composition

Proximate composition of the sausages was measured using the steamed sausage samples following standard procedures of the Association of Official Analytical Chemists (AOAC 2000).

Folding test (FT)

The FT was conducted according to Lanier (1992). A sausage was cut into 3 mm thick slices. The slices were folded slowly to observe the way in which they broke. They were graded as follows: (1) breaks by finger pressure, (2) cracks immediately when folded in half, (3) cracks gradually when folded in half,

(4) no cracks showing after folding in half, and (5) no cracks showing after folding twice.

Gel strength

Gel strength was measured using a texture analyzer (TA-XT plus, Stable Micro Systems, Surrey, UK) according to method of Supavititpatana and Apichartsrangkoon (2007) with slight modification. Sausages were cut into 2.5 cm thick slices. A slice was placed horizontally on the platform and then was penetrated by a spherical probe (type P/0.25) at a constant 1 mm/s rate until 11 mm depth was reached. The trigger force used was 5 g, with 1 mm/s of pre-test speed and 10 mm/s of post-test speed. The load cell capacity of the texture analyzer was 5 kg, and the return distance was 35 mm. Gel strength (g mm) was calculated by multiplying the penetration force (g) by with distance of the penetration (mm).

Texture profile analysis (TPA)

Texture profile analysis (TPA) followed the procedure described by Hayes et al. (2005). Hardness, cohesiveness, springiness, and chewiness were measured using a texture analyzer (TA-Hdi, Stable Micro Systems) and a 25 kg load cell. Sausages were cut into 2.5 cm thick slices. A slice was placed horizontally on the platform and then compressed by a compression platen (P.75) at a constant 1 mm/s rate. The trigger force used was 10 g for 2 s, with 3 mm/s of pre-test speed and post-test speed, and the return distance was 35 mm. Hardness was defined by peak force required for first compression. Cohesiveness was calculated as the ratio of the area under the curve of second compression to the area under the curve of first compression. Springiness was defined as a ratio of distance of the second area at second compression and the first area at first compression. Chewiness was calculated by multiplying hardness, cohesiveness, and springiness. TPA was measured in triplicate for each batch from two replicates experiment trials.

Color analysis

Color was analyzed following Supavititpatana and Apichartsrangkoon (2007) using a colorimeter (Minolta

Spectrophotometer, Model CM-3500d, Osaka, Japan). L^* (lightness), a^* (redness), and b^* (yellowness) were measured in triplicate for the inner part of the sausages. Color also was measured for frozen surimi and rehydrated surimi powder. Whiteness was calculated using the following equation (1) from Lanier (1992):

$$\text{Whiteness} = 100 - \left[(100 - L^*)^2 + a^{*2} + b^{*2} \right]^{1/2}.$$

Water holding capacity (WHC)

WHC was measured according to the method of Lin and Huang (2003) with slight modification. Approximately 5 g of homogenized raw emulsion of sausage (exact weight recorded) were placed in a 50 ml centrifuge tube, to which 10 ml of distilled water were added. The mixture was centrifuged (Heraeus Multifuge X1R, Thermo Electron LED GmbH, Osterode, Germany) at 2,000 g at 15 °C for 10 min. The supernatant was decanted and the final sample weight was determined. WHC was calculated as following equation (2):

$$\text{WHC} = \frac{\text{final sample weight} - \text{original sample weight}}{\text{original sample weight}}$$

Emulsion stability (% TEF)

The emulsion stability was measured following the method of Hughes et al. (1997), which involves determining the percentage of total expressible fluid (% TEF). Approximately 25 g (exact weight recorded) of the raw emulsion of sausage was placed in a centrifuge tube and centrifuged (Heraeus Multifuge X1R) for 1 min at 3,600 g. The sample was heated in a water bath (Wisebath® fuzzy control system, Daihan Scientific, Seoul, South Korea) for 30 min at 70 °C and then centrifuged for 3 min at 3,600 g. The pelleted sample was removed and weighed. The volumes of TEF was calculated as following equation (3):

$$\text{TEF} = (\text{weight of centrifuge tube and sample}) - (\text{weight of centrifuge tube and pellet})$$

$$\% \text{TEF} = \frac{\text{TEF}}{\text{Sample weight}} \times 100$$

Cooking yield (CY), moisture retention (MR) and fat retention (FR)

