Original article

Effect of storage on the gel-forming properties of yam-containing surimi gels

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Summary The breaking forces, deformations and water-holding capacities of pollock surimi gels (PSG) containing 20% fresh Tainung No. 1 (TNG1) yam (*Dioscorea alata*) stored at room temperature, 17 and 10 °C, were determined for 12 weeks to evaluate the feasibility of using fresh yam as a healthy ingredient and an alternative source for starch in surimi seafoods. The results showed that the texture properties of TNG1-PSG decreased during storage regardless of the storage temperatures, except for an insignificant change found in the water-holding capacity at 10 °C. Most changes in the texture properties occurred within 1 week, thus the use of fresh TNG1 immediately after harvest is required for producing TNG1-PSG with good texture properties. Frozen storage of TNG-PSG was also undertaken at −20 °C for 6 months. After 6-months of storage, the breaking force and water-holding capacity of TNG1-PSG decreased by about 22% and 19%, respectively.

Keywords Storage, surimi, texture, Yam.

Introduction

Yam has been classified as one of the important staples in the diets of many tropical countries because of the carbohydrate it provides. For example, yam is widely grown in west Africa (Waitt, 1963; Coursey & Haynes, 1970). Some yams are also used as medicines in oriental countries to prevent diarrhoea and diabetes (Hsu *et al.*, 1984; Yen, 1992), thus yams are considered to be helpful to human health. It has been suggested that yam (*Dioscorea alata*) have nutritional superiority when compared with other tropical root crops (Wanasundera & Ravindran, 1994). Yam is composed mainly of starch (75–84% of the dry weight) with small amounts of proteins, lipids and most vitamins, and is very rich in minerals (Omonigho, 1988; Lasztity *et al.*, 1998). The average crude protein content of seven yam cultivars was 7.4%, which was higher than those reported for other tropical roots, and the protein from yam also showed a better amino acid balance for human nutrition (Baquar & Oke, 1976; Bradbury, 1988; Marcus *et al.*, 1998). Researches have shown that yam extracts can reduce blood sugar (Hikino *et al.*, 1986; Undie & Akubue, 1986) and blood lipid (Araghiniknam *et al.*, 1996), inhibit microbe activity (Hu *et al.*, 1996, 1999; Kelmanson *et al.*, 2000) and show anti-oxidative activity (Farombi *et al.*, 2000). Farombi *et al.* (2000) demonstrated that brown yam flour contained natural anti-oxidants and might mitigate damage and diseases caused by oxidative components. Chen *et al.* (2002) reported *Dioscorea alata* L. Var. *purpurea* (M.) Pouch. (Purpurea), one strain of Taiwanese yam tuber, exerted trophic effects in the caecum by mediating luminal fermentation. Fang & Kong (2002) found that yam (*Dioscrea japonica*) could enhance serum IgG concentrations and promote splinic lymphocyte proliferation. The active components of yam include steroidal sapogenin, glycan and polyphenol oxidase. Diosgenin, extracted from *Dioscorea* species, is a natural steroidal sapogenin used as a precursor in the industrial synthesis of steroids. Araghiniknam *et al.* (1996) found that the steroid extract from yam significantly reduced serum lipid peroxidation, lowered serum triglyceride and phospholipid levels, and increased high density lipid level in older humans. Discorin, the storage protein of yam tuber, was reported to display scavenging activity towards 1,1-diphenyl-2-picrylhydrazyl radical.

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Dioscorans, a glycan isolated from *Dioscorea japonica*, was shown to significantly inhibit the hypoglycaemic affects in normal and alloxan-induced hyperglycaemia mice (Hikino *et al*., 1986).

Surimi is a washed fish mince to which cryoprotectants, such as sorbitol and sucrose, are added, to maintain protein functionality during frozen storage (Lee, 1984; Matsumoto & Noguchi, 1992). Surimi can be further processed into various surimi-based gelled products, such as artificial crab legs and meats. Such gelled surimi seafoods are popular to consumers because of their unique texture properties. Starch, such as potato starch, is often added in the range of 8–15% to modify the textural properties of surimi-based seafoods. Our main interest was to evaluate the potential of using yam as a health ingredient and an alternative source of starch in surimi seafoods.

However, the use of yam may also change the textural properties of surimi seafoods. It has been reported that the hardness and cohesiveness of cooked trifoliate yam (*Dioscorea dumetorum*) increased tremendously at tropical ambient temperatures after 72 h of storage (Afoakwa & Sefa-Dedeh, 2001, 2002a). Afoakwa & Sefa-Dedeh (2002a) pointed out that the variation in starch microstructure led to the hardening of the tuber. Therefore, it is important to determine the effect of the quality change after harvest on the textural properties of surimi gel containing yam. The effect of storage on the composition, appearance, and physical properties of yam has been investigated (Treche & Agbor-Egbe, 1996; Afoakwa & Sefa-Dedeh, 2001, 2002a,b; Sefa-Dedeh & Afoakwa, 2002). In this study, the effect of storage on the texture properties of surimi gel containing fresh yam stored at room temperature, 17 and 10 °C were investigated. The effect of frozen storage on the texture properties of yam-containing surimi gels stored at −20 °C was also determined.

