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Physicochemical and sensory analysis of surimi sausage incorporated with rolled oat powder subjected to frying

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Abstract

In the present work, the effects of rolled oat powder (ROP) incorporated into surimi sausage on the physicochemical and sensory attributes of sausage were investigated. The incorporation of ROP into surimi sausage significantly increased moisture content, protein content, and water holding capacity, but decreased shrinkage and cooking loss. The incorporation of ROP was also able to significantly decrease fat absorption during frying. However, increased amount of ROP caused a significant decrease in texture especially after frying. Although a decrease in texture was recorded, the sensory analysis score did not display any significant difference on the colour, hardness, and overall acceptability of the surimi sausage. The development of surimi sausage incorporated with ROP could be an approach to utilise fish as a commodity, and produce a healthier and more nutritious sausage even after frying.

Introduction

Nowadays, consumers demand for healthier options of foods which include foods with high protein and fibre. However, fish products such as fish ball and crab stick do not naturally contain fibre as they are made from surimi. Surimi (concentrated myofibrillar protein) is an intermediate product which is used in the production of seafood-based products (Gani and Benjakul, 2018). Sausage is a convenient food that is high in protein and fat. Sausage is usually made from meat, and rarely from fish. Therefore, using surimi to produce sausages is an alternative to incorporate fish meat in sausages. Multiple researches have focused on improving the nutrition of a product in term of fibre by adding ingredients such as animal proteins, plant proteins, and polysaccharide derivatives (Zeng *et al.,* 2016). Many of the fibres used in fishery products are soluble, and come from algae or seeds, which are selected for their functional properties such as high water holding capacity, emulsifying capacity, and thickening or gel-forming properties (Borderias *et al.,* 2005). The addition of fibre has been reported to improve cooking yield and enhance texture (Piñero *et al.,* 2008; Petersson *et al.,* 2014; Kim *et al.,* 2016; Ananey-Obiri *et al.,* 2020).

Oat (*Avena sativa* L.) has received considerable attention owing to its high content of dietary fibres, phytochemicals, and nutritional values (Lapveteläinen *et al.,* 1994; Rasane *et al.,* 2015; Qian *et al.,* 2020). Studies have revealed that oat possesses beneficial health effects against gastrointestinal problems (Stark and Madar, 1994), and boasts anti-cancerous effects (Gallaher, 2000). Oat consumption has increased due to its health benefits associated with dietary fibres such as β-glucan, functional proteins, lipids, starches, and phytochemicals present in the oat grains (Rasane *et al.,* 2015; Schlörmann *et al.,* 2020). The nutritional benefits of oat have drawn the attention of researchers worldwide, and resulted in the increased interest of food industry in using oats as food ingredient in various food products including surimi (Alakhrash *et al.,* 2016), low-fat sausages (Petersson *et al.,* 2014), beverages (Gupta *et al.,* 2010), chicken meat patties (Talukder and Sharma, 2010), and breakfast cereals (Ryan *et al.,* 2011).

Frying is a common cooking method due to its effect on sensory characteristics which alters the flavour, texture, and colour of food (Liberty *et al.,* 2019; Multari *et al.,* 2019). However, frying causes physicochemical changes to products which are added with oat such as moisture, gel formation, fat content,

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and texture (Petersson *et al.,* 2014). Other than that, frying also causes the formation of aldehydes, ketones, alcohols, furans, and acids which influence the aroma of oil and the products (Perestrelo *et al.,* 2017). Fibre has been reported to reduce fat absorption in several products such as breaded fish balls, battered chicken strips, and battered fish fillets during frying (Zeng *et al.,* 2016). Brannan *et al.* (2013) reported that the incorporation of oat and frying caused significant changes on the colour attributes, lipid, and moisture content. Sensory analyses conducted on low-fat beef patties revealed that the presence of oat fibre produced juicier and tastier attributes as fibre helps retain moisture and prevents drying during cooking (Piñero *et al.,* 2008).

The present work was therefore undertaken to investigate the influence of different concentrations of rolled oat powder incorporated into surimi sausage, and its effect on the physicochemical properties during deep frying. The changes in physicochemical properties of surimi sausage after frying such as composition, colour, water holding capacity, cooking loss, shrinkage, and texture were investigated. Sensory analysis was also conducted to determine the acceptability of the sausage incorporated with rolled oat powder after frying.

