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## Effects of Different Dryoprotectants on Functional Properties of Threadfin Bream Surimi Powder

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### ABSTRACT

This study investigated the effect of five different dryoprotectants (sucrose, sorbitol, polydextrose, palatinose and trehalose) to protect protein of surimi powder during the drying process. Threadfin bream (*Nemipterus japonicus*) surimi powders treated with five different dryoprotectants and a control without dryoprotectant were produced using the oven-drying method at  $60\pm 5^{\circ}\text{C}$  and their functional properties were compared. Treated surimi powders contained 74.80-75.34% protein which was lower than that of the control (88.60%). In contrast, the carbohydrate content of treated surimi powders (13.06-14.83%) was also higher than that of the control (0.01%). Treated surimi powders exhibited better emulsification, foaming properties and protein solubility in 3% NaCl compared to the control. However, there was no significant difference in water holding capacity among treated samples and the control ( $p>0.05$ ). Overall, this study found that the addition of trehalose provided the best dryoprotective effect, followed by palatinose, sucrose, polydextrose and sorbitol.

**Key words:** Surimi powder, functional properties, dryoprotectants, low sweeteners sugars, oven drying

### INTRODUCTION

The term surimi refers to myofibrillar protein extracted from minced and water-washed fish tissue that is stored frozen (Okada, 1992). Surimi, which has unique gelling characteristic, is preferred as the main ingredient in various seafood products. It is also considered as low fat products. It is widely used as a main ingredient in a Japanese traditional food, Kamaboko and in other seafood-derived products (Park and Lin, 2005). The surimi industry has grown in many countries, including Japan, the United States and countries in Southeast Asia (Park, 2005). This growth has been driven by the increasing worldwide demand for surimi.

In the surimi industry, freezing equipment has been essential to maintaining the quality of surimi. However, such equipment is very expensive, which is a big problem for developing countries. Converting surimi to a dried form may be an option for reducing the cost of surimi production and distribution, as it does not require frozen storage. Beside it still has acceptable quality, surimi powder also offers many advantages, ease of handling and the ability to be used in dry mix applications (Niki *et al.*, 1992). Surimi powders have been produced from a number of marine fish, including Allasca pollock (Niki *et al.*, 1992), saithe (Shaviklo *et al.*, 2010a, b), tilapia (Ramirez *et al.*, 1999), fat sleeper (Ramirez *et al.*, 1999) and threadfin bream (Huda *et al.*, 2000b, 2001).

When surimi are produced to be frozen blocks, a sugar is added as a cryoprotectant to prevent the protein denaturation during freezing. Production of surimi powder requires the addition of a sugar as a dryoprotectant to protect the protein during the drying process as well (Huda *et al.*, 2001). To date, few studies have evaluated the dryoprotective effect of different sugars, especially low sweeteners sugars. Thus, the objective of this study was to investigate the protective effect of different dryoprotectants (sucrose, sorbitol, polydextrose, palatinose and trehalose) on the functional properties of protein during the drying of threadfin bream surimi powder using a hot-air convection oven.

## **MATERIALS AND METHODS**

**Materials:** Threadfin bream were purchased from local market in Penang and processed into surimi following Ohkuma *et al.* (2008). Different sugars (6% sucrose, 6% sorbitol, 6% polydextrose, 6% palatinose and 6% trehalose) were added to different surimi samples to act as a dryoprotectant. Surimi without a dryoprotectant added served as the control. All of the surimi preparation and analysis was conducted at the Fish and Meat Processing Laboratory, Food Technology Programme, Universiti Sains Malaysia over the period of January 2010 to July 2011.

**Preparation of surimi powder:** Surimi samples were dried using the oven-drying method following Huda *et al.* (2000b) with slight modification. The raw surimi samples were placed into 50×30 cm aluminium trays and dried using a hot-air conventional oven (AFOS Mini Kiln, Hull, England) at a temperature of 60±5°C. During the drying process, the sample was turned over and mixed every hour to ensure even heat distribution throughout the sample. The surimi samples were dried until their moisture content reach about ±7%. The dried samples were milled into powder using a commercial blender (Panasonic MX 799S, Selangor, Malaysia), sieved through a 30 mm screen mesh and kept in capped bottles at 2°C until further analysis.

**Proximate composition:** Proximate composition was measured in triplicates for each treatment from two drying trials. Proximate composition of the surimi powders was determined using standard procedures of the Association of Official Analytical Chemists (AOAC, 2000). Moisture content was determined using the air-oven method and crude protein content was determined using the Kjeldahl 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.

