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Effect of Different Sugar Concentration on the Rheological and Textural Properties of Fish Mince

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Abstract
Fish mince were prepared from Alaska Pollock where fish were headed, gutted, washed and minced. The fish mince were subjected to three formulations with different types of sugar which was sucrose, sorbitol and mannitol at 4%, 6% and 8% (w/w) concentration. Rheological properties and textural properties of the fish mince is determined using a rheometer and texture analyser. Rheological properties showed that as the sugar concentration increases, the fish mince displayed more elastic properties rather than viscous. Higher stress and force were needed for deformation of fish mince at higher sugar concentration. Fish mince added with mannitol at 8% (w/w) displayed the highest value of G' and G''. Textural properties also concur with rheological results as it shows that an increase in sugar concentration, increases the gelling strength of the fish mince especially with mannitol (p<0.05). An increase from 4% to 6% concentration of sugar showed a significant difference for all sample (p<0.05). However, sucrose and sorbitol does not display any significant difference with an increase from 6% to 8% (p>0.05). This indicates that a lower sugar concentration could be used to produce similar gelling strength of higher sugar concentration.

Keywords: fish, rheology, texture, gel strength, sugar

Introduction

Freezing is a preservation technique widely used during handling and transportation of surimi. However, denaturation occurs during frozen storage which promotes protein aggregation thus reducing gel forming ability (Zhou et al., 2006; Shenouda, 1980). Cryoprotectants were introduced as a solution to prevent and slower the rate of denaturation during frozen storage (MacDonald and Lanier, 1994). Cryoprotectants added has the ability to alter the surface hydrophobicity of surimi thus preventing oxidation and protein aggregation (Parvathy and George, 2014; Campo-Deaño, Tovar and Borderías, 2010; Zhou et al., 2006). The ability of cryoprotectants to increase the hydration of surimi also decreases the rate of protein denaturation (Nopianti et al., 2012: Yoon and Lee, 1990). Various low molecular sugars such as sucrose and sorbitol have been identified as cryoprotectants and have been added to surimi to prevent freezing damage (Campo-Deaño, et al., 2010; Carvajal, Lanier and MacDonald, 2005). These sugars are chosen because they are economical, easy to obtain and cause minimal Maillard browning reaction to surimi (Carvajal et al, 1999). However, due to its high calorie content and sweetness (sucrose), other sugars with lower calorie content and sweetness such as trehalose, polydextrose, maltodextrin have been researched to promote a much healthier product (Campo-Deaño et al., 2009; Zhou et al., 2006; Sych et al., 1991). Sych et al. (1991) reported that polydextrose, a branched polysaccharide with no sweetness could substitute sucrose/sorbitol mixture as cryoprotectant on cod. However, a high concentration of polydextrose causes the natural actomyosin to possess higher viscosity thus making it harder to be processed (Herrera and Mackie, 2004). This study was done to understand the rheological and textural properties of Alaska Pollock surimi when sucrose, sorbitol and mannitol were added as cryoprotectants. In addition, the feasibility of using mannitol as a cryoprotectant was also investigated. So far, only few reports on the use of mannitol as cryoprotectant exist. In conjunction to that, the effects of sugar concentrations on the rhelogical and textural properties of surimi paste and gel were also investigated. Lowering sugar concentrations might produce a less sweet surimi with low calorie content. Rheological properties and textural properties of surimi are used as an indicator of surimi quality. Understanding these properties will further assist seafood manufacturers to design their processing line efficiently and effectively.

Materials and methods

Fish paste preparation

Fresh Alaska Pollock fish obtained from the local market. The fish was beheaded, gutted, washed and cleaned to obtain fish meat. The fish was then minced using a food processor to attain uniformity and homogeneity. The fish mince underwent washing with water to mince ratio 3:1 (w/w). Washing was done using chilled distilled water at 4°C. The mixture was stirred gently for 5 minutes and filtered using cheesecloth. The paste was then mixed with different type of sugar and sugar concentration as presented in Table 1. The sample was then stored inside a freezer at -18°C overnight.