Materials and methods

Surimi preparation

Fresh threadfin bream (*Nemipterus* spp.) was purchased from Taman Seri Serdang Public Market (Selangor, Malaysia), while the rolled oat powder (ROP) was purchased from Tesco Kajang (Selangor, Malaysia). The fresh threadfin was beheaded, gutted, and washed prior to deboning. Mechanical fish separator (Fish Deboner Machine, Asasemarak (M) Sdn. Bhd., Kuala Lumpur, Malaysia) was used to separate the flesh from bone. Then, the mince was washed using a washing tank (Fish Leaching Tank, SWE-FLST 75, Safe World Enterprise, Selangor, Malaysia) with cold water to maintain the temperature at 4°C. The mince:water ratio used was 1:3 (w/w). Any impurities in the mince were then removed by a refiner. After refining process, the mince was dewatered using a decanter (Decanting Machine, Ban Hing Holding Sdn. Bhd., Kuala Lumpur, Malaysia) to remove the excess water. Surimi was prepared by using fish, salt, sugar, water, and ROP at different concentrations (0, 2, 4, and 6%; formulations A, B, C, and D, respectively), and was mixed until they were homogenous. The surimi paste was packed in a Ziploc bag with labels, and stored in a freezer at -18°C. Formulation A served as control.

Surimi sausage preparation

Frozen surimi paste was thawed in a 4°C refrigerator for 2 h to prepare the surimi gel. A silent bowl cutter (TQ5A, Taat Bestari Sdn. Bhd., Selangor, Malaysia) was used to chop each sample of surimi into small pieces, and ground for 5 min. The surimi for each formulation was then extruded into casings of 15 mm diameter and 100 mm length. The ends of the casing were tightly sealed before incubation in a water bath at 90°C for 30 min. Heated surimi gels were immediately chilled with 4°C water, and stored at -18°C before analysis.

Frying

The surimi sausage samples were thawed at chill temperature (7°C) overnight. Approximately, 1.5 L of commercial sunflower oil was heated to 165°C in a fryer. The samples were then deep-fried for 4 min. The fried sausages were removed from the fryer, drained for 5 min, and allowed to cool to room temperature (Dilek *et al.,* 2011). Samples were immediately analysed after cooling.

Chemical composition

Samples before and after deep frying were cut into small pieces. Moisture, crude protein (N% × 6.25), crude fat (Soxhlet extraction), and ash were determined according to the Association of Official Analytical Chemists (AOAC, 2000). The experiment was done in triplicate.

Colour measurement

Surimi sausage samples were equilibrated to room temperature. Then, samples before and after deep frying were measured using a colorimeter (Minolta CR-410, Japan) for the degree of lightness (L*), redness / greenness (a*), and blueness / yellowness (b*) at 20 mm diameter and 50 mm thickness. The experiment was done in triplicate.

Water holding capacity

Surimi sausage sample (10 g) was added with 50 mL of distilled water, and centrifuged at 2000 *g* for 10 min at 4°C. The homogenised sample was weighed (W_1), and the final weight of sample was recorded (W_2). The experiment was done in triplicate. Water holding capacity was determined using Eq. 1:

$$\text{Water holding capacity (\%)} = \frac{W_2 - W_1}{W_1} \times 100 \quad \text{(Eq.1)}$$

Cooking loss

Cooking loss of samples was determined by measuring the weight differences of the uncooked (W_u)

and cooked samples (W_c) in triplicate, using Eq. 2:

$$\text{Cooking loss} = \frac{W\ -W}{W} \times 100 \qquad \text{(Eq.2)}$$

Shrinkage

Shrinkage of samples was determined by measuring the length differences of the uncooked (L_u) and cooked samples (L_c) in triplicate, using Eq. 3:

$$\text{Shrinkage} = \frac{L\ -L}{L} \times 100 \qquad \text{(Eq.3)}$$

Texture analysis

Texture of surimi sausage samples before and after deep frying were analysed in triplicate using TA-XT2i Texture Analyser (Stable Micro System Ltd., Surrey, UK) by compression test. Samples with diameter of 2 cm and height of 2.5 cm were pierced to breaking point using a 75 mm-diameter round-ended metal probe at room temperature (Solo-De-Zaldívar *et al.,* 2014). The samples were subjected to two compression cycles at a cross head speed of 127 mm/min to 50% compression of the original sample height. Important parameters such as hardness, springiness, cohesiveness, gumminess, and chewiness were measured.