## **Physicochemical analysis**

**Protein solubility:** Protein solubility of the surimi powders was analyzed in triplicates for each treatment from two drying trials following Venugopal *et al.* (1996). The protein solubility was calculated on the basis of 100% solubility of the protein.

**Water Holding Capacity (WHC):** The WHC of surimi powder samples was analyzed in triplicates for each treatment from two drying trials following Miller and Groninger (1976) with slight modification. One gram of surimi powder was added to 40 mL of 3% NaCl solution in a 50 mL centrifuge tube. The sample was homogenized for 5 min using a vortex mixer (Thermolynen Maxi Mix II, Dubuque, IA, USA) and then centrifuged for 5 min at 7500 rpm at room temperature using a Hettich Universal 30 RF centrifuge (Tuttlingen, Germany). The supernatant was poured through a funnel into a 50 mL calibrated measuring cylinder. The volume of the supernatant was subtracted from the original 40 mL and the result was reported as mL of H<sub>2</sub>O held by 1 g of protein.

**Emulsification properties:** Emulsifying capacity and stability was measured in triplicates for each treatment from two drying trials following Yatsumatsu *et al.* (1972) with slight modification. Five gram of surimi powder were added to 20 mL of distilled water and 20 mL of corn oil. The mixture was blended (Waring Blender, New Hartford, CT, USA) for 1 min and transferred to a 50 mL calibrated centrifuge tube and centrifuged (Hettich Universal 30 RF, Tuttlingen, Germany) at 7500 rpm for 5 min. Emulsifying stability was determined by the same procedure, except that before the sample was centrifuged, the emulsion was heated for 30 min at 90°C in a water bath (Wisebath® fuzzy control system, Daihan Scientific, Seoul, Korea) followed by cooling in tap water for 10 min. The emulsion capacity and emulsion stability were calculated using the same formula:

$$\text{Emulsion} = (\text{emulsion volume after centrifugation}/\text{original emulsion volume}) \times 100$$

**Foaming properties:** The foaming properties of the surimi powders were determined in triplicates for each treatment from two drying trials following Miller and Groninger (1976). The foaming capacity represents the ability of surimi powder to produce foam, while the foaming stability represents the stability of foam after 30 min.

**Density:** Density was measured in triplicates for each treatment from two drying trials to know the ratio of samples volume to its weight. The density of the powder samples is expressed as mL volume per 10 g powder (Venugopal *et al.*, 1996).

**Colour:** The colour of surimi powder samples was determined using a Konica Minolta 3500d spectrophotometer (Minolta, Kyoto, Japan). The sample was evaluated using the colour-difference meter and L\* (lightness), a\* (redness/greenness) and b\* (yellowness/blueness) were measured. The instrument was calibrated using a standard white tile (L\* = 98.46, a\* = 0.0 and b\* = 2.18). The colour of each treatment was recorded for five spots per sample.

**Statistical analysis:** SPSS 17 (SPSS Inc, Chicago IL) was used to conduct statistical analyses and significance was set at  $p < 0.05$ . All chemical analyses were performed in triplicate, whereas at least five determinations for each treatment were conducted for physical analyses, including colour. Data were subjected to one-way analysis of variance (ANOVA). Comparison of means was performed using Duncan's multiple-range test. Excel (Microsoft Inc.) was used to determine standard deviation and average values of the data.

## RESULTS AND DISCUSSION

**Proximate composition:** Table 1 shows the proximate compositions of each type of surimi powder. Protein was the main component in threadfin bream surimi powder, followed by carbohydrate, moisture, ash and fat. The protein content in surimi powders treated with a dryoprotectant varied from 75.34 to 77.42%, whereas the protein content of the control sample was higher (88.60%). In a previous study, the protein content of oven and freeze-dried surimi powder obtained from threadfin bream was 72.60-72.90% (Huda *et al.*, 2000b, 2001). Shaviklo *et al.* (2010a) reported that the protein content of spray-dried surimi powder obtained from saithe was 74.50%. Carbohydrate was the second main component of the surimi powders treated with dryoprotectant. The carbohydrate content of treated samples was 13.06-14.83%.

