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The Addition of Hydrocolloids (Carboxymethylcellulose, Alginate and Konjac) to Improve the Physicochemical Properties and Sensory Characteristics of Fish Sausage Formulated with Surimi Powder

Palestina Santana[1], Nurul Huda[1,*], Tajul Aris Yang[1]

[1] Fish and Meat Processing Laboratory, Food Technology Programme, School of Industrial Technology, Universiti Sains Malaysia 11800, Penang Malaysia.

* Corresponding Author: Tel.: +60.4 6532112; Fax: +60.4 6573678;
E-mail: nrlhd@usm.my

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Abstract

Fish sausages were prepared using threadfin bream (*Nemipterus japonicus*) surimi powder, to which 0.5% carboxymethylcellulose (sCMC), 0.5% alginate (ALG), 0.5% konjac (KJC), or no hydrocolloid (SP) was added. A fifth batch was prepared using frozen surimi (FS). The physicochemical properties and sensory characteristics of each sausage type were analyzed. All samples received a grade of 5 in the folding test. However, sCMC, ALG, and KJC had significantly higher ($P<0.05$) hardness, springiness, and cooking yield values than SP. KJC had significantly improved ($P<0.05$) gel strength (2255.42 g mm) compared to that of SP (1784.98 g mm). KJC also had better fat retention than sCMC and ALG. Sensory characteristics were evaluated by 12 trained panelists using a quantitative descriptive analysis (QDA). sCMC, ALG, and KJC scored higher than SP for hardness, cohesiveness, and springiness, but the scores were quite close to those of FS. The addition of CMC, alginate, or konjac did not influence the oiliness, fish flavor, and color of fish sausages. Overall, of the hydrocolloids tested, konjac was the best at improving the physicochemical properties and sensory characteristics of sausage prepared with surimi powder, followed by alginate and CMC

Keywords: Fish sausage, surimi powder, texture, hydrocolloid, QDA.

Introduction

Surimi is a concentrated myofibrial protein extracted from fish flesh by a washing process (Santana *et al.*, 2012), and it needs to be kept frozen (of –23 to –25°C) to maintain its quality (Matsumoto and Noguchi, 1992). Surimi powder, the dry form of surimi, offers many advantages compared to frozen surimi, such as ease of handling, more convenient storage at ambient temperature, and its usefulness in dry mixtures (Green and Lanier, 1985). The drying process can cause protein denaturation due to the aggregation of protein when water is removed from the matrix (Carjaval *et al.*, 2005), but denaturation can be prevented by the addition of sugar and polyols as dryoprotectants (Suzuki, 1981).

The use of surimi powder in friable or snack-based products, such as in snack extrusion (Gogoi *et al.*, 1996), fish crackers (Huda *et al.*, 2001), and corn fish snacks (Shaviklo *et al.*, 2011), has been studied previously. Surimi powder also is a potentially useful raw material for making seafood products such as fish sausage, as long as it retains high gelling and emulsifying properties (Santana *et al.*, 2012). Although the functional properties of surimi powder are not as good as those of frozen surimi, Huda *et al.* (2003) showed that freeze-dried surimi powder from threadfin bream (*Nemipterus japonicus*) is a potentially useful raw material for gel-based products such as fish balls.

Sausage is a product in which meat flesh is mixed with additives, stuffed into suitable casings, and heat processed (Raju *et al.*, 2003). Fish sausage is a product that sausage manufactures have started producing due to changing consumer preferences toward healthier lifestyles and safer and cheaper foods (Panpipat and Yongsawatdigul, 2008; Nowsad and Hoque, 2009). However, scientific results about the application of surimi powder in fish sausage are lacking.

In a previous study about the physicochemical properties and sensory characteristics of sausage formulated with surimi powder, we found that fish sausage containing surimi powder had lower physicochemical properties than fish sausage formulated with frozen surimi due to the denaturation of protein caused by freeze-drying process (Santana *et al.*, 2013). By adding biopolymers possessing gel-forming ability, such as hydrocolloids, it has been possible to develop a large variety of analogues based on modification of the functional and textural properties of surimi (Gómez-Guillén and Montero, 1996).