Sensory analysis

Surimi sausage samples were freshly prepared and fried prior to the sensory analysis. The samples were then cut into small pieces, and labelled with code number. The sensory analysis was conducted with 50 panellists in the sensory room. The hedonic preference test was done. The parameters analysed were colour, odour, flavour, juiciness, hardness, and overall acceptability. The data were then collected and analysed. Panellists ranked the fried products on a scale of 1 to 9 with 1 = "dislike extremely", and 9 = "like extremely". The responses on various attributes of the samples were statistically analysed, and the mean values were reported.

Statistical analysis

The present work utilised completely randomised design (CRD) research design, in which only one factor (the incorporation of different concentrations of ROP) was affecting the physicochemical and sensory changes of surimi sausage samples subjected to frying. One-way analysis of variance (ANOVA) was performed to analyse the data. All experiments were performed in triplicate. Data were then presented as means and standard deviations (mean ± SD). Minitab 19 (Minitab Inc., State College, PA, USA) was used to perform the ANOVA, and Tukey's test was adopted using a 95% confidence interval.

Results and discussion

Chemical composition

Table 1 shows the chemical composition of surimi sausage incorporated with different concentrations of ROP before and after frying. It is apparent that sample D yielded the highest moisture content ($p < 0.05$) before and after frying. This result is similar to a study done by Alakhrash *et al.* (2016) that recorded higher moisture content with higher concentration of oat bran in surimi gels. Kim *et al.* (2016) also obtained similar results, and reported that dietary fibre had positive impact on the amount of moisture content in frozen beef patties. Dawkins *et al.* (1999) recorded higher moisture content of patties due to the property of β-glucan in oat bran that plays a role in binding and interacting with microstructure system to trap water.

Frying causes a significant decrease in moisture content (Table 1). This water loss is due to its evaporation by heat (Zeng *et al.,* 2016). The moisture loss was approximately 30% when compared between before and after frying. Before frying, moisture is trapped between the gelation network of protein (Ananey-Obiri *et al.,* 2020). However, when heat is induced during frying, starch begins to swell by absorbing water, and some water evaporate into steam hence creating more air pores in the product (Math *et al.,* 2004). This further causes a reduction in moisture after frying.

Table 1. Chemical composition of surimi sausage incorporated with different concentrations of ROP before and after frying.

Formulation	Moisture (%)		Ash (%)		Protein (%)		Fat (%)	
	Before frying	After frying	Before frying	After frying	Before frying	After frying	Before frying	After frying
A	71.62 ± 0.41^{Ba}	56.23 ± 0.23^{Db}	3.82 ± 1.03^{Ba}	3.98 ± 0.92^{Ba}	11.36 ± 0.89^{Bb}	11.38 ± 0.46^{Ba}	5.34 ± 6.15^{Ab}	12.87 ± 0.37^{Aa}
B	72.32 ± 0.62^{Ba}	58.91 ± 0.35^{Cb}	4.35 ± 0.52^{Aa}	4.46 ± 0.72^{Aa}	11.45 ± 0.27^{Bb}	11.35 ± 0.26^{Ba}	5.65 ± 2.74^{Ab}	11.36 ± 0.36^{Ba}
C	72.97 ± 0.34^{Ba}	61.16 ± 0.27^{Bb}	4.46 ± 0.63^{Aa}	4.43 ± 0.24^{Aa}	12.64 ± 0.95^{ABb}	12.23 ± 0.26^{Bb}	6.24 ± 6.95^{Ab}	10.27 ± 0.34^{BCa}
D	73.54 ± 0.58^{Aa}	64.87 ± 0.92^{Ab}	4.77 ± 0.55^{Aa}	4.72 ± 0.31^{Aa}	14.29 ± 0.84^{Aa}	14.52 ± 1.35^{Aa}	6.85 ± 0.89^{Ab}	9.38 ± 0.39^{Ca}

Data are mean ± standard deviation of triplicates (n = 3). Different superscript (uppercase) letters indicate significant difference ($p < 0.05$) between formulations. Different subscript (superscript lowercase) letters indicate significant difference ($p < 0.05$) between means of before and after frying for each chemical composition.