Table 1: Proximate analysis of surimi powders treated with different dryoprotectants

Treatment	Moisture	Protein	Fat	Ash	Carbohydrate
Control	7.71±0.16 <sup>a</sup>	88.60±0.24 <sup>a</sup>	1.26±0.01 <sup>a</sup>	2.33±0.07 <sup>a</sup>	00.10±0.00 <sup>a</sup>
Sucrose	7.39±0.01 <sup>b</sup>	75.34±0.55 <sup>c</sup>	0.82±0.01 <sup>b</sup>	1.73±0.10 <sup>c</sup>	14.72±0.10 <sup>b</sup>
Sorbitol	7.52±0.06 <sup>a</sup>	75.11±1.02 <sup>c</sup>	0.80±0.01 <sup>b</sup>	1.74±0.03 <sup>c</sup>	14.83±0.82 <sup>b</sup>
Palatinose	7.33±0.01 <sup>b</sup>	77.15±0.16 <sup>b</sup>	0.81±0.02 <sup>b</sup>	1.44±0.01 <sup>a</sup>	13.27±1.07 <sup>d</sup>
Polydextrosee	7.75±1.20 <sup>a</sup>	74.80±0.24 <sup>d</sup>	0.83±0.02 <sup>b</sup>	1.97±0.17 <sup>b</sup>	14.65±0.35 <sup>c</sup>
Trehalose	7.11±0.23 <sup>b</sup>	77.42±0.10 <sup>b</sup>	0.78±0.01 <sup>c</sup>	1.63±0.03 <sup>d</sup>	13.06±0.75 <sup>e</sup>

\*Values are means of triplicate determinations of two drying trials with ±SD. Different letters in the same column indicate significant differences (p<0.05)

Table 2: Water holding capacity and protein solubility in a 3% NaCl solution of surimi powders treated with different dryoprotectants

Treatment	Solubility in 3% NaCl	Water holding capacity (mL g <sup>-1</sup> )
Control	24.66±0.16 <sup>d</sup>	2.80±0.07 <sup>a</sup>
Sucrose	31.25±0.63 <sup>b</sup>	2.80±0.14 <sup>a</sup>
Sorbitol	25.95±0.78 <sup>d</sup>	2.60±0.21 <sup>a</sup>
Palatinose	32.21±0.74 <sup>b</sup>	2.90±0.44 <sup>a</sup>
Polydextrose	29.78±0.35 <sup>c</sup>	2.90±0.21 <sup>a</sup>
Trehalose	37.40±0.66 <sup>a</sup>	3.00±0.08 <sup>a</sup>

\*Values are means of triplicate determinations of two drying trials with ±SD. Different letters in the same column indicate significant differences (p<0.05)

Because the protein content of all of the surimi powders tested was > 65%, surimi powder can be classified as Fish Protein Concentrate (FPC) type A, as proposed by the Food and Agriculture Organization (Barzana and Garibay, 1994). The surimi powders described by Huda *et al.* (2000b, 2001) and Shaviklo *et al.* (2010a) also can be classified as FPC type A.

**Protein solubility and WHC:** Table 2 shows the protein solubility and the WHC of the surimi powder samples. Protein solubility of treated samples in 3% NaCl solution varied from 29.78 to 37.40%, whereas the control had the lowest value (24.66%). Huda *et al.* (2000a) reported that the protein solubility of oven-dried surimi powder produced from lizardfish at a drying temperature of 60°C was 30.2%. Dryoprotectant can protect protein from losing its solubility property after drying. The dryoprotectant works by raising the surface tension of water which may stabilize the protein by forbidding the solute from escaping to the protein surface and by improving the strength of the intermolecular hydrophobic interaction (MacDonald *et al.*, 2000).

The protein solubility in the 3% NaCl solution varied significantly (p>0.05) among the treated surimi powders. The solubility of the trehalose-treated sample was 37.40% which was significantly higher (p<0.05) than that of the other samples. The mechanism by which trehalose stabilizes protein during drying is related to its molecular conformation (Richards *et al.*, 2002). Previous studies of trehalose have illustrated its efficiency in stabilizing protein under many conditions, including in very hot and very cold environments (Donnamaria *et al.*, 1994).

There was no significant difference (p>0.05) in WHC among any of the surimi powders, including the control. The WHC of the samples was 2.80-3.00 mL g<sup>-1</sup>. The use of an oven at high temperature to dry the samples affected the proteins and caused them to lose their capacity to hold water. The WHC of threadfin bream surimi powder processed using a freeze drier was higher (19.5 mL g<sup>-1</sup>) (Huda *et al.*, 2001). In contrast, the WHC of freeze-dried saithe surimi powder was lower at 2.53 mL g<sup>-1</sup> (Shaviklo *et al.*, 2010b). Niki *et al.* (1982) reported the WHC of spray-dried

surimi powder from Alaska pollock to be  $\sim 27 \text{ mL g}^{-1}$ . Thus, different drying methods, species and use of dryoprotectant may influence the WHC of surimi powder.

Surimi powder treated with trehalose has the highest WHC (3.00%) among the treated samples. This protective attribute can be attributed to the high glass transition temperature of this sugar (Sussich and Cesaro, 2008). Trehalose has low hygroscopicity and it is stable during processing (Schiraldi *et al.*, 2002). In addition, its protective effect on surimi protein is almost similar to that of sorbitol and sucrose (Osako *et al.*, 2005).