Fish gel preparation

For fish gel preparation, the frozen samples were thawed at room temperature for 1 hour. The samples were then blended using a food processor to produce a homogenized fish paste. The samples were inserted into an extruder and extruded into a polyvinilydine casing with a diameter of 25 mm. Both ends of the casing were tightly sealed. The samples were then boiled in water at 40°C for 30 min and 90°C for 20 min as described by Benjakul et al. (2002) two-step heating. The samples were cooled under running water and stored at -18°C overnight before analysis.

Table 1: Fish sample formulations with different types of sugars and sugars combination.

Sample	Formulation (w/w)
C	No additives
SU4	4% Sucrose
SU6	6% Sucrose
SU8	8% Sucrose
SO4	4% Sorbitol
SO6	6% Sorbitol
SO8	8% Sorbitol
MA4	4% Mannitol
MA6	6% Mannitol
MA8	8% Mannitol

Rheological tests

Small amplitude oscillatory shear (SAOS) tests were performed using a Discovery HR-2 Hybrid Rheometer using 40 mm 4° cone and plate geometry with 59 µm truncation gap. The sample was thawed at room temperature prior to analysis. Fish paste was spread evenly on the lower plate and any excess sample was carefully removed. The sample was covered using a moisture trap during measurement to prevent moisture evaporation.

Stress sweep test was done to determine the linear viscoelastic region (LVR). Stress values ranging from 0.1 Pa to 1500 Pa were implemented on the fish paste at 1 Hz and 20°C. The storage modulus (G') and loss modulus (G'') were observed and recorded.

Temperature sweep test was performed to analyse the variations in storage modulus (G') and loss modulus (G'') when the temperatures changed. The temperature sweep was done at 0.5% strain with 1°C per minute increase from 10°C to 90°C.

Textural properties

Puncture test was done using a TA-XT plus Texture Analyser (Stable Micro System Ltd., Surrey, UK). Samples with a diameter of 25 mm and a height of 25 mm were pierced to a breaking point using a round-ended cylindrical metal probe (P/0.25s). The crosshead speed was set at 1 mm/sec and a 5 kg load cell was used. The force required to cause deformation represents the breaking force (g) and the depth of penetration represents the breaking deformation (cm) as the gel loses its strength and ruptures. Gel strength was calculated using the equation by Huda, Leng and Nopianti (2011) as below:

Gel Strength (g/cm) = Breaking Force (g) x Breaking Deformation (cm)

Statistical Analysis

Statistical analysis was performed by using MINITAB 16 statistical software. Analysis of variance (ANOVA) was conducted to test the significant difference ($p < 0.05$) of the experimental results with Tukey test. Data are reported as mean values of triplicates ($n = 3$) ± standard deviation (SD). Data with significant difference between them ($p < 0.05$) will display difference letters (a,b,c and etc.).

Results and discussion

Rheological properties

Stress sweep tests were done to determine the effects of different concentration of sugar on its linear viscoelastic region (LVR). Figure 1 shows the effects of different types of sugar at 4%, 6% and 8% sugar concentrations (w/w) on the storage modulus (G'). All samples in Figure 1 displayed similar results in which as the stress increased to a certain level, G' value started to decrease. The point where G' value started to decrease is considered as the maximum value of stress that can be applied to the sample before it deforms. This indicates that all cryoprotectants display similar behaviour when subjected to a range of stress.

G' value of samples with different formulations also displayed similar result. This is shown when all sample displayed similar curve trend when subjected to stress. However, it was found that 4% (w/w) sugar concentration for all samples displayed the lowest value of G' and as concentration increased, the G' values also increased. Another observation that is apparent in Figure 1 is that as sugar concentration increased, the LVR became wider. Strong gels exhibit a much wider range of LVR compared to weak gels (Steffe, 1996) as evidenced when the sugar concentration increased, the gel strength of all samples increased.