CY, MR, and FR of the finished products were measured according to Murphy et al. (1975). A sausage was cut into slices about 5 cm thick, and then slices were

boiled for 4 min at 90 °C in a waterbath (Wisebath® fuzzy control system) until the internal temperature reached 75 °C. CY represents the percentage of sausage weight compared to the original weight before boiling. FR shows the percentage of fat retained after boiling. CY and FR were calculated as following equation (4):

$$CY(\%) = \frac{\text{Boiled sausage weight}}{\text{Unboiled sausage weight}} \times 100$$

$$FR(\%) = \frac{(\text{Boiled weight}) \times (\% \text{fat in boiled sausage})}{(\text{Unboiled sausage weight}) \times (\% \text{fat in boiled sausage})} \times 100$$

The MR value represents the percentage of moisture retained in the sausage after cooking and was determined as following equation (5):

$$MR(\%) = \frac{CY \times (\% \text{moisture in boiled sausage})}{100}$$

Sensory analysis

Quantitative Descriptive Analysis (QDA) was used to perform the sensory analysis of the sausages using a descriptive scaling and presented with a spider web following Stone and Sidel (1985) and Powers (1984). Out of 60 potential panelists consisting of undergraduate students, post-graduate students, and postdoctoral fellows at Universiti Sains Malaysia, the 12 panelists were selected through prescreening questionnaires, acuity tests (visual scaling exercise), duo-trio test, a ranking screening test for solid oral texture attributes, and interviews following Meilgaard et al. (1999). Those panelists were categorized as semi-trained panelist since they had relatively little experience in evaluating fish sausage (Chambers et al. 1981). The selected panelists were trained for 18 h in the sensory evaluation laboratory. The panel leader facilitated the panelists to develop the terminology and how to use descriptive scaling. The panelists participated in six practice sessions. The attributes and the list of sensory vocabulary from the panel training are presented (Table 2). This sensory vocabulary was used to describe the intensity of each attribute for a given sample using an unstructured scale (0 to 150). Similar selection, training, attributes, and evaluation procedures were reported for analyzing duck meat balls (Nurkhoeriyati et al. 2011).

Prior to QDA, samples were thawed for 3 h at room temperature and then boiled (90 °C) for 4 min (internal temperature 75 °C). Each sample consisted of two of 1.5 cm sausage slices that each was labeled with a 3-digit random

number code. For a given test, three randomized samples were presented on a tray to panelists who were situated in individual booths. Water was provided between samples to cleanse the palate. Samples were evaluated for the four TPA attributes of hardness, springiness, chewiness, and cohesiveness. Samples were also evaluated for whiteness, fish flavor, juiciness, and oiliness. Sensory evaluation was conducted on duplicates for each treated samples and control.

Statistical analysis

SPSS software (SPSS 17.0 for Windows, SPSS Inc, Chicago, IL, USA) was used to evaluate the data. All analyses were

Table 2 Sensory vocabulary for analysis of cooked sausages

Sensory attribute	(0–150)		General definitions
Whiteness	Dark brown	White	Inner part: Is the color white or dark?
Fish flavor	None	Very strong	Cooked threadfin bream fish flavor
Springiness	No recovery	Very springy	Degree to which sample returns to its original shape
Chewiness	None	Much	How many chews are needed until the sausage is ready to be swallowed?
Hardness	None	Much	Hardness in the first bite
Cohesiveness	Little	Much	Little: easy to take apart in the first bite
Juiciness	Dry	Juicy	The sensation after 5 times chewing: dry (sample draws liquid from mouth) or juicy (samples give away liquid)
Oiliness	None	Much	The sensation after 5 times chewing: none (no oil expressed from sample) or very oily

performed in triplicate and all experiments were replicated twice. Analytical variation was established through one way analysis of variance (ANOVA). Data are reported as mean $\pm$ standard deviation. The QDA data was converted to be spider web by using Microsoft Excel.