**Emulsification and foaming properties:** The emulsification properties of surimi powders are shown in Fig. 1. There was no significant difference ( $p > 0.05$ ) in emulsifying capacity among the treated surimi powders, but the treated samples had a significantly higher ( $p < 0.05$ ) emulsifying capacity than the control. This result shows that the dryoprotectant helps fish protein maintain its emulsification properties. Ramirez *et al.* (1999) evaluated the emulsification properties of surimi powders obtained from tilapia and fat sleeper fish at different temperatures. They found that the emulsion capacity is optimum when the protein had a balance between hydrophilic and hydrophobic residues (Foegeding and Davis, 2011). Denaturation may decrease the emulsifying capacity of surimi powder due to changes in the hydrophilic to hydrophobic ratio, but the presence of dryoprotectant maintains the hydrophilic residues after drying (Matsumoto and Noguchi, 1992). Surimi powder treated with trehalose had the highest emulsifying capacity (63%), followed by palatinose (62%), polydextrose (60.5%), sucrose (60%) and sorbitol (55%). Christensen *et al.* (2008) reported that trehalose helped maintain protein stability during drying. In the current study, when the emulsifying stability was evaluated after 30 min, it was decreased compared to the initial emulsifying capacity. The emulsifying stability of surimi powders treated with palatinose and trehalose were significantly higher ( $p < 0.05$ ) than the stability of the other samples. However, results of previous studies show that dryoprotected freeze-dried samples have better emulsion stability than oven-dried samples. Freeze-dried surimi powder from saithe treated with 5% sucrose and 0.2% phosphate had an emulsifying stability of 76.5% (Shaviklo *et al.*, 2010b). Huda *et al.* (2001) reported that freeze-dried surimi powder made from threadfin bream had an emulsifying stability of 82.8%.

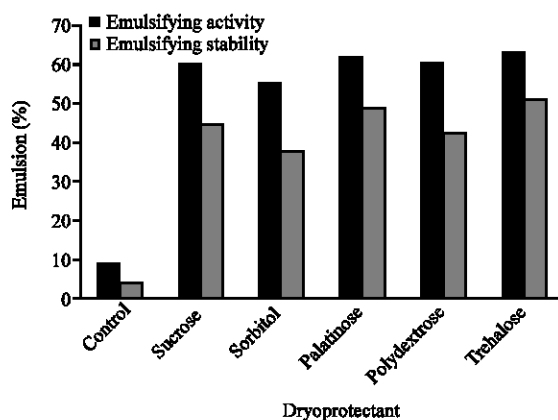


Fig. 1: Emulsion capacity and emulsion stability (measured after 30 min) of surimi powders treated with different dryoprotectants

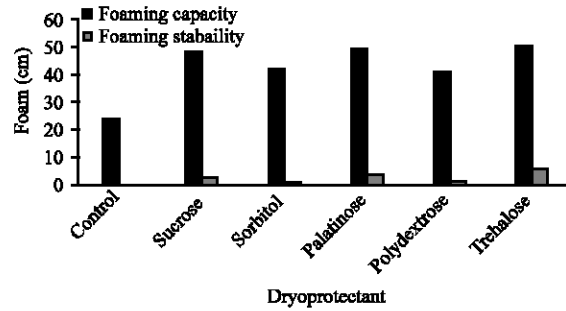


Fig. 2: Foaming capacity and foaming stability (measured after 30 min) of surimi powders treated with different dryoprotectants

The foaming properties of surimi powders are shown in Fig. 2. Functional properties of protein in foams have to do with the protein's ability to form interfacial films within two phases (Foegeding and Davis, 2011). The foaming capacity of raw surimi powder was only 24%; with dryoprotectant added, the foaming capacity increased to 41-49%. This result means that dryoprotectant helps improve the foaming capacity of surimi powder. Similar to those said by Huda *et al.* (2001) and Shaviklo *et al.* (2010a, b). The foaming capacity of surimi powder treated with sucrose, palatinose and trehalose was significantly higher ( $p < 0.05$ ) than that of surimi powder treated with sorbitol and polydextrose. The foaming capacity of oven-dried surimi powders in this study was higher than that of freeze-dried surimi powder obtained from threadfin bream (34.6%), purple-spotted big eye (29.9%) and lizardfish (28.8%) (Huda *et al.*, 2001).