Hydrocolloids such as carboxymethylcellulose (CMC), alginate, and konjac are already used in beef frunkfurters, sausages, and patties (Lin and Keeton, 1998; Ruusunen *et al.*, 2003; Jiménez-Colmenero *et al.*, 2010). The addition of konjac flour greatly reinforced the shear stress of surimi gels made from Alaska pollock and Pacific whiting (Park, 1996). Andrés-Bello *et al.* (2012) found that the addition of konjac and CMC improved the water holding capacity (WHC) of restructured fish products. The addition of 0.5% alginate to chicken myosin gels increased the WHC up to 40% compared to the same gels without hydrocolloids because of greater entrapment of water by the protein-polysaccharide matrix (Xiong and Blanchard, 1993). However, relatively little is known about the possible interactions of such additives and their effect on the protein network structure of the dried myofibrillar proteins in surimi powder. The goal of this study was to determine if the addition of CMC, alginate, and konjac could improve the physicochemical properties and sensory chacarteristics of fish sausage formulated using surimi powder.

Materials and Methods

Surimi Powder Preparation

Surimi powder was prepared following the method described by Huda *et al.* (2001). Frozen surimi blocks made from threadfin bream, which contained 6% sucrose and 0.3% phosphate as cryoprotectants, were produced by a local surimi manufacturer. The frozen blocks were transported by refrigerated truck to the laboratory and stored at –18°C. Frozen surimi blocks were sliced into 20 x 1 x 10 cm pieces using a meat and bone saw (Powerline, Norwalk, CT, USA). Sliced frozen surimi then was freeze-dried (Labconco FreezeDry system, Kansas City, MOi, USA) at a pressure of 0.050 mm Hg in the chamber and with a condensing plate temperature of –40 °C for 72 h until the moisture content reached 5%. The surimi was milled using a mill (Hui^{TM}, Selangor, Malaysia) for 10 s and then sieved using a 28 mm screen mesh. The surimi powder was vacuum packed (Audionvac VMS 133, Weesp, Netherlands) and kept at 6°C for sausage preparation.

Fish Sausage Preparation

The materials and the preparation procedures for the fish sausage used in this study are described in Dincer and Cakli (2010) and Raju *et al.* (2003). Five different surimi based sausages were produced. Four of them were produced by using surimi powder as a raw material added with 0.5% CMC (sCMC), 0.5% alginate (in sodium alginate form) (ALG), 0.5% konjac (KJC), and no hydrocolloids (SP). Another one batch was produced by using frozen surimi without hydrocolloids (SF). CMC, alginate, and konjac were purchased from a local supplier. For each type of sausage, two 1 kg batches were produced. To make the sausage, frozen surimi blocks were thawed at 6°C overnight and then chopped in a cutter mixer (Robot Coupe BLIXER 3, Burgundy, France) with all of the other ingredients listed in Table 1. Cold water was added to the surimi powder until the water content of rehydrated surimi powder was similar to that of frozen surimi blocks (±76%). Salt was added at the beginning of the process to extract myofibrial protein, followed by the hydrocolloid (for three of the batches), ice, sugar, spices, cooking oil, and tapioca starch. The mixture then was stuffed into 2.5 cm diameter casings using a stuffer (Mainca, Barcelona, Spain). Sausages were steamed in a steamer (Kerres

Table 1. Formulation of the fish sausage preparations

Materials	Formula (%)				
	sCMC	ALG	KJC	SP	FS
Frozen surimi (water content 76%)	0	0	0	0	65
Surimi powder (water content 5%)	16.42	16.42	16.42	16.42	0
Cold water (for rehydrating surimi powder)	48.58	48.58	48.58	48.58	0
Tapioca starch	4.5	4.5	4.5	5	5
Cooking oil	5	5	5	5	5
Salt	2	2	2	2	2
Sugar	1	1	1	1	1
CMC	0.5	0	0	0	0
Alginate	0	0.5	0	0	0
Konjac	0	0	0.5	0	0
Garlic powder	1.1	1.1	1.1	1.1	1.1
White pepper powder	0.75	0.75	0.75	0.75	0.75
Monosodium glutamate	0.15	0.15	0.15	0.15	0.15
Ice	20	20	20	20	20

sCMC= Sausage made with surimi powder and 0.5% CMC, ALG= Sausage made with surimi powder and 0.5% alginate, KJC= Sausage made with surimi powder and 0.5% konjac, SP= Sausage made with surimi powder without hydrocolloid, FS= Sausage made with frozen surimi

CS350, Backnang, Germany) at 90±3 ^oC until the internal temperature reached 75 ^oC (measured by 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 type of sausage, a ~300 g sample was directly analyzed for folding, gel strength, texture profile, and color. The rest of the sample was blast-freezed (Irinox, Carbanese, Italy) and stored in a freezer (–18^{o}C) until analysis for proximate composition, cooking yield, water retention, fat retention, and sensory analysis.