Different types of sugar did not display any difference in trend and this implies that all types of sugars behaved similarly in which as concentration increased, the G' value for LVR increased. Results obtained also suggested that as sugar concentration increased, the structure of the fish paste became more intact and rigid which is represented by the G' value (Campo-Deaño Tovar and Borderías, 2010). As a result, the fish paste is predicted to have better gel strength when compared to others. As sugar concentration increased, the moisture content and water activity decreased (Chen *et al.*, 2002) thus, the cryoprotective quality was enhanced.

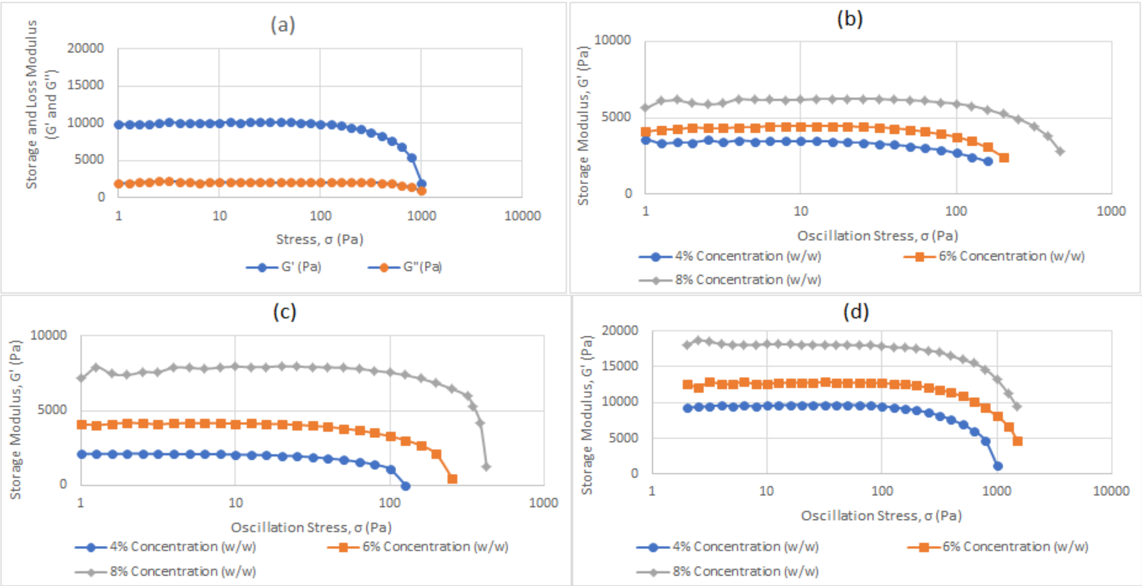

Figure 1: The storage modulus (G') for fish mince added with (a) control, (b) sucrose, (c) sorbitol, (d) mannitol at 4%, 6% and 8% (w/w) concentration subjected to stress sweep

Temperature sweep tests were done to determine the effects of sugar concentration on the gelation profile of fish paste. Figures 2 displays the effects of sugar concentration on the gelation profile of fish paste with different sugar combinations. All samples show the 4-stage gelation. However, 6% (w/w) sugar concentration showed a much more distinct peak between the first gelation point and second gelation point (between 40°C to 55°C) especially for sucrose and mannitol. This suggests that between these two points, the protein-protein interaction was more complex and requires more energy to dissociate (Poowakanjana, Mayer and Park, 2012). Lower energy consumption to induce gelation will display lower peak. These are represented by peaks with 4% and 8% sugar concentrations when compared with 6%. The final gelation point of each sample was found to decrease as concentration increased. These points are defined as the temperature where the second G' value started to increase (50°C to 60°C range). From this point onwards, gel strengthening phase took place. The protein (actin) started to form a much denser, complex and irreversible gel network with other proteins (Campo-Deaño, Tovar and Borderías., 2010). The amount of protein networking at this stage increased thus reinforcing the gel matrix to form irreversible gel (Campo-Deaño et al., 2009). Lower gelation temperature is beneficial for food manufacturers as less energy is required to induce gelation.