Materials and methods

Frozen high grade Alaska pollock (*Theragra chalcogramma*) surimi were purchased from Kasei Frozen Foods Works Co., Ltd, Juifang, Taipei, Taiwan. The surimi was stored at −20 °C until use. Potato starch from Sigma Chemicals Co. (St Louis, MO, USA) for determination of amylase activity was used as the control additive in the surimi gel. Tainung No. 1 (TNG1) yam (*D. alata*), within 1 week post-harvest, was purchased from a local farmer in Mingjian Shiang, Nantou county, Taiwan.

Chill storage of fresh yam

Fresh yam was stored at three temperatures until sampling, they were: room temperature (25 ± 8 °C), 17 ± 2 °C and 10 ± 1.5 °C. The sampling times were 0, 1, 3, 7 and 12 weeks. At each sampling point, stored yams were removed, peeled and blended with pollock surimi to produce yam-containing surimi gels.

Surimi gel preparation

The frozen surimi was partially thawed at room temperature for approximately 2 h to prevent rapid increase of sample temperature during the subsequent blending procedures. The sample temperature increased quickly during the blending procedure. In order to prevent undesirable protein denaturation and gellation prior to cooking, and also to obtain proper mixed sample, it was easier to work with only partially thawed surimi instead of complete thawed surimi. Surimi was blended with a 2% NaCl and 20% yam in a mixer (Model AT7; Moulinex Co., Ecully Cedex, France) for 4 min to produce a mixture with total weight of 1 kg. Ice-water was also added during mixing to adjust the final moisture content to 78% while maintaining the temperature of the mixture in the range of 5–10 °C. When potato starch powder was used, dry weight of the powder was equal to that of fresh yam. The mixture was extruded into stainless steel cooking tubes (inside diameter 3.0 cm, length 15 cm), and surimi gels were then produced by heating in a 90 °C water-bath for 15 min, followed by cooling in ice-water for 10 min. Surimi gels were stored in ziplock bags and refrigerated at about 5 °C. The gels were removed from refrigerated storage within 48 h, left at room temperature for 1 h, and then cut into small sections (diameter 3.0 cm, length 3.0 cm) for texture measurements.

Measurement of texture properties of yam-containing surimi gel

The texture properties of yam-containing surimi gel were measured by a texture analyzer (Model TA-XT2; Stable Micro systems, Haslemere, UK) using a ball plunger with a diameter of 5 mm at a constant punch speed of 4 cm min^{-1} with a maximum punch distance of 15 mm, and the results were expressed as breaking force (g) and deformation (mm). Water-holding capacity was determined by slicing the gel into a thickness of about 2 mm, wrapping about 5 g sliced gel with filter paper (Whatman no. 1) and then centrifuging at $3000 \times g$ for 20 min. The percentage ratio of the weight of the gel after centrifuging to the original weight provided a water-holding capacity index.

Frozen storage of yam-containing surimi gels

Pollock surimi gel (PSG) containing 20% fresh yam or potato starch was stored at −20 °C. The textural properties of these gels were determined at 0, 1, 2, 3 and 6 months. The textural properties were determined after thawing and measurements were carried out at room temperature (22 ± 4 °C).

Statistical analysis

One-way analysis of variance (one-way ANOVA) was conducted using a package (SAS Institute Inc., Cary, NC, USA). Duncan's multiple ranges test was used to determine the significant difference between different treatments.

Results and discussion

In a previous study, we measured the texture properties of PSG containing 20 and 30% TNG1. The results showed that PSG containing 30% TNG1 had poor texture properties, indicated by low breaking force and deformation values (Chiang *et al.*, 2005). Therefore, in this study we evaluated the effect of TNG1 storage on the texture properties of TNG1 containing PSG (TNG1-PSG) on the basis of 20% level. This particular yam species was selected because its price was the cheapest and its anti-oxidative activities were the highest among five common Taiwanese yam cultivars.