As the concentration of ROP increased, no significant difference ($p > 0.05$) was found on the ash content. Control sample significantly ($p < 0.05$) yielded the lowest % ash value of 3.82 ± 1.03 when compared to other samples incorporated with ROP. This could be due to the fact that oat has several minerals such as K, Ca, Mg, Fe, Zn, Mn, and P (Ekholm *et al.,* 2003). Generally, the incorporation of oat powder helps to increase the mineral content of a food product. When the sample was subjected to frying, the ash content of all samples showed no significant difference ($p > 0.05$). Therefore, this suggests that frying does not cause minerals from the oil to be absorbed into the sample during frying, as oil naturally contains some minerals (Math *et al.,* 2004).

An increasing trend was observed on the protein content of surimi sausage samples as the concentration of ROP increased, as shown in Table 1. This can be considered as an added value to the surimi sausage. Additionally, oat has been reported to have the highest protein content among cereal grains, and consists of essential amino acids (Qian *et al.,* 2020). Alakhrash *et al.* (2016) found that the amount of protein content in surimi gel increased with increasing concentration of oat bran. Frying was found to have no significant effect ($p > 0.05$) on the protein content. Fish products has low protein digestibility, and have been reported to retain protein during deep frying from 96 to 100% (Ananey-Obiri *et al.,* 2018). This is an indicator that the protein is preserved even at frying temperature, which would then benefit the consumers.

Table 1 also shows that the fat content significantly ($p < 0.05$) increased with increasing ROP concentration. Fat increase could be due to the high lipid content of oat as oat contains around 5 - 7.5% lipid and several other lipolytic enzymes such as lipoxygenase and lipase (Qian *et al.,* 2020). A significant difference ($p < 0.05$) was observed on the fat content of the samples before and after frying. Sample A significantly yielded high amount of fat with approximately 100% increase after frying. Deep fat frying causes various changes on the physicochemical properties and the microstructure due to the mass and heat transfer; hence, as more water is removed by the process, the higher the amount of oil uptake (Rahimi *et al.,* 2017). Moisture evaporation produces void spaces in the product which allow fat molecules to enter, thus, increasing the fat content (Brannan *et al.,* 2013; Zang *et al.,* 2016). Without proper gelation, water binding properties, and fibre gel network to prevent, oil will be absorbed into the food. It has been reported that soluble fibre can form a gel network that increases the water phase viscosity and disrupts the penetration of oil into the food (Ananey-Obiri *et al.,* 2018). The results presented in Table 1 concur with this statement, in which significant decrease ($p < 0.05$) of fat content after frying was observed when ROP concentration increased. Sample D significantly ($p < 0.05$) yielded the lowest value of fat with about 30% increase as compared to sample A with 100% increase. Oats have been reported to inhibit fat absorption during deep-fat frying (Brannan *et al.,* 2013; Zang *et al.,* 2016). Other than that, proteins have also been reported to reduce fat absorption up to 30% in chicken patties (Liberty *et al.,* 2019). This can also be seen from the results in Table 1 as sample D is shown with the highest protein content and lowest fat content.