Results and discussion

Proximate composition

Table 3 shows the proximate compositions of the SP100, SP50, and control samples. Moisture was the main component in fish sausage, followed by carbohydrate, protein, fat, and ash. There was no significant difference ($P>0.05$) in moisture, protein, fat, ash, and carbohydrate content among the SP100, SP50, and control samples. The process of rehydrating the surimi powder was done properly, as the moisture content of all formulations was similar (67.21–67.43 %). Protein content of the SP100, SP50, and control samples was 12.60–12.75 %. The protein content of the fish sausages prepared in this study was higher than that of other Malaysian commercial fish sausages (8.18–10.77 %) reported by Huda et al. (2012).

Fat content of the SP100, SP50, and control samples was 4.07–4.12 %, which is within the range (0.93–6.53 %) reported for other Malaysian commercial fish sausage (Huda et al. 2012). Ash content of the SP100, SP50, and control samples was 2.52–2.56 %. Salt likely is the main ingredient contributing to the ash content. Carbohydrate content in the SP100, SP50, and control samples was 13.35–13.53 %. The sugar and tapioca starch that were added to the formulation contributed to the amount of carbohydrate in the samples. The addition of starch is very important because it is a functional ingredient that helps to form the network structure of surimi-starch gels (Park and Lin 2005).

Texture

Table 4 presents the FT, gel strength, and TPA results. In the folding test, the SP100, SP50, and control samples showed no cracks after folding twice (grade 5), which suggests that the

use of surimi powder in fish sausage formulations can produce a good quality sausage. Similar results were reported for fish balls formulated with surimi powder (Huda et al. 2003). The FT results in this study were better than those for fish sausage prepared from hake (*Merluccius capensis*), which had folding grade 3 (Cardoso et al. 2008). FT also can be used to distinguish differences in gel cohesiveness (Lanier 1992). It corresponds to the cohesiveness value of the SP100, SP50, and control samples, which was 0.29–0.31. However, the FT result does not represent the entire textural profile of samples (Huda et al. 2003). To evaluate the texture of samples, gel strength and TPA were measured.

Physical gel properties or gel strength can be evaluated to determine the gelation properties of surimi powder. Gel strength of the SP100, SP50, and control samples varied significantly ($P<0.05$). The control samples had the highest gel strength (2492.56 g mm), followed by the SP50 samples (2168.66 g mm) and the SP100 samples (1784.98 g mm). Raju et al. (2003) reported that fish sausage made from threadfin bream minced meat had a gel strength 2,450 g mm. The low gel strength of the SP100 samples likely is related to the denaturation of myosin and actomyosin, which are responsible for gelation properties, that occurs during the drying process. However, the gel strength of the SP100 samples is still considered to be good for fish sausage. In comparison, fish sausage prepared from hake had a gel strength of $\sim$ 1,805 g mm (Cardoso et al. 2008). The rheological properties of freeze dried surimi powder stored at 2 °C was reported to have quite similar rheological properties with conventional frozen surimi in 1, 3 and 6 months but higher after 18 months of storage (Reynolds et al. 2002). Thus, it is possible that the application of surimi powder in sausage would produce texture quality as good as frozen surimi in same period of storage.

Hardness values exhibited a significant ($P<0.05$) decreasing trend with increasing surimi powder content. The protein content is responsible for the hardness, as rheological parameters are strongly influenced by protein concentration in processed muscle foods such as sausage (Colmenero et al. 1995). However, because there was no significant difference in protein content among the SP100, SP50, and control samples ($P>0.05$), the structure of the raw material likely was the