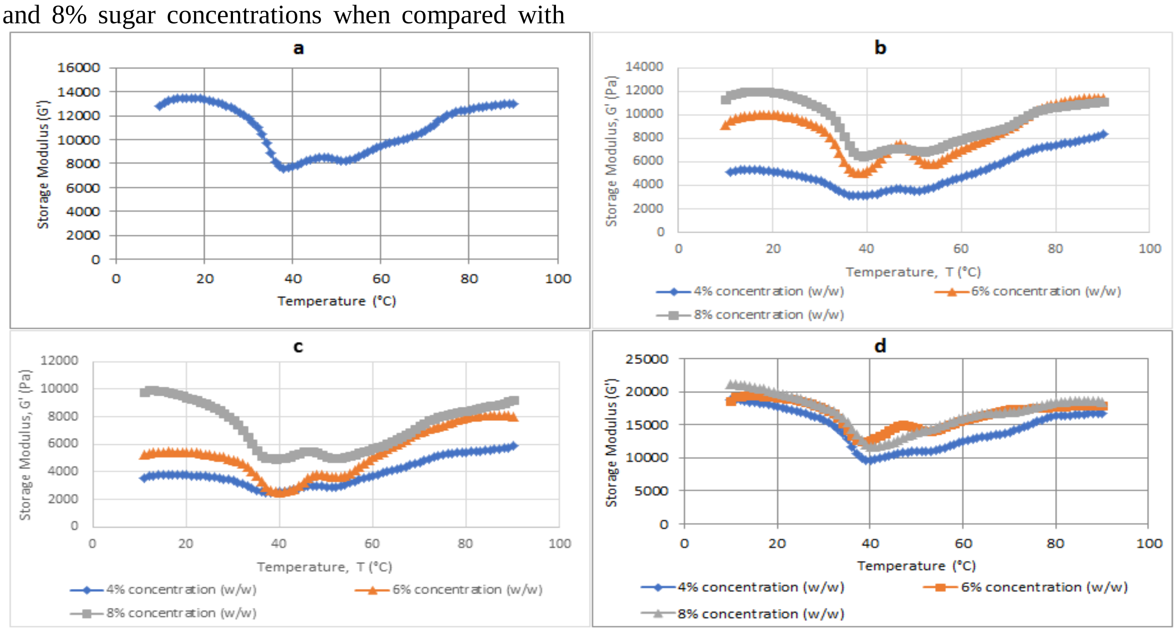

Figure 2: The storage modulus (G') for (a) control fish mince and fish mince added with (b) sucrose, (c) sorbitol, (d) mannitol at 4%, 6% and 8% (w/w) concentration subjected to temperature sweep

The G' value was found to be similar for samples at 6% at 8% at the end of the temperature profile (80°C to 90°C). This temperature range is when the final structure of surimi is shaped and becomes permanent (Belibagli et al., 2003). This suggests that the gelling strength of sugar concentration at 6% and 8% might have a similar value. However, this will be further discussed and proven with texture analysis.

Textural properties

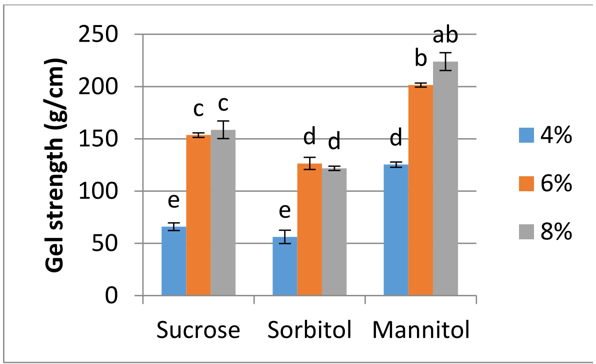

Figure 3: Effects of different sugar concentrations on the gel strength of fish gel. Values are means ± SD of triplicates (*n* = 3). Different letters indicate significant differences ($p < 0.05$).