Colour

Table 2 shows the L*, a*, and b* of the surimi sausage samples incorporated with different concentrations of ROP before and after frying. The incorporation of ROP was found to increase the L* value of surimi sausage samples before frying. Sample D showed significantly ($p < 0.05$) highest L* of 66.0 ± 0.6 as compared to other samples. However, the tristimulus colour values (L*, a*, and b*) did not significantly affect ($p > 0.05$) the colour when the concentration of ROP was increased from 2 to 6% after frying. The only significant difference ($p < 0.05$) recorded was for the control sample. The incorporation of ROP into surimi sausage in all samples resulted in lower L* values. Furthermore, the greatest yellowness of sausage was exhibited by sausage without oat; followed by sausage with 4% of oat. In accordance with this, Yılmaz and Dağlıoğlu (2003) reported that the presence of carotenoid pigments in the oat may influence the yellow colour of the end product into which the oat is incorporated. The colour of the surimi sausage was also affected by Maillard reaction because oat has been reported to contain glucose (Qian *et al.,* 2020). Other than glucose, Maillard reaction is also dependent on the amount of lipid present, as frying causes lipid oxidation which will form carbonyl group that will interact with protein and cause Maillard reaction (Rannou *et al.,* 2016). Sudha *et al.* (2012) similarly reported a significant decrease in L* of wheat-based biscuits associated with cereal fibres including oat bran and wheat. However, Hughes *et al.* (1997) claimed that the incorporation of oat fibre to frankfurters gave no impact on the colour despite the fat level of the frankfurters, while Reitmeier and Prusa (1991) indicated that yellow colour may be

Table 2. Colour values of surimi sausage incorporated with different concentrations of ROP before and after frying.

Formulation	L*		a*		b*	
	Before Frying	After Frying	Before Frying	After Frying	Before Frying	After Frying
A	62.8 ± 1.3^{Ba}	50.1 ± 0.8^{Ab}	2.0 ± 0.0^{Bb}	6.2 ± 1.0^{Aa}	13.7 ± 0.4^{Ba}	9.2 ± 3.0^{Ab}
B	63.6 ± 0.6^{Ba}	46.6 ± 0.2^{Bb}	2.3 ± 0.0^{Ab}	4.6 ± 0.8^{Aa}	15.9 ± 0.2^{Aa}	6.5 ± 2.1^{Ab}
C	64.1 ± 0.6^{ABa}	46.2 ± 0.6^{Bb}	2.0 ± 0.0^{Bb}	5.5 ± 0.4^{Aa}	15.8 ± 0.1^{Aa}	8.4 ± 1.2^{Ab}
D	66.0 ± 0.6^{Aa}	45.3 ± 0.7^{Bb}	1.9 ± 0.0^{Bb}	5.1 ± 0.1^{Aa}	16.2 ± 0.2^{Aa}	7.3 ± 0.9^{Ab}

Data are mean ± standard deviation of triplicates ($n = 3$). Different superscript uppercase letters indicate significant difference ($p < 0.05$) between formulations. Different superscript lowercase letters indicate significant difference ($p < 0.05$) between means of before and after frying for each colour parameter.

reduced when fat level is reduced, since fat imparts a yellow-white colour to fresh meat.

Water holding capacity, cooking loss, and shrinkage

Table 3 shows the water holding capacity (WHC) of surimi sausage samples incorporated with different concentrations of ROP before and after frying. The WHC is an important parameter that indicates the juiciness and texture of food (Piñero *et al.,* 2008; Petersson *et al.,* 2014). A food structure with high WHC is capable of physically preventing the release of water from the protein's three-dimensional structure (Hema *et al.,* 2016). Based on Table 3, the WHC of surimi sausage samples significantly ($p < 0.05$) increased with increasing concentration of ROP before and after frying. This result is similar to that reported by Kim *et al.* (2016), who found that the addition of dietary fibre can improve the WHC. They reported that beef patties with fibre were able to absorb more water released during protein denaturation. Other than that, this result is also parallel to the increase in moisture content and protein content previously presented in Table 1.

Frying was found to cause a significant increase ($p < 0.05$) in WHC for all samples. This could be due to the abundant network linkages by protein three-dimensional gelation that prevents moisture loss during frying, thus allowing protein-protein interaction to trap more water in its gelling network, and increase the WHC (Ananey-Obiri *et al.,* 2020). Protein to moisture ratio also influences the WHC of food. Smaller moisture to protein ratio indicates better WHC (Dawkins *et al.,* 2001). This is shown in Table 1, where sample D had lower ratio (5:15) as compared to sample A (6:30), B (6:32), and C (5:77) before frying. Other than that, the presence of oats might also contribute to the increase in WHC by absorbing more water in its fibrous network as oat also gelatinises as starch (Piñero *et al.,* 2008). β-glucan present in oat bran is also known to interact and bind with microstructure system to reduce mobility of water and increase water binding capability (Dawkins *et al.,* 1999).