Table 3 Proximate composition of control, SP50, and SP100 samples

Samples	Control	SP50	SP100
Moisture (%)	67.21 $\pm$ 0.28 ^a	67.27 $\pm$ 0.20 ^a	67.43 $\pm$ 0.39 ^a
Protein (dry basis) (%)	12.62 $\pm$ 0.10 ^a (38.45 $\pm$ 0.04 ^a)	12.75 $\pm$ 0.03 ^a (38.97 $\pm$ 0.33 ^a)	12.60 $\pm$ 0.42 ^a (38.69 $\pm$ 1.77 ^a)
Fat (dry basis) (%)	4.12 $\pm$ 0.01 ^a (12.55 $\pm$ 0.14 ^a)	4.07 $\pm$ 0.09 ^a (12.42 $\pm$ 0.35 ^a)	4.10 $\pm$ 0.07 ^a (12.60 $\pm$ 0.05 ^a)
Ash (dry basis) (%)	2.52 $\pm$ 0.02 ^a (7.69 $\pm$ 0.01 ^a)	2.56 $\pm$ 0.02 ^a (7.81 $\pm$ 0.01 ^a)	2.52 $\pm$ 0.03 ^a (7.72 $\pm$ 0.08 ^a)
CHO (dry basis) (%)	13.53 $\pm$ 0.17 ^a (41.27 $\pm$ 0.18 ^a)	13.35 $\pm$ 0.30 ^a (40.80 $\pm$ 0.67 ^a)	13.35 $\pm$ 0.74 ^a (40.99 $\pm$ 1.79 ^a)

SP50: formulation of sausage using surimi powder: frozen surimi=50:50; SP100 formulation of sausage using 100 % surimi powder. Means in each row with different superscript letters are significantly different at $P<0.05$. Values shown are averages of triplicates analysis on duplicates sausage productions

Table 4 Folding test, gel strength, and texture profile analysis of control, SP50, and SP100 samples

Samples	Control	SP50	SP100
Folding test	5±0.00 ^a	5±0.00 ^a	5±0.00 ^a
Gel strength (g.mm)	2492.56±6.39 ^a	2168.66±15.94 ^b	1784.98±4.03 ^c
Hardness (g)	5843.80±6.51 ^a	5033.10±20.79 ^b	4137.90±12.30 ^c
Cohesiveness (ratio)	0.31±0.00 ^a	0.31±0.01 ^a	0.29±0.00 ^b
Springiness (ratio)	0.32±0.01 ^a	0.29±0.01 ^b	0.26±0.00 ^c
Chewiness (g)	570.38±6.81 ^a	454.39±19.17 ^b	321.76±3.71 ^c

SP50: formulation of sausage using surimi powder: frozen surimi=50:50; SP100 formulation of sausage using 100 % surimi powder. Means in each row with different superscript letters are significantly different at $P < 0.05$. Values shown are averages of triplicates analysis on duplicates sausage productions

main factor contributing to the observed differences in sample hardness. The SP100 samples had lower hardness (4137.90 g) because surimi in the powdered form was less hard compared to frozen surimi in the controls. Freeze-dried surimi powder has an amorphous matrix due to the loss of liquid material during drying, which causes a collapse in structure and softening of the matrix (Lanier 1992). Previous studies reported that Malaysian commercial fish sausage had a hardness of about 3,280–5,670 g (Huda et al. 2012), so the hardness of the SP100 and SP50 samples in the present study were within the range reported for Malaysian commercial fish sausage.

There was no significant difference ($P < 0.05$) in cohesiveness and springiness between control and SP50 samples. This suggests that replacement of frozen surimi with up to 50 % surimi powder did not affect the degree to which the sample held together in a mass. However, the SP100 samples were significantly lower ($P < 0.05$) in cohesiveness and springiness compared with the control and SP50 samples. In the current study, the springiness and chewiness values of the SP100 and SP50 samples were within the range (0.28–0.42 mm and 14,520–44,180 g mm, respectively) reported for Malaysian commercial fish sausage (Huda et al. 2012).

Colour

L^* , a^* , and b^* values are presented in Table 5. There was no significant difference ($P > 0.05$) in L^* , b^* , and whiteness values among the SP100, SP50, and control samples. However, the a^* value of the SP100 samples was higher than those of the control and SP50 samples. The higher a^* value indicates that the SP100 samples were more red in color. However, this higher a^* value of the SP100 samples did not influence its whiteness, as whiteness did not differ significantly among the sample types ($P > 0.05$). This data indicates that drying process may affect the redness value of surimi. Factor such as mixing fish flesh with cryoprotectants, drying method, drying temperature and lipid oxidation may affect the color of the surimi powder (Shaviklo et al. 2010b). The study reported by Reynolds et al. (2002) found that freeze dried surimi stored at 2 °C and 22 °C had lower whiteness around 18–28 points than conventional frozen surimi after 9 months of storage. However, the storage of freeze-dried surimi at −18 °C could maintain the color characteristics of surimi powder during storage (Reynolds et al. 2002).