Texture properties of PSG containing TNG1 stored at three different temperatures

Table 1 shows the effect of TNG1 storage on the breaking force of TNG1-PSG. When incorporated TNG1 stored at room temperature, a significant decrease in the breaking force of TNG1-PSG was found even after 1 week of storage. For TNG1 stored at 17 and 10 °C, the breaking forces also significantly decreased at 1 week, but the level of the decline at 10 °C was lower than that of TNG1 stored at room temperature. After 1 week, the breaking forces at 17 and 10 °C were higher than those at room temperature. The results indicated that using TNG1, stored at chill temperatures, as the ingredient for TNG1-PSG could obtain higher breaking force values. Table 2 shows the effect of TNG1 storage on the deformation of TNG1-PSG. Regardless of the storage temperatures, the deformations of TNG1-PSG decreased during storage. Like the breaking force, even 1 week storage could result in a significant change in the deformation. In general, the deformations at chill temperatures were higher than those at room temperature. It was noted that at 10 °C significant changes in the deformation were only observed at 1 week, while no significant change was found after 1 week. Afoakwa & Sefa-Dedeh (2001, 2002a) found that the hardness and cohesiveness of cooked trifoliate yam (*Dioscorea dumetorum*) increased tremendously at tropical ambient temperature (28 °C) after 72 h storage. Afoakwa & Sefa-Dedeh (2002b) stated that storage caused decreases in the rheological properties of trifoliate yam starch. Therefore, the decrease of the texture properties of TNG1-PSG was mainly because of the change in the rheological properties of TNG1 starch during storage. Our data showed that PSG containing TNG1 stored at chill temperatures (17 and 10 °C) resulted in higher texture properties than at room temperature. This finding agreed with the result reported by Afoakwa & Sefa-Dedeh (2002b), in which low temperature storage (4 °C) significantly decreased the rate of texture deterioration in trifoliate yam starch. Table 3 shows the effect

Table 1 The changes of the breaking force of pollock surimi gel containing 20% yam stored at room temperature, 17 and 10 °C

Week	Room temperature	17 °C	10 °C
0	328 ± 17^{a}	328 ± 17^{a}	328 ± 17^{a}
1	176 ± 17^{c}	191 ± 17^{d}	275 ± 15^{b}
3	146 ± 11^{d}	266 ± 11^{b}	227 ± 15^{d}
7	177 ± 15^{c}	248 ± 10^{c}	252 ± 7^{c}
12	228 ± 18^{b}	272 ± 5^{b}	254 ± 12^{c}

The values are mean ± SD.
The values in the same column followed by different superscript letters were significantly different ($P < 0.05$).

Table 2 The changes of the deformation of pollock surimi gel containing 20% yam stored at room temperature, 17 and 10 °C

Week	Room temperature	17 °C	10 °C
0	9.7 ± 0.6^{a}	9.7 ± 0.6^{a}	9.7 ± 0.6^{a}
1	7.9 ± 0.5^{c}	7.4 ± 0.4^{c}	8.8 ± 0.3^{b}
3	7.2 ± 0.3^{d}	8.6 ± 0.2^{b}	8.4 ± 0.4^{b}
7	8.3 ± 0.5^{c}	8.8 ± 0.4^{b}	8.6 ± 0.2^{b}
12	8.9 ± 0.7^{b}	9.4 ± 0.3^{a}	8.7 ± 0.2^{b}

The values are mean ± SD.
The values in the same column followed by different superscript letters were significantly different ($P < 0.05$).

Table 3 The changes of the water-holding capacity of pollock surimi gel containing 20% yam stored at room temperature, 17 and 10 °C

Week	Room temperature	17 °C	10 °C
0	83.8 ± 1.2^{a}	83.8 ± 1.2^{a}	83.8 ± 1.2*
1	80.7 ± 1.4^{b}	80.7 ± 2.2^{b}	82.3 ± 2.5
3	77.6 ± 1.4^{c}	85.4 ± 1.3^{a}	84.8 ± 2.8
7	78.9 ± 2.2^{bc}	83.1 ± 0.8^{a}	81.8 ± 2.2
12	80.7 ± 2.4^{b}	80.6 ± 3.2^{b}	81.8 ± 2.0

*The values in the same column were not differ significantly.
The values are mean ± SD.
The values in the same column followed by different superscript letters were significantly different ($P < 0.05$).

of TNG1 storage on the water-holding capacity of TNG1-PSG. The water-holding capacity of PSG containing TNG1 stored at room temperature decreased during storage, in particular, the water-holding capacities of TNG1-PSG at room temperature for 3 and 7 weeks were lower than 80%. At 17 and 10 °C, the changes in water-holding capacity were insignificant. The overall data indicated that PSG containing TNG1 stored at 17 and 10 °C resulted higher breaking force, deformation and water-holding capacity values than that stored at room temperature. However, the differences in the texture properties of TNG1-PSG between 17 and 10 °C were negligible.