The foaming stability of the sample treated with trehalose was significantly higher ( $p < 0.05$ ) than that of the other treated samples. The sample treated with trehalose had 4% foaming stability, whereas that of the control was only 0.5%. However, all samples exhibited reduced foaming stability after 30 min. Proteins that have great formability may not necessarily produce stable foam (Wilde and Clark, 1996). High drying temperature may effect the foaming stability of surimi powder. Shaviklo *et al.* (2010a) reported that spray-dried surimi powder had lower foaming stability compared to freeze-dried samples due to the use of high temperature in the spray-drying method.

**Density and colour:** Table 3 shows the density, lightness ( $L^*$ ), redness (a) and yellowness (b) of surimi powder treated with different dryoprotectants. The density values of treated surimi powders ranged from 6.60 to 7.15 mL/10 g powder, whereas density of the control was 6.50 mL/10 g powder. There was little difference in density among sample types because they were produced using the same drying method (oven drying) and the same species of fish. However, the density of treated surimi powders in this study was higher than that of spray-dried and freeze-dried surimi powders (Niki *et al.*, 1982; Venugopal *et al.*, 1996; Huda *et al.*, 2001; Shaviklo *et al.*, 2010a, b). The drying method, the amount of additive used and the method of drying may affect the final density of surimi powder (Huda *et al.*, 2001).

The  $L^*$  values of samples treated with sorbitol and trehalose were significantly higher ( $p < 0.05$ ) than those of the other treated surimi powders. Moreover, there was no significant difference ( $p > 0.05$ ) in the  $L^*$  value among the control (73.23) and the surimi powders treated with sorbitol (72.97) and trehalose (73.18). This finding indicates that samples treated with sorbitol and trehalose maintained the lightness of surimi powder after drying. However, the lightness value in this study was lower than that of freeze-dried threadfin bream surimi powder (89.57) reported by

Table 3: Density and colour characteristics of surimi powders treated with different dryoprotectants

Treatment	Density	Lightness (L*)	Redness (a*)	Yellowness (b*)
Control	6.50±0.14 <sup>b</sup>	73.23±0.58 <sup>a</sup>	4.46±0.01 <sup>e</sup>	28.14±0.06 <sup>f</sup>
Sucrose	7.15±0.01 <sup>a</sup>	66.97±0.76 <sup>b</sup>	7.00±0.02 <sup>b</sup>	36.21±0.08 <sup>a</sup>
Sorbitol	6.60±0.14 <sup>b</sup>	72.97±0.19 <sup>a</sup>	3.00±0.14 <sup>f</sup>	28.36±0.10 <sup>d</sup>
Palatinose	7.05±0.07 <sup>a</sup>	71.07±0.47 <sup>b</sup>	7.56±0.06 <sup>a</sup>	33.44±0.02 <sup>b</sup>
Polydextrose	7.10±0.14 <sup>a</sup>	67.64±0.52 <sup>c</sup>	5.39±0.04 <sup>c</sup>	33.62±0.04 <sup>b</sup>
Trehalose	7.12±0.03 <sup>a</sup>	73.18±1.10 <sup>a</sup>	4.78±0.03 <sup>d</sup>	31.41±0.77 <sup>c</sup>

\*Values are means of triplicate determinations of two drying trials with ±SD. Different letters in the same column indicate significant differences (p<0.05)

Huda *et al.* (2001). The use of high temperature in oven drying could enhance the Maillard reaction. This Maillard reaction contributes in reducing lightness of surimi powder.

Surimi powder treated with sucrose had a significantly higher b\* value (p<0.05) than that of the other treated samples and the control. Besides, surimi powder treated with palatinose had a significantly higher a\* value (p<0.05) than that of the other treated samples and the control. These data suggest that different types of dryoprotectant may affect the colour characteristics of surimi powder.

## CONCLUSIONS

The results of this study indicate that the dryoprotectants tested played a role in maintaining the functional properties of surimi powder against heat denaturation during the drying process. Treated surimi powders exhibited higher emulsification, good foaming properties and better solubility attributes compared to the control (i.e., raw surimi powder). However, the presence of dryoprotectants did not affect the WHC of the surimi powders. Trehalose had the best dryoprotective effect in surimi powder, as shown by higher protein solubility in 3% NaCl solution and better emulsifying stability and foaming capacity compared to the other dryoprotectants. Surimi powder treated with trehalose did not differ significantly (p<0.05) in lightness compared with raw surimi powder and surimi powder treated with sorbitol. Palatinose was the next best dryoprotectant after trehalose in giving dryoprotection to the surimi powder. Sucrose as a commercial cryoprotectant also has shown to be a good dryoprotectant in the surimi powder. Sorbitol and polydextrose did not have a very strong protective effect on the surimi powder functionality.

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