The whiteness of the SP100, SP50, and control samples was 69.68–70.05, which is lower than that of fish sausage made from hake (75.1) (Cardoso et al. 2008). Previous studies indicate that Malaysian commercial fish sausages have variable color characteristics (e.g., L^* =58.73–79.56, a^* =−0.58–17.43, and b^* =12.69–22.96) (Huda et al. 2012). The values measured in this study were within these ranges.

WHC, emulsion stability (% TEF), CY, MR, and FR

Table 6 lists the WHC, emulsion stability, CY, MR, and FR of SP100, SP50, and control samples. The WHC is important for the formation of gels and emulsions. WHC of the control (1.13 g water/g sample) was significantly higher ($P < 0.05$) than that of the SP50 (1.09 H₂O/g sample) and SP100 (1.05 H₂O/g sample) samples. These results clearly show that the SP100 samples, which consisted of 100 % surimi powder, had a lower ability to hold water compared to the control, which contained 100 % frozen surimi. The loss of water that occurs during drying leads to the aggregation of protein (Lanier

Table 5 Color characteristics and pH of control, SP50, and SP100 samples and frozen surimi and rehydrated surimi powder

Samples	Control	SP50	SP100	Frozen surimi	Rehydrated surimi powder
L^*	72.03±0.62 ^a	72.11±0.80 ^a	72.25±0.42 ^a	75.36±0.03 ^b	76.01±1.23 ^b
a^*	0.02±0.00 ^b	0.02±0.14 ^b	0.16±0.07 ^a	−1.63±0.01 ^d	−0.97±0.01 ^c
b^*	10.68±0.30 ^{bc}	10.60±0.04 ^{bc}	12.17±0.70 ^{ab}	9.50±0.02 ^c	13.18±0.31 ^a
Whiteness	70.05±0.48 ^b	70.15±0.74 ^b	69.68±1.06 ^b	72.67±1.14 ^a	71.22±1.76 ^a

SP50: formulation of sausage using surimi powder: frozen surimi=50:50; SP100 formulation of sausage using 100 % surimi powder. Means in each row with different superscript letters are significantly different at $P < 0.05$. Values shown are averages of triplicates analysis on duplicates sausage productions

Table 6 WHC, emulsion stability (%TEF), CY, MR and FR of control, SP50, and SP100 samples

Samples	Control	SP50	SP100
WHC (g H ₂ O/ g sample)	1.13±0.00 ^a	1.09±0.01 ^b	1.05±0.01 ^c
Emulsion Stability (%TEF)	0.59±0.01 ^c	0.77±0.01 ^b	0.88±0.04 ^a
CY(%)	98.81±0.19 ^a	97.81±0.12 ^b	95.04±0.05 ^c
MR(%)	66.95±0.20 ^a	65.91±0.34 ^b	63.51±0.12 ^c
FR(%)	44.22±0.16 ^a	42.88±0.67 ^a	39.23±0.73 ^b

SP50: formulation of sausage using surimi powder: frozen surimi=50:50; SP100 formulation of sausage using 100 % surimi powder. Means in each row with different superscript letters are significantly different at $P < 0.05$. Values shown are averages of triplicates analysis on duplicates sausage productions

1992). This aggregation causes the proteins to lose their three-dimensional structure, which results in irreversible denaturation and thus to the loss of WHC.

Emulsion stability is one of the most important attributes of sausage. There were significant differences ($P > 0.05$) in % TEF among the SP100, SP50, and control samples. The SP100 samples had a significantly higher ($P < 0.05$) % TEF (0.88 %) than the SP50 (0.77 %) and control (0.59 %) samples. This means that the use of surimi powder in the sausage formulation decreased the emulsion stability of the sausage due to the higher amount of fluid that can be expressed. This result agreed with the lower WHC measured for the SP100 samples compared to the control samples. The higher % TEF suggested that the SP100 samples had lower emulsion stability compared to the other sample types.