Proximate Composition

Proximate composition of the steamed sausage samples was determined using standard procedures of the Association of Official Analytical Chemists [AOAC] (2000). Moisture content was determined using the oven method, and crude protein content was measured using the Kjedahl method. Fat content was measured with the Soxhlet method, and ash content was determined using the dry ashing method. Carbohydrate content was calculated by difference.

Texture Analyses

Texture analyses consisted of folding test, texture profile analysis (TPA), and gel strength. The folding test 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. TPA was conducted following the procedure described by Hayes *et al.* (2005). The analysis, which included hardness, cohesiveness, springiness, and chewiness, was measured using a texture analyzer (TA-HDi, Stable Micro Systems, Ltd., Surrey, UK) 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 rate of 1 mm/s. 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. Gel strength was measured using a texture analyzer (TA-XT plus, Stable Micro Systems) according to method of Supavititpatana and Apichartsrangkoon (2007). A slice of fish sausage (2.5 cm thickness) was placed horizontally on the platform and then penetrated by a spherical probe (type P/0.25) at a constant rate of 1 mm/s 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 distance of the penetration (mm).

Cooking Yield, Water Retention, and Fat Retention

Cooking yield, water retention, and fat retention were measured according to Murphy *et al.* (1975). Sausages were sliced into ~5 cm sections and then boiled for 4 min at 90 °C in a waterbath (Wisebath® fuzzy control system) until the internal temperature reached 75 ^oC. Cooking yield is the percentage of cooked sausage weight compared to the original weight before cooking. Fat retention is the percentage of fat retained after cooking. Cooking yield and fat retention were calculated using the following equations (1 and 2):

$$\text{Cooking yield (\%)} = \frac{\text{Cooked sausage weight}}{\text{Uncooked sausage weight}} \times 100 \quad \text{(Eq. 1)}$$

$$\text{Fat retention (\%)} = \frac{(\text{Cooked weight}) \times (\%\text{fat in cooked sausage})}{(\text{Raw weight}) \times (\%\text{fat in raw sausage})} \times 100 \quad \text{(Eq. 2)}$$

The water retention value represents the percentage of moisture retained in the sausage after cooking, and it was determined using the following equation (3):

$$\text{Water retention (\%)} = \frac{\text{Cooking Yield} \times (\%\text{moisture in cooked sausage})}{100} \quad \text{(Eq. 3)}$$

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) of the inner part of sausages were measured in triplicate. Whiteness was calculated using the following equation (4) from Lanier (1992):

$$\text{Whiteness} = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2}. \quad \text{(Eq. 4)}$$

Sensory Analysis

Quantitative descriptive analysis (QDA) was used to perform the sensory analysis of the sausages using a descriptive scaling system, and data are presented in a spider web format following Stone and Sidel (1985) and Powers (1984). Out of 60 potential panelists consisting of undergraduate students, post-graduate students, and post-doc fellows at Universiti Sains Malaysia, 12 panelists were selected through prescreening questionnaires, acuity tests (visual scaling exercises), a duo-trio test, a ranking screening test for solid oral texture attributes, and interviews. The selected panelists were trained for 18 h in the sensory evaluation laboratory. The panel leader helped panelists develop the terminology and learn how to use descriptive scaling. The panelists participated in six practice sessions. Table 2 lists the attributes and the list of sensory vocabulary from the panel training. This sensory vocabulary was used to describe the intensity of each attribute for a given sample using an unstructured scale (0 to 150 mm).

Prior to the 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 1.5 cm thick sausage slices, each labled with a three-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, juiceness, and oiliness. Sensory evaluation was conducted in duplicate for each sample type.

Statistical Analysis

SPSS software (SPSS 17.0 for Windows, SPSS Inc, Chicago, IL, USA) was used to evaluate the data. All analyses were performed duplicate and all experiments were replicated twice. Analytical variation was established through one way analysis of variance (ANOVA). Data are reported as mean±standard deviation. Comparison of means was performed using Duncan's multiple-range test with a level of significance of 0.05. The QDA data were converted to a spider web format using Microsoft Excel 2007.