Figure 3 shows that the gel strength of each sample increased almost twice from 4% to 6% sugar concentration. A higher value in gel strength can be related to the cryoprotective effect. As the concentration increases, protein deformation is better prevented thus producing better gel quality (Huda, Leng and Nopianti., 2011; Yoon and Lee, 1990). Even though all samples displayed similar trend, only mannitol displayed a significant difference at different mannitol concentrations ($p < 0.05$). However, 6% sugar concentration did not show any significant difference with 8% concentration ($p > 0.05$). Although initially the hypothesis was that 8% sugar concentration was to yield higher gel strength, the obtained data do not seem to support that hypothesis. Huda, Leng and Nopianti. (2011) also found that gel strength did not differ when cryoprotectant (polydextrose)'s concentration was increased from 6% to 9%. Another research on threadfin bream also showed a minimal increase of gel strength when concentration of sucrose:sorbitol (1:1 w/w) was increased from 6% to 8% (Parvathy and George, 2014). This indicates that the cryoprotective effect in this range (6% to 8%) might be similar.

Poowakanjana, Mayer and Park (2011) stated that certain sugar might inhibit gel formation. This might be true for the case of sugar at 4% concentration as all samples at this concentration appeared to display the lowest gel strength. Different types and concentrations of cryoprotectants differently affect the rate of protein denaturation, chemical structure and gelation properties of surimi (Huda, Leng and Nopianti., 2011; Belibagli et al., 2003; Sych et al., 1991). Overnight frozen storage was reported to induce protein (myosin) deformation which leads to lower gel strength (Nopianti et al., 2012). Without an effective cryoprotectant, the surimi gel quality decreases rapidly. However, when compared to the rheological tests done on the viscoelastic properties of samples, it was found that the results presented and recorded supported all the outcomes of texture analysis, thus, making rheology a feasible method to predict the gelling behaviour of fish paste.

Conclusions

In the present work, mannitol has showed promising results and could be considered as an alternative to sucrose and sorbitol which are commercially used in the surimi industry. Rheological tests and texture analysis showed similar trends for all sugar combinations. Sample with mannitol presented the highest value of gel strength which indicates high quality when compared with other fish gel and sugar combinations. Effects of sugar concentrations on gelling strength showed only significant difference from 2% (w/w) to 4% (w/w). Increment from 6% to 8% did not show any significant difference on gelling strength. Thus, using 6% sugar concentration would be better in achieving a healthier low calorie surimi. 6% (w/w) concentration could be used in the surimi industry whilst maintaining its quality similar to the commercial amount of 8% (w/w).

References

Belibagli, K.B., Speers, R.A., & Paulson, A.T. (2003). Thermophysical properties of silver hake and mackerel surimi at cooking temperatures. Journal of Food Engineering, 60, 439-448.

Benjakul, S., Visessanguan, W., Riebroy, S, Ishizaki, S., and Tanaka, M. (2002). Gel-forming properties of surimi produced from bigeye snapper, Pricanthus tayenus and P macracanthu, stored in ice. Journal of the Science of Food and Agriculture 82; 1442-1451

Campo-Deaño, L., Tovar, C.A., Pombo, M.J., Solas, M.T., and Borderías, A.J. (2009). Rheological study of giant squid surimi (Dosidicus gigas) made by two methods with different cryoprotectants added. Journal of Food Engineering 96 pg. 26-33

Campo-Deaño, L., Tovar, C.A., & Borderías, A.J. (2010). Effect of several cryoprotectants on the physicochemical and rheological properties of suwari gels from frozen squid surimi made by two methods. Journal of Food Engineering, 97, 457- 464.