These higher values in the SP100 samples might be related to the functional properties of surimi powder itself. The WHC and emulsion stability of surimi powder are lower than those

of frozen surimi. The drying process used to produce surimi powder causes protein denaturation (Carjaval et al. 2005). Even though the freeze drying process is considered to be the most suitable for inhibiting protein denaturation compared to other drying methods because it occurs at a low temperature, denaturation still occurs, as shown by the lower WHC and higher % TEF by the SP100 samples.

All of the physicochemical properties described above correspond to the CY. CY of the control (98.80 %) samples was significantly higher ($P < 0.05$) than those of the SP50 (97.80 %) and SP100 (95.05 %) samples. During boiling, water and fat likely were released from the sausage matrix. This premise is supported by the decreased MR and FR of sausage after boiling as the proportion of surimi powder increased. The highest MR was found in the control (66.94 %) and the lowest in the SP100 (63.51 %) samples. The FR of the control (44.22 %) was significantly higher ($P < 0.05$) than those of the SP50 (42.88 %) and SP100 (39.23 %) samples. This result shows that during boiling, the SP100 samples lost more fat than the control samples. The lower MR of the SP100 samples is confirmed by the lower WHC of the SP100 compared with the control samples. These properties are clearly related to the denaturation of surimi powder protein during the drying process, which leads to the loss of functional properties such as WHC and emulsion stability.

Sensory evaluation

Figure 1 presents the sensory QDA of SP100, SP50, and control samples in a spider web. Panelists reported that the different sample type did not differ in terms of whiteness, fish flavor, and oiliness. This suggests that fish sausage formulated with surimi powder did not affect the color, odor, or oiliness of

Fig. 1 Spider web for quantitative descriptive analysis of control, SP50, and SP100 samples

the sausage. The spider web showed that hardness, springiness, chewiness and cohesiveness tended to decrease from the control to the SP50 to the SP100 samples. Because the protein content of the SP100, SP50, and control samples did not differ significantly ($P > 0.05$), these texture changes were not influenced by the protein content. Instead, the textural attributes may have been affected by the quality of the protein, as freeze-dried surimi powder contains denatured protein due to the drying process. This premise is supported by the gel strengths of the samples: Fish sausage formulated with surimi powder (SP100 and SP50) had lower gel strength than fish sausage formulated with frozen surimi (control). In contrast, the juiciness of the SP100 samples was higher than that of the SP50 and control samples. This result corresponds with the lowest water retention of SP100 among other samples, which means the water in SP100 tends to be released easier than other samples, thus resulting to the higher of juiciness. The presence of surimi powder in the SP100 and SP50 formulations increased the juiciness of the sausage. The characteristic of raw material is likely influenced the texture of final product. The different of texture detected in a QDA by a trained panelist on smoked salmon with salt replacement as reported by Almli and Hersleth (2012). This can be related due to the similar protein content among sausages. However, different treatment would effect the texture of final product.

This result suggests that the use of surimi powder in fish sausage would decrease the hardness, cohesiveness, springiness, and chewiness of the product. In other words, replacement of frozen surimi with rhydrated surimi powder would soften the texture of fish sausage. Drying process in making surimi powder could caused denaturation of protein as well as freezing process which occurs in storing frozen surimi, due to the aggregation of protein when water removed out from the matrix (Carjaval et al. 2005). Nevertheless, the data indicated that the drying process impacted the texture properties of surimi when it was used in fish sausage.

Conclusion

The use of surimi powder in the fish sausage formulation resulted in FT at grade 5 as well as FT of control. TPA results showed that SP100 and SP50 samples had lower hardness, cohesiveness, springiness, and chewiness than the control. However, the textural properties of SP100 and SP50 samples and the control were still within the textural range of Malaysian commercial fish sausages. WHC, emulsion stability, CY, MR, and FR of SP100 and SP50 samples were also lower than those of the control. These results are possibly due to the denaturation of proteins in surimi powder caused by the drying process. Sensory evaluation revealed that SP100 and SP50 samples and the control did not differ in color, odor, and oiliness. These results indicate that surimi powder is a useful

and acceptable raw material for producing sausage on a commercial scale. Further study is needed to determine the acceptable percentage of surimi powder to replace frozen surimi in sausage in order to have a comparable characteristics of sausage with that of sausage from frozen surimi.