Results and Discussion

Composition

Table 3 shows the results of proximate analysis of samples. There was no significant difference (P>0.05) in moisture content (67.28–67.57%), which indicates that the rehydration process was done properly. No significant difference (P>0.05) in carbohydrate, protein, fat, and ash content was found among the samples. Hsu and Chiang (2002) previously reported that the addition of gums did not have a significant effect on the proximate composition of the products of their study. The proximate compositions of samples in this study were within the range for Malaysian commercial fish sausages reported by Huda *et al.* (2012), with the exception of the protein content. In this study, protein content was 12.62–12.72%, whereas Huda *et al.* (2012) reported a range of 8.18% to 10.77%.

Texture

Table 4 presents the results of the folding test, TPA, and gel strength measurements of the samples. All samples received a grade of 5 in the folding test, which means that none of the samples cracked after folding twice. This result visually showed the good gelling ability of the sausages. Huda *et al.* (2003) also

Table 2. Sensory vocabulary for analysis of cooked sausages

Sensory atribute	(0–150)		General definitions
Whiteness	Dark brown	White	Inner part: Is the color white or dark?
Fish odor	None	Very strong	Cooked threadfin bream fish odor
Springiness	No recovery	Very springgy	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 of the first bite
Cohesiveness	Little	Much	Little: easy to take apart in the first bite
Juiceness	Dry	Juicy	The sensation after five chews: dry (sample draws liquid from the mouth) or juicy (samples gives off liquid)
Oiliness	None	Much	The sensation after five chews: none (no oil expressed from sample) or very oily

Table 3. Proximate composition of samples

Samples	sCMC	ALG	KJC	SP	FS
Moisture	67.44±0.27[a]	67.45±0.28[a]	67.28±0.10[a]	67.53±0.33[a]	67.57±0.39[a]
Protein	12.70±16[a]	12.72±0.11[a]	12.62±0.31[a]	12.69±0.33[a]	12.63±0.24[a]
Fat	4.11±0.13[a]	4.11±0.07[a]	4.10±0.08[a]	4.10±0.09[a]	4.10±0.01[a]
Ash	2.54±0.03[a]	2.52±0.01[a]	2.53±0.03[a]	2.52±0.02[a]	2.52±0.01[a]
CHO	13.21±0.39[a]	13.19±0.35[a]	13.46±0.28[a]	13.15±0.32[a]	13.17±0.30[a]

*Values are means±SD. Different letters in the same row indicate significant differences (P<0.05).

sCMC= Sausage made with surimi powder and 0.5% CMC, ALG= Sausage made with surimi powder and 0.5% alginate, KJC= Sausage made with surimi powder and 0.5% konjac, SP= Sausage made with surimi powder without hydrocolloid, FS= Sausage made with frozen surimi

Table 4. Folding test, TPA and gel strength of samples

Texture characteristics	sCMC	ALG	KJC	SP	FS
Folding test	5±0.00[a]	5±0.00[a]	5±0.00[a]	5±0.00[a]	5±0.00[a]
Hardness (kg)	4.44±0.38[b]	5.53±1.08[a]	5.59±0.11[a]	4.15±0.02[b]	5.73±0.08[a]
Cohesiveness (ratio)	0.31±0.00[a]	0.31±0.49[a]	0.31±0.02[a]	0.29±0.02[a]	0.32±0.01[a]
Springiness (mm)	0.32±0.02[a]	0.30±0.03[a]	0.30±0.00[a]	0.24±0.04[b]	0.33±0.01[a]
Chewiness (g mm)	440.10±46.24[c]	503.77±26.80[b]	526.90±38. 08[b]	294.33±3.22[d]	594.44±1.32[a]
Gel strength (g mm)	1865.68±127.93[c]	2206.58±75.01[b]	2255.42±62.16[ab]	1755.98±23.31[c]	2396.56±71.67[a]

*Values are means±SD. Different letters in the same row indicate significant differences (P<0.05).
sCMC= Sausage made with surimi powder and 0.5% CMC, ALG= Sausage made with surimi powder and 0.5% alginate, KJC= Sausage made with surimi powder and 0.5% konjac, SP= Sausage made with surimi powder without hydrocolloid, FS= Sausage made with frozen surimi

reported that fish balls formulated with surimi powder received a grade of 5. The folding test results in this study were better than those for fish sausage prepared from hake (*Merluccius capensis*), which had a folding grade of 3 (Cardoso *et al.*, 2008).