Size reduction and weight loss due to water exudation causes the product to be less acceptable by consumer (Ananey-Obiri *et al.,* 2020). Cooking loss is the process of losing moisture during cooking period which causes shrinkage. Table 3 also shows the reduction in cooking loss and shrinkage of surimi sausage samples as ROP was incorporated. Sample D yielded the significantly lowest percentage of cooking loss ($p < 0.05$) as compared to the other samples. This could be due to the presence of soluble dietary fibre (SDF) that may act as water binding

Table 3. Water holding capacity, cooking loss, and shrinkage (%) of surimi sausage incorporated with different concentrations of ROP before and after frying.

Formulation	Water holding capacity		Cooking loss (%)	Shrinkage (%)
	Before frying	After frying		
A	37.18 ± 1.55^{Cb}	52.71 ± 2.93^{Da}	38.03 ± 0.83^{A}	10.53 ± 0.29^{A}
B	38.48 ± 4.86^{Cb}	57.91 ± 3.35^{Ca}	29.49 ± 0.93^{B}	8.75 ± 0.10^{B}
C	43.81 ± 2.00^{ABb}	61.22 ± 2.34^{Ba}	26.23 ± 1.25^{BC}	8.64 ± 0.37^{B}
D	46.56 ± 4.33^{Ab}	65.32 ± 2.13^{Aa}	25.14 ± 0.24^{C}	5.56 ± 0.56^{C}

Data are mean ± standard deviation of triplicates ($n = 3$). Different superscript uppercase letters indicate significant difference ($p < 0.05$) between formulations. Different superscript lowercase letters indicate significant difference ($p < 0.05$) between means of before and after frying for each parameter.

agent as well as the absorbent effect possessed by oat. Apart from that, β-glucan, which is a component in oat is hydrophilic, and therefore attaches to the free water available (Dawkins *et al.,* 1999). β-glucan is a hydrocolloidal fibre which not only traps water but also fat within its three-dimensional matrix (Piñero *et al.,* 2008). Carbohydrate and protein present in oat also increase the integrity of the sausage by gelatinisation and formation of protein network which reduces cooking loss and shrinkage of the sausage (Zeng *et al.,* 2016; Ananey-Obiri *et al.,* 2018; Liberty *et al.,* 2019).

Fibres, especially the soluble group, play an important role in reducing oil uptake during frying (Petersson *et al.,* 2014; Zeng *et al.,* 2016). Several studies claimed that oat β-glucan leads to lesser oil uptake of batters during frying, as it possesses greater water retention ability as well as greater viscosity (Lee and Inglett, 2007; Schlörmann *et al.,* 2020). The action mode of fibre in reducing the oil uptake is mainly correlated with its porous structure; when the water is entrapped in the pores, it will decrease the possibility for the oil to bind, thus aiding in maintaining the crispiness of the fried product (Yadav and Rajan, 2012; Liberty *et al.,* 2019). In addition, better WHC has also been reported with the incorporation of fibres in deep-fried chicken meat cutlets. Brannan *et al.* (2013) reported that one of the ingredients that may aid in oil uptake inhibition is hydrocolloid, and oat can be classified as non-protein hydrocolloid. The process that occurs is when the oat obstructs the moisture from leaching out, oil uptake is reduced. Therefore, it can be suggested that the incorporation of oat in surimi sausage will not increase the oil uptake during frying, thus reducing the cooking loss and shrinkage of the sausage.