Acknowledgments The authors acknowledge with gratitude the support given by Universiti Sains Malaysia for our research in this area and the aid of a research grant from the MALAYAN SUGAR MANUFACTURING COMPANY BERHAD.

References

- Almli V, Hersleth M (2012) Salt replacement and injection salting in smoked salmon evaluated from descriptive and hedonic sensory perspectives. *Aquac Int*, in press. doi: [10.1007/s10499-012-9615-4](https://doi.org/10.1007/s10499-012-9615-4)
- Association of Official Analytical Chemists (AOAC) (2000) *Methods of analysis*, 17th edn. AOAC, Gaithersburg
- Cardoso C, Mendes R, Nunes ML (2008) Development of a healthy low-fat fish sausage containing dietary fibre. *Int J Food Sci Technol* 43:276–283. doi:[10.1111/j.1365-2621.2006.01430.x](https://doi.org/10.1111/j.1365-2621.2006.01430.x)
- Carjaval PA, Lanier TC, Macdonald GA (2005) Stabilization of protein in surimi. In: Park JW (ed) *Surimi and surimi seafood*, 2nd edn. CRC Press, Boca Raton, FL, pp 163–213
- Chambers E IV, Bowers JA, Dayton AD (1981) Statistical designs and panel training/experience for sensory analysis. *J Food Sci* 46:1902–1906. doi:[10.1111/j.1365-2621.1981.tb04515.x](https://doi.org/10.1111/j.1365-2621.1981.tb04515.x)
- Colmenero FJ, Barreto G, Mota N, Carballo J (1995) Influence of protein and fat content and cooking temperature on texture and sensory evaluation of bologna sausage. *Lebensm-Wiss u-Technol* 28:481–487. doi:[10.1006/fstl.1995.0081](https://doi.org/10.1006/fstl.1995.0081)
- Dincer T, Cakli S (2010) Textural and sensory properties of fish sausage from rainbow trout. *J Aquat Food Prod Technol* 19:238–248. doi:[10.1080/10498850.2010.509539](https://doi.org/10.1080/10498850.2010.509539)
- Gogoi BK, Oswalt AJ, Choudhury GS (1996) Reverse screw elements and feed composition effects during twin-screw extrusion of rice flour and fish muscle blends. *J Food Sci* 3:590–595. doi:[10.1111/j.1365-2621.1996.tb13165.x](https://doi.org/10.1111/j.1365-2621.1996.tb13165.x)
- Hayes JE, Desmond EM, Troy DJ, Buckley DJ, Mehra R (2005) The effect of whey protein-enriched fractions on the physical and sensory properties of frankfurters. *Meat Sci* 71:238–243. doi:[10.1016/j.meatsci.2005.03.005](https://doi.org/10.1016/j.meatsci.2005.03.005)
- Huda N, Abdullah A, Babji AS (2001a) Functional properties of surimi powder from three Malaysian marine fish. *Int J Food Sci Technol* 36:401–406. doi:[10.1046/j.1365-2621.2001.00473.x](https://doi.org/10.1046/j.1365-2621.2001.00473.x)
- Huda N, Abdullah A, Babji AS (2001b) Substitution of tapioca flour with surimi powder in traditional crackers. Paper presented In: 16th Scientific Conference Nutrition Society of Malaysia, Kuala Lumpur, March 24–25, p 6
- Huda N, Abdullah A, Mustapha WAW, Babji AS (2003) Penggunaan tepung surimi dalam formulasi bebola ikan. *Sains Malaysiana* 32:27–38, ISSN: 0126–6039
- Huda N, Alistair TLJ, Lim HW, Nopianti R (2012) Some quality characteristics of Malaysian commercial fish sausage. *Pak J Nutr* 11(8):700–705. ISSN 1680–5194
- Hughes E, Cofrades S, Troy DJ (1997) Effects of fat level, oat fibre and carrageenan on frankfurters formulated with 5, 12 and 30 % fat. *Meat Sci* 45:273–281. doi:[10.1016/S0309-1740\(96\)00109-X](https://doi.org/10.1016/S0309-1740(96)00109-X)
- Lanier TC (1992) Measurement of surimi composition and functional properties. In: Lanier TC, Lee CM (eds) *Surimi technology*. Marcel Dekker Inc, New York, pp 123–163