Hardness is strongly influenced by protein concentration in processed muscle foods such as sausage (Colmenero *et al.*, 1995). Because there was no significant difference in protein content among samples in this study (P>0.05), it is likely that the structure of the raw material also contributed to the hardness of the samples. A significant decrease in hardness from FS to SP was detected. This was expected, as the drying process lowers the textural properties of surimi powder due to protein denaturation. In our previous unpublished study, we found that the use of 0%, 50%, and 100% surimi powder to replace frozen surimi resulted in a decreasing trend of hardness (5.84 kg, 5.03 kg, and 4.14 kg, repectively) (Santana *et al.*, 2013). As surimi is a concentrated myofibiral protein from fish meat, thus corresponds to the hardness of fish sausage in the current study (Suzuki, 1981). The addition of alginate and konjac improved the hardness value of fish sausage formulated using surimi powder. There was no significant difference (P>0.05) in hardness among the ALG, KJC, and FS, and the hardness of ALG, KJC, and FS was significantly higher (P<0.05) than that of SP and sCMC. Pérez-Mateos and Montero (2000) found that fish gels containing hydrocolloids such as alginate were harder than the hydrocolloid-free samples. Hardness values of ALG, KJC, and FS in this study were higher than that of fish sausage made from fresh rainbow trout fillets (±4.73 kg, Dincer and Cakli, 2010).

The addition of hydrocolloids did not affect the cohesiveness of samples, as no significant differences (P>0.05) in cohesiveness were detected among the samples. Barbut and Mittal (1996) found that the addition of 0.35% CMC to low-fat frankfurters did not affect cohesiveness. In the current study, sCMC, ALG, and KJC had quite similar cohesiveness values (0.31), which were higher than that of SP (0.29). Jiménez-Colmenero *et al.* (2010) reported that the addition of 10.5% konjac gel slightly improved the cohesiveness of reduced-fat frankfurters from 0.67 (control) to 0.69.

While the drying process significantly (P<0.05) decreased the springiness of samples, the addition of CMC, konjac, and alginate improved the springiness of sausages made from surimi powder to levels similar to that of sausage made from frozen surimi. The drying process also affected the chewiness of samples, as the chewiness of SP was significantly lower (P<0.05) than that of FS. However, the addition of CMC, alginate, and konjac improved the chewiness value so that chewiness of ALG and KJC did not differ significantly (P<0.05) from that of FS. Previous studies reported that the addition of konjac gel could increase the springiness of low-pork sausage (Osburn and Keeton, 1994), low-fat bologna (Chin *et al.*, 1998), and low-fat frankfurters (Jiménez-Colmenero *et al.*, 2010). The improved TPA parameters caused by the addition konjac likely are due to interaction between konjac gel and other ingredients such as starch that form a stable, viscoelastic gel matrix; the konjac also helps to absorb water immediately and to form a heat-stable gel (Chin *et al.*, 1998).

The hardness, springiness, and chewiness of all samples in this study were within the range previously reported for Malaysian commercial fish sausage (3.28–5.67 kg, 0.28–0.42 mm, and 14520–44180 g mm, respectively) (Huda *et al.*, 2012). This result illustrates that even though the drying process lowers the textural properties of surimi, the textural properties of sausage produced from surimi powder with hydrocolloids added is acceptable.

ALG, and KJC had higher gel strength (~26 and 28%, respectively) than SP, but sCMC, ALG, and KJC had lower gel strength (~22, 8, and 6%, respectively) compared to FS. Freeze-dried surimi powder has an amorphous matrix due to loss of liquid material during drying, which causes a collapse structure and softening of the matrix (Lanier, 1992). However, the addition of alginate and konjac reinforced the gel strength of fish sausage formulated with surimi powder, whereas the addition of CMC did not affect gel strength. Nielsen *et al.* (1996) reported that the addition alginate increased the breaking force of a restructured beef sample and that 0.5% alginate was the best concentration in terms of sensory acceptability. Clarke *et al.* (1988) found that penetration force was increased with lower pH and the presence of sodium alginate in the formulation in the structured beef product. Yaseen *et al.* (2005) showed that konjac had higher elastic yield stress than CMC and that konjac had higher viscous and elastic components at the concentration of 0.5%. Gel strength of FS (2396 g mm) in the current study was quite close to that of fish sausage made from threadfin bream minced meat (2450 g mm; Raju *et al.*, 2003). ALG and KJC in this study had higher gel strength compared to fish sausage prepared from hake (*Merluccius capensis*) (1805 g mm; Cardoso *et al.*, 2008).