Effect of frozen storage on the texture properties of TNG1-PSG

Frozen storage is a common way to preserve surimi gelled seafoods, thus, it is important to determine the effect of frozen storage on the texture properties of TNG1-PSG. The frozen storage was conducted at −20 °C for 6 months. Figure 1 shows the effect of frozen storage on the breaking force of TNG1-PSG using PSG containing potato starch (PS-PSG) as the control. Although there was no difference in the breaking force between fresh (unfrozen) TNG1-PSG and PS-PSG, they exhibited extremely different behaviours during frozen storage. The breaking force of TNG1-PSG decreased after frozen, however, frozen PS-PSG tended to have higher breaking force than fresh (unfrozen) PS-PSG. Figure 2 shows the effect of frozen storage on the deformation of TNG1-PSG. Fresh TNG1-PSG showed a lower deformation value than fresh PS-PSG. During frozen storage, there was no significant difference in the deformation of TNG1-PSG, but the deformation of PS-PSG increased slightly after freezing for 2 months. Figure 3 shows the effect of frozen storage on the water-holding capacity of TNG1-PSG. It was found that the water-holding capacity of fresh TNG1-PSG was similar to that of PS-PSG, but frozen TNG1-PSG had lower water-holding capacity than frozen PS-PSG. The water-holding capacity of frozen TNG1-PSG decreased after frozen for 1 and 2 months, and no significant change was found after 2 months. Compared with fresh PS-PSG, frozen PS-PSG also showed lower water-holding capacity values. The data indicated that frozen TNG1-PSG had a lower breaking force, deformation and water-holding capacity than frozen PS-PSG. Although after 6-months of storage the breaking force and water-holding capacity of TNG1-PSG decreased by about 22 and 19%, respectively, the texture of TNG1-PSG could be graded between AA and A grades based on a folding test developed for grading surimi gel quality in Japan.

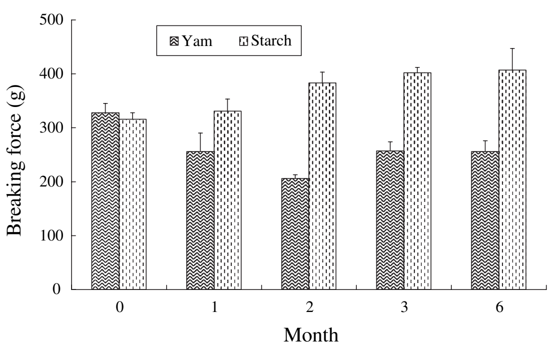

Figure 1 The change of the breaking force of surimi gel containing yam or potato starch during frozen storage at −20 °C.

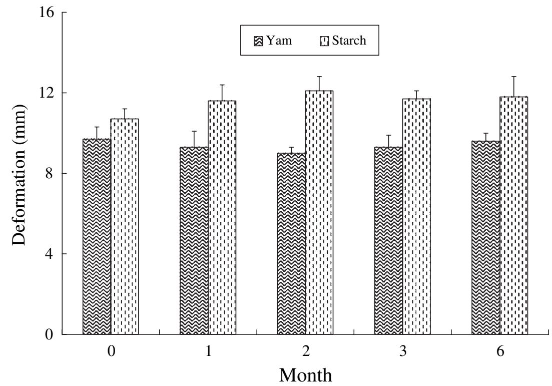

Figure 2 The change of the deformation of surimi gel containing yam or potato starch during frozen storage at −20 °C.

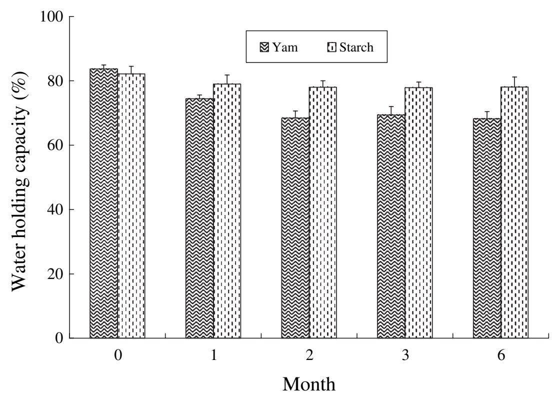

Figure 3 The change of the water-holding capacity of surimi gel containing yam or potato starch during frozen storage at −20 °C.

Conclusions

The breaking force, deformation and water-holding capacity of PSG containing 20% TNG1 stored at room temperature, 17 and 10 °C decreased during storage with the exception of an insignificant change in the water-holding capacity at 10 °C. Compared with chill temperatures (17 and 10 °C), room temperature resulted in lower texture values. Most changes in texture properties occurred within 1 week. Therefore, it is highly recommended that (i) TNG1 should be made into dried powder immediately after harvest to prevent the loss of texture properties, or (ii) fresh TNG1 should be used immediately after harvest to produce TNG1-PSG with good texture properties. Frozen TNG1-PSG stored at −20 °C had a lower breaking force, deformation and water-holding capacity than frozen PS-PSG. Although after 6-months of storage the breaking force and water-holding capacity of TNG1-PSG decreased to about 22% and 19%, respectively, the texture of TNG1-PSG could be graded between AA and A grades based on a folding test developed for grading surimi gel quality in Japan.

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