- Lin KW, Huang HY (2003) Konjac/gellan gum mixed gels improve the quality of reduced-fat frankfurters. *Meat Sci* 65:749–755. doi:10.1016/S0309-1740(02)00277-2
- Matsumoto JJ, Noguchi SF (1992) Cryostabilization of protein in surimi. In: Lanier TC, Lee CM (eds) *Surimi technology*. Marcel Dekker Inc, New York, pp 357–388
- Meilgaard M, Civille GV, Carr BT (1999) *Sensory evaluation techniques*, 3rd edn. CRC Press, Boca Raton, FL
- Murphy EW, Criner PE, Grey BC (1975) Comparison of methods for calculating retentions of nutrients in cooked foods. *J Agric Food Chem* 23:1153–1157. doi:10.1021/jf60202a021
- Niki H, Matsuda Y, Suzuki T (1992) Dried Forms of Surimi. In: Lanier TC, Lee CM (eds) *Surimi technology*. Marcel Dekker Inc, New York, pp 209–244
- Nurkhoeriyati T, Huda N, Ahmad R (2011) Physicochemical properties and sensory analysis of duck meatballs containing duck meat surimi-like material during frozen storage. *J Food Sci* 71(1):91–98. doi:10.1111/j.1750-3841.2011.02519.x
- Okada M (1992) History of surimi technology in Japan. In: Lanier TC, Lee CM (eds) *Surimi technology*. Marcel Dekker Inc, New York, pp 3–21
- Park JW, Lin TM (2005) Surimi: manufacturing and evaluation. In: Park JW (ed) *Surimi and surimi seafood*. CRC Press, Boca Raton, FL, pp 33–98
- Parvathy U, Sajan G (2011) Influence of cryoprotectant levels on storage stability of surimi from *Nemipterus japonicus* and quality of surimi-based products. *J Food Sci Technol* :1–6. doi: 10.1007/s13197-011-0590-y
- Powers JJ (1984) Current practices and application of descriptive method. In: Piggott JR (ed) *Sensory analysis of foods*. Elsevier App Sci Pub, Barking, Essex, pp 179–242
- Raju CV, Shamasundar BA, Udupa KS (2003) The use of nisin as a preservative in fish sausage stored at ambient (28 ± 2 °C) and refrigerated (6 ± 2 °C) temperatures. *Int J Food Sci Technol* 38:171–185. doi:10.1046/j.1365-2621.2003.00663.x
- Reynolds J, Park JW, Choi YJ (2002) Physicochemical properties of Pacific whiting surimi as affected by various freezing and storage conditions. *J Food Sci* 67(6):2072–2078. doi:10.1111/j.1365-2621.2002.tb09503.x
- Shaviklo GR, Olafsdottir A, Sveinsdottir K, Thorkelsson G, Rafifour F (2010a) Quality characteristics and consumer acceptance of high fish protein puffed corn fish snack. *J Food Sci Technol* 48:668–676. doi:10.1007/s13197-010-0191-1
- Shaviklo GR, Thorkelsson G, Arason S, Kristinsson HG, Sveinsdottir K (2010b) The influence of additives and drying methods on quality attributes of fish protein powder made from saithe (*Pollachius virens*). *J Sci Food Agric* 90:2133–2143. doi:10.1002/jsfa.4062
- Shaviklo GR, Thorkelsson G, Sveinsdottir K, Pourreza, F (2013) Studies on processing, consumer survey and storage stability of ready-to-reconstitute fish cutlet mix. *J Food Sci Technol* 50(3):900–908
- Stone H, Sidel JL (1985) *Sensory evaluation practices*. Academic, Orlando, FL
- Supavititpatana T, Apichartsrangkoon A (2007) Combination effects of ultra-high pressure and temperature on the physical and thermal properties of ostrich meat sausage (yor). *Meat Sci* 76:555–560. doi:10.1016/j.meatsci.2007.01.007
- Toyoda K, Kimura I, Fujita T, Noguchi SF, Lee CM (1992) Surimi manufacturing process. In: Lanier TC, Lee CM (eds) *Surimi technology*. Marcel Dekker Inc, New York, pp 79–166