Cooking and Color Properties

Table 5 presents cooking yield, water retention, fat retention and color characteristics results. Cooking properties also are affected by the quality of the raw material, thus the drying process could reduce the cooking yield of sausage made from surimi powder. Water and fat might be released from the emulsion, and this can be measured as the water retention and fat retention after cooking. The use of surimi powder reduced the ability of the emulsion to hold water and fat during cooking, as shown by the significantly lower (P>0.05) fat and water retention of SP compared to FS. The protein denaturation that occured during drying could be the reason for this result. The addition of CMC, alginate, and konjac increased the cooking yield and water retention of sausages formulated with surimi powder. Xiong *et al.* (1999) also found that low-fat beef sausage containing 0.5% alginate had increased cooking yield. The water that is already immobilized by konjac and other gums likely is difficult to remove from sausage. In the current study, KJC had the highest fat retention among the samples tested.

Generally, the drying process and the addition of gums did have a great effect on the color of the samples (Table 5). The L* value of samples ranged from 71.80 to 72.18, the a* value ranged from 0.57 to 0.66, and the b* value ranged from 13.21 to 14.52, resulting in whiteness of sausage ranging from 68.87 to 69.17. Huda *et al.* (2012) reported that Malaysian commercial fish sausages had the following color characteristics: L* values of 58.73–79.56, a* values of –0.58–17.43, and b* values of 12.69–22.96. The color characteristics of the samples in this study were within these ranges.

Sensory Evaluation

Figure 1 shows the QDA results in the form of a spider web. The whiteness, fish odor, and oiliness of samples were quite similar. The whiteness score of samples ranged from 11.71 to 12.01, fish flavor ranged from 6.40 to 6.84, and oiliness ranged from 4.33 to 4.64. Poynton (1996) reported that the human eye can only detect changes in L* above one unit. The QDA result for the whiteness of samples was confirmed by the instrumental color result; the difference between the two analysis methods was less than one unit in L* value. These results for whiteness, fish odor, and oiliness of samples indicated that the drying process as well as the addition of the three hydrocolloids did not affect the fish flavor of the samples. The sCMC, ALG, and SP had lower fat retention then did KJC and FS. This means that more fat was released from sCMC, ALG, and SP during cooking, resulting in lower fat retained in these sausages after cooking. However, this did not influence the oiliness score of the samples.

In terms of hardness, the panelists scored SP (6.49) lower than FS (8.21). sCMC (8.13), ALG (8.17), and KJC (8.14) received scores similar to that of FS. Protein content is positively correlated with the hardness in processed muscle foods (Colmenero *et al.*, 1995). Because the protein content of samples did not differ significantly (P>0.05), the differences in hardness clearly were not influenced by the protein content; the quality of the protein may have an effect on hardness. The removal of water during freeze-drying is more drastic than during freezing, thus dryoprotectant is charged as a removed water, preventing denaturation of protein induced by drying (Carpenter *et al.*, 2004). However, the data indicated that the freeze-drying process lowered the hardness of the surimi in the fish sausage, resulting in panelists detecting that SP was softer than FS.

Although the surimi powder in the sausage formulation was less springy and less cohesive than

Table 5. Cooking yield, water retention, fat retention, and colour caracteristics of samples

Samples	sCMC	ALG	KJC	SP	FS
Cooking yield (%)	98.66±0.55[a]	98.72±0.13[a]	99.09±0.36[a]	95.59±0.44[b]	99.14±0.20[a]
Water retention(%)	68.56±0.35[ab]	69.16±0.54[a]	68.34±0.17[ab]	63.31±0.97[c]	66.97±1.99[b]
Fat retention(%)	40.90±0.10[c]	41.33±1.71[c]	69.85±1.04[a]	39.58±0.56[c]	45.23±0.26[b]
Colour characteristics					
L*	72.04±0.08[a]	71.80±0.31[a]	72.00±0.55[a]	72.15±0.04[a]	72.18±0.11[a]
a*	0.66±0.26[a]	0.62±0.03[a]	0.61±0.10[a]	0.63±0.01[a]	0.57±0.01[a]
b*	13.63±0.42[a]	14.52±0.33[a]	13.23±1.00[a]	13.21±0.26[a]	13.84±0.08[a]
Whiteness	68.87±0.23[a]	68.72±0.42[a]	68.87±0.25[a]	69.17±0.12[a]	68.93±0.08[a]