Texture analysis

Table 4 shows the texture analysis of surimi sausage incorporated with different concentrations of ROP before and after frying. As expected, the control sausage had significantly ($p < 0.05$) highest hardness value amongst the sausage samples, regardless of before or after frying. Previous studies also reported similar effect of fibre on food products (Ktari *et al.,* 2014; Petersson *et al.,* 2014). This could be related to their higher water content as presented in Table 1. Ktari *et al.* (2014) reported that higher water content causes a decrease in hardness of beef sausages added with fibre. Generally, sausages incorporated with oat flour exhibited less firm property (Lapveteläinen *et al.,* 1994). Another significant difference is the content of myofibrillar protein. Control sample contained higher myofibrillar protein that can perform complete gelation without competing water for starch gelatinisation of oat, thus producing higher value of hardness and higher gelling strength (Kong *et al.,* 2016). The hardness of fried sausage samples gradually decreased ($p > 0.05$) with increasing ROP concentration. Before frying, the hardness slightly decreased with the incorporation of ROP as compared to control sausage but showed no significant difference ($p > 0.05$). A previous study correlated fat content with the hardness of the sausage where higher fat content contributed to a much firmer texture (Petersson *et al.,* 2014). This has been shown in Table 1, as increased concentration of ROP in sausages reduced the fat content after frying. Comparing the hardness of sausages before and after frying, no significant effect ($p > 0.05$) was found between these two treatments for sausages incorporated with ROP. These results might indicate that the incorporation of ROP is useful in making sausage with low fat and enhanced fibre content with less firm texture.

According to Kerr *et al.* (2005), cohesiveness is defined as the breaking difficulty degree of the inner structure of the sausages. Based on Table 4, cohesiveness of surimi sausages incorporated with ROP were significantly ($p < 0.05$) lower than the control samples before and after frying. In addition, higher cohesiveness when fibre is absent was also previously shown by Choi *et al.* (2014) and Ktari *et al.* (2014). A significantly

Table 4. Textural analysis of surimi sausage incorporated with different concentrations of ROP before and after frying.

Formulation	Before frying				After frying			
	A	B	C	D	A	B	C	D
Hardness (N)	25.50 ± 2.45^{Ab}	20.52 ± 1.10^{Ba}	19.61 ± 2.66^{Ba}	17.65 ± 1.96^{Ba}	50.01 ± 2.27^{Aa}	21.57 ± 2.48^{Ba}	17.01 ± 1.19^{Ca}	15.91 ± 1.29^{Da}
Cohesiveness (ratio)	0.71 ± 0.02^{Aa}	0.58 ± 0.03^{Ba}	0.57 ± 0.03^{Ba}	0.57 ± 0.021^{Ba}	0.67 ± 0.04^{Aa}	0.44 ± 0.03^{Bb}	0.41 ± 0.02^{BCb}	0.38 ± 0.04^{Cb}
Springiness (mm)	0.90 ± 0.05^{Aa}	0.90 ± 0.01^{Aa}	0.87 ± 0.02^{ABa}	0.87 ± 0.02^{Ba}	0.91 ± 0.01^{Aa}	0.82 ± 0.034^{BCb}	0.75 ± 0.03^{Cb}	0.72 ± 0.03^{Cb}
Gumminess (N)	15.22 ± 0.52^{Ab}	15.27 ± 1.49^{Aa}	14.67 ± 1.01^{ABa}	12.01 ± 0.33^{Ba}	31.90 ± 2.49^{Aa}	9.65 ± 1.54^{Bb}	6.75 ± 2.33^{Bb}	6.15 ± 1.46^{Bb}
Chewiness (N)	16.17 ± 1.27^{Ab}	12.29 ± 1.60^{Ba}	12.25 ± 1.03^{Ba}	9.64 ± 1.91^{Ba}	30.25 ± 1.44^{Aa}	12.33 ± 1.78^{Ba}	7.42 ± 1.63^{Cb}	3.87 ± 1.67^{Db}

Data are mean ± standard deviation of triplicates ($n = 3$). Different superscript uppercase letters indicate significant difference ($p < 0.05$) between formulations. Different superscript lowercase letters indicate significant difference ($p < 0.05$) between means of before and after frying for each textural parameter.

Table 5. Sensory scores of surimi sausage incorporated with different concentrations of ROP after frying.