Carvajal, P.A., Lanier, T.C., & Macdonald, G.A. (2005). Stabilization of proteins in surimi in J.W. Park (2nd Edition), 493-576 pp. CRC Press, Boca Raton.

Carvajal, P.A., MacDonald, G., & Lanier, T.C. (1999). Cryostabilization mechanism of fish muscle proteins by maltodextrins. Cryobiology, 38,(1), 16-26.

Chen, W.S., Liu, D.C., & Chen, M.T. (2002). Effects of high level of sucrose on the moisture content, water activity, protein denaturation and sensory properties in Chinese-style pork jerky. Asian-Australasian Journal of Animal Science, 15(4), 585-590.

Dileep, A.O., Shamasundar, B.A., Binsi, P.K., Badii, F., and Howell, N.K. (2011). Composition, physicochemical and rheological properties of fresh bigeye snapper fish (Pricanthus hamrur) mince. Journal of Food Biochemistry ISSN 1745-4514

Ferry, J.D. (1980). Viscoelastic properties of polymers (3rd ed.) New York: John Wiley and Sons, Inc.

Herrera, J.R., & Mackie, I.M. (2004). Cryoprotection of frozen-storage actomyosin of farmed rainbow trout (Oncorhynchus mykiss) by some sugars and polyols. Food Chemistry, 84, 91-97.

Huda, N., Leng, O.H., & Nopianti, R. (2011). Cryoprotective effects of different levels of polydextrose in Threadfin Bream surimi during frozen storage. Journal of Fisheries and Aquatic Sciences, 6(4), 404-416.

Karthikeyan, M. Dimeep, A.O, and Shamasundar, B.A. (2006). Effect of water washing on the functional and rheological properties of proteins from threadfin bream (Nemipterus japonicas) meat. International Journal of Food Sciencs and Technology, 41, 1002-1010

Macdonald, G.A., & Lanier, T.C. (1994). Actomyosin stabilization to freeze-thaw and heat denaturation by lactate salts. Journal of Food Science, 59, 101-105.

Nopianti, R., Huda, N., Fazilah, A., Ismail, N., and Easa, A.M.(2012). Effect of different types of low sweetness sugar on physicochemical properties of threadfin bream surimi (Nemipterus spp.) durinf frozen storage. International Food Research Journal 19 (3). Pg 1011-1021

Parvathy, U., & George, S. (2014). Influence of cryoprotectant levels on storage stability of surimi from Nemipterus japonicas and quality of surimi-based products. Journal of Food Science and Technology, 51(5), 982-987.

Poowakanjana, S., Mayer, S.G., Park, J.W. (2011). Optimum chopping condition for Alaska Pollock, Pacific Whiting and Threadfin Bream surimi paste and gel based on rheological and raman spectroscopic analysis. Journal of Food Science 77 (4), E88-E97

Ramírez, J.A., Uresti, R.M., Velazquez, G., and Vázquez, M. (2011). Food hydrocolloids as additives to improve the mechanical and functional properties of fish products: A review. Food Hydrocolloids 25 pg. 1842-1852

Shenouda, S.Y.K. (1980). Protein denaturation in frozen fish. Advances in Food Research, 26, 175-311.

Sych, J., Lacroix, C., & Carrier, M. (1991). Determination of optimal level of lactitol for surimi. Journal of Food Science, 56, 285-290

Yoon, K.S, & Lee, C.M. (1990) Cryoprotectant effects in surimi and surimi / mince-based extruded products. Journal of Food Science, 55, 1210-1216.

Zhou, A., Benjakul, S., Pan, K., Gong, J., & Liu, X. (2006). Cryoprotective effects of trehalose and sodium lactate on tilapia (Sarotherodon nilotica) surimi during frozen storage. Food Chemistry, 96, 96-103.