*Values are means±SD. Different letters in the same row indicate significant differences (P<0.05).
sCMC= Sausage made with surimi powder and 0.5% CMC, ALG= Sausage made with surimi powder and 0.5% alginate, KJC= Sausage made with surimi powder and 0.5% konjac, SP= Sausage made with surimi powder without hydrocolloid, FS= Sausage made with frozen surimi

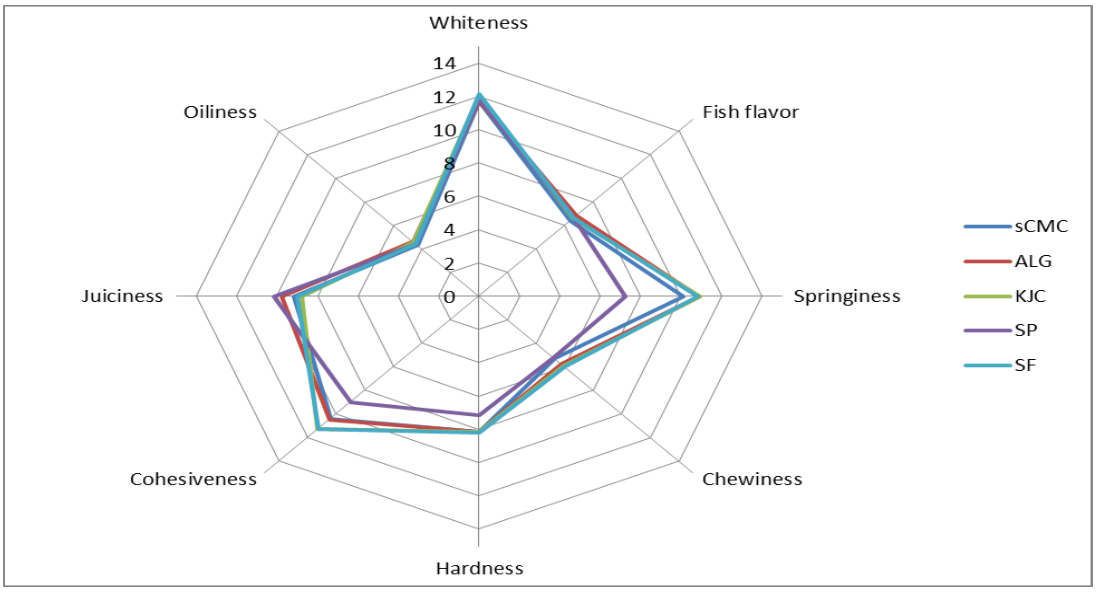

Figure 1. Spider web for QDA sensory analysis of samples.

the frozen surimi, the addition of CMC, alginate, and konjac increased the springiness and cohesiveness of sausage formulated with surimi powder. The QDA springiness and cohesiveness scores followed the same trend as the TPA values of springiness and cohesiveness. Unlike springiness and cohesiveness, the chewiness scores of sCMC, ALG, and KJC were lower than that of FS, although the scores were higher than that of SP. The drying process increased the juiciness of SP relative to FS. This might be due to the softer texture of SP, which resulted in greater expression of fluid after chewing. The juiciness of KJC was higher than that of SP but quite similar to that of FS; this might be because konjac helped to hold water in the surimi powder gel. Same result also reported by Osburn and Keeton (1994) that konjac gel higher the textural sensory attributes and lower the juiciness of pork sausages. From the correlation between sensory attributes measured by people and by instrument, it was found that only instrumental springiness of the sausages was positively correlated with sensory springiness (R^2 = 0.625, P>0.05).

Conclusion

The addition of hydrocolloids such as CMC, alginate, and konjac at ~0.5% final concentration can improve the textural and sensory properties of sausages formulated with surimi powder. Samples containing konjac had up to 26% greater gel strength than fish sausages without hydrocolloids. All three hydrocolloids improved the sensory characteristics of sausages formulated with surimi powder, especially hardness and springiness. In summary, konjac, followed by alginate and CMC, are useful additives for improving the physicochemical properties and sensory characteristics of sausages formulated with surimi powder.

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