Formulation	Frying			
	A	B	C	D
Colour	7.28 ± 2.16^{A}	7.25 ± 1.72^{A}	7.32 ± 1.52^{A}	7.35 ± 2.21^{A}
Flavour	6.68 ± 1.22^{A}	6.04 ± 1.33^{B}	6.21 ± 1.31^{B}	6.18 ± 1.45^{B}
Juiciness	6.11 ± 1.10^{B}	7.55 ± 1.20^{AB}	7.71 ± 1.23^{AB}	8.31 ± 1.04^{A}
Hardness	6.03 ± 1.24^{B}	8.18 ± 1.82^{A}	8.41 ± 1.59^{A}	8.91 ± 1.39^{A}
Overall acceptability	7.54 ± 1.17^{A}	7.61 ± 1.11^{A}	7.60 ± 1.08^{A}	7.91 ± 1.03^{A}

Data are mean ± standard deviation of triplicates ($n = 3$). Different superscript uppercase letters indicate significant differences ($p < 0.05$) between formulations.

($p < 0.05$) lower cohesiveness could be perceived as higher moisture content and fat content in surimi sausage. However, in fried sample, a significantly ($p < 0.05$) lower cohesiveness value was recorded with increasing amount of ROP. This could be related to the higher WHC of sample as presented in Table 3. As fried sample is cooled, moisture will evaporate to the surface and cause shrinkage, thus leading to the development of porous structure and roughness (Liberty *et al.,* 2019).

Higher springiness value indicates higher elasticity. However, based on Table 4, despite the incorporation of ROP and frying process, no significant difference ($p > 0.05$) in springiness was recorded as compared to the control. This result indicates that ROP did not have any impact on the springiness of the surimi sausages. However, Lazaridou and Biliaderis (2009) claimed that moisture content, moisture redistribution, and retrogradation of starch can greatly affect the springiness. As reported by Intarapichet *et al.* (1995), fat levels may be associated with the gel-emulsion and elasticity of sausages, as lower fat levels result in greater elasticity of myofibrillar proteins during storage.

Based on Table 4, the gumminess and chewiness of surimi sausages portrayed almost similar trend after frying, in which, it decreased with increasing concentration of ROP. As reported by Pietrasik (1999), chewiness and gumminess of the product are influenced by protein content. However, Dawkins *et al.* (2001) claimed that textural properties were improved by the addition of oat bran, soy protein, or starch. Despite water holding functionality, reduction in binding of proteins can also be interrupted by the incorporation of starch and texture-modifying extenders (Kerr *et al.,* 2005; Kong *et al.,* 2016).

Sensory analysis

Table 5 shows the sensory scores of surimi sausage incorporated with different concentrations of ROP after frying. It is apparent that the incorporation of ROP did not have a significant effect ($p > 0.05$) on the colour perception of surimi sausage. This is similar with the result reported by Borderias *et al.* (2005), in which up to 6% of wheat fibre added to white fish (hake) mince had virtually no effect on the final appearance.

The incorporation of ROP yielded a significant effect ($p > 0.05$) on the flavour. The flavour of control sample was more preferred by the panellist. Flavour is caused by lipid oxidation that generates volatile compounds such as aldehydes, ketones, and alcohols (Guan *et al.,* 2019). This is shown in Table 1 as control contained higher fat as compared to sample with ROP after frying. Other than that, the presence of aldehydes and ketones in oil that migrated into the surimi sausage during frying could also increase the flavour intensity (Zeng *et al.,* 2016). Aldehydes and ketones are flavour compounds that are also present in oil (Perestrelo *et al.,* 2017; Multari *et al.,* 2019).

Sample D displayed significant difference ($p < 0.05$) in the preference of sausage juiciness. The panellists significantly preferred the juiciness of sample D as compared to the other samples. Juiciness could be influenced by the high WHC as shown in Table 3 where sample D recorded the highest value. It was found that ROP incorporated into surimi sausage had significant effect ($p < 0.05$) on the hardness perception. The result indicates that the panellists preferred the hardness of surimi with ROP as compared to control as it might be easier to chew. The overall acceptability score did not show any significant difference ($p < 0.05$) in panellist preference. All samples showed high acceptability, and recorded favourable scores (7.5 above) as shown in Table 5.

Conclusion

In the present work, it was found that the incorporation of ROP into surimi sausages decreased fat absorption during frying, shrinkage, and cooking loss, whilst increasing the protein content and water holding capacity. Sensory analysis revealed that the incorporation of ROP in surimi sausages was acceptable and did not differ from the control sample. Overall acceptability of fried surimi sausage was in the acceptable range, and this could lead to the formulation of acceptable surimi sausage with fibre.

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