Food Science and Technology Research, **22** (3), 307–316, 2016
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doi: 10.3136/fstr.22.307

http://www.jsfst.or.jp

Technical paper

Noodle Qualities of Fresh Pasta Supplemented with Various Amounts of Purple Sweet Potato Powder

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Received September 15, 2015 ; Accepted January 5, 2016

Sweet potato is a nutritious, cost-effective and abundantly available food crop in Asia. In an effort to utilize sweet potato for food processing, the effects of purple sweet potato powder (PSPP)-supplementation on the quality of fresh pasta was determined. Results showed that PSPP-supplementation produced fresh pasta dark purple in color, attributable to the intrinsic anthocyanin content. Moreover, PSPP provided a higher amount of gelatinized starch, resulting in softer and more elastic raw fresh pasta; and the boiled fresh pasta showed a softer texture, as indicated by its hardness, rupture force and energy. However, PSPP-supplementation decreased the cooking weight gain of fresh pasta. Sensory evaluation rated the quality of boiled fresh pasta with 7.5% and 10% PSPP as more acceptable and equally acceptable as the control, respectively. Thus, this study suggests that PSPP-supplementation results in an acceptable noodle product, potentially increasing the utilization of purple sweet potato.

Keywords: purple sweet potato, fresh pasta, noodle quality

Introduction

Pasta is generally a simple dough product made of durum wheat semolina and water, and is obtained by extrusion or lamination and successive drying (Alexander, 2000; Carini *et al.* 2009). Fresh pasta, on the other hand, is usually made of common wheat flour and is not subjected to drying, but it is pasteurized and stored at temperatures < 4℃ (Carini *et al.* 2010). Pasta, including fresh pasta, is one of the most consumed food products in the world because of its ease of cooking and nutritional qualities (Brennan *et al.* 2004; Nouviaire *et al.* 2008). In addition, durum wheat semolina pasta, common wheat flour fresh pasta and starch noodles are considered healthy, and are ideally suited for enrichment with nutrients (Silva *et al*. 2013).

Sweet potato is an abundantly available, inexpensive food crop in developing countries; however, it remains an underutilized food resource (Hathorn *et al*. 2008). It has significant socio-economic importance because of its high nutrient value, and superior carotenoid and anthocyanin contents, which are responsible for the stable yellow, orange and purple colors of sweet potato varieties (Yang and Gadi, 2008; Antonio *et al*. 2011; Lu and Gao, 2011). Their superior biochemical and nutritional composition makes them a better alternative than synthetic food colorants, and give them high potential as value-added and functional food products in human food systems (Suda *et al.* 2003; Bovell-Benjamin, 2007). “Ayamurasaki” is a purple sweet potato variety that has received much attention because of its nutritional value and heat stable anthocyanin content (Oki *et al.* 2002; Bovell-Benjamin, 2007). Anthocyanin stability in purple-fleshed sweet potato has been

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confirmed at steaming and baking temperatures (Kim *et al.* 2012). Thus, “Ayamurasaki” has been used as a natural food colorant in beverages, confectioneries, breads and noodles (Oki *et al.* 2002; Suda *et al*. 2003; Yang and Gadi, 2008; Choi *et al*. 2011). However, sufficient studies on the use of “Ayamurasaki” purple sweet potato powder for pasta processing and its effect on noodle quality are required.

“Yumehiryu” is wheat flour milled from the cultivar “Yumechikara”. It is characterized by a low ash content, bright color and high protein content, and produces extra strong dough, making it suitable for fresh pasta processing (Ito *et al.* 2012). In this study, the effects of purple sweet potato powder (PSPP)-supplementation on the moisture content, cooking quality, color, texture, rupture and sensory properties of “Yumehiryu” fresh pasta were evaluated.

Materials and Methods

Fresh pasta treatments and preparation Fresh pasta was prepared using the following formulation as the control: 200 g Yumehiryu wheat flour (13.5% moisture, Nisshin Flour Milling Co., Ltd., Tokyo, Japan), 3 g salt (The Salt Industry Center of Japan, Tokyo, Japan), 3 g olive oil (J-Oil Mills, Inc., Tokyo, Japan) and 65 g water. For the supplemented treatments, 2.5, 5.0, 7.5, 10% of the original wheat flour was replaced with PSPP (Kumamoto Flour Milling Co., Ltd., Kumamoto, Japan). PSPP was processed by heat-treatment, resulting in almost complete starch gelatinization, as evidenced by 54% damaged starch content (Santiago *et al*. 2015), and maintenance of its dark purple color, with L*, a* and b* values of 52.70 ± 1.35, 21.86 ± 0.51, −8.13 ± 0.33, respectively. All ingredients were mixed using a food processor (MK-K80P-W, Panasonic Corporation, Osaka, Japan) for 1 min at high speed and extruded through a no. 15 dice using a pasta machine (SIRIOMATIC TR-5, Imperia Corporation, Sant’Ambrogio di Torino, Italy). The extruded fresh pasta were cut into approximately 20 cm strips using kitchen scissors, and stored for 2 hrs at 20℃ in a polyethylene bag. Raw fresh pasta strips were boiled for 3 or 7 min in 3 L of boiling water, and then cooled in a water bath at 20℃ for 3 min. Excess water on the surface of the fresh pasta was dried using paper towel.

Moisture content and cooking quality of fresh pasta Moisture content of the raw and boiled fresh pastas was determined based on the AOAC official method (AOAC, 2000). After removing any excess water, the boiled fresh pastas (B) were weighed and then oven-dried at 135℃ for 3 hrs to determine the residual dry matter (R). The cooking

$$\text{CWG}\ (\%) = \frac{B - R}{I} \times 100 \qquad \cdots\cdots \text{Eq. 1}$$

$$\text{CDML}\ (\%) = \frac{I - R}{I} \times 100 \qquad \cdots\cdots \text{Eq. 2}$$

weight gain (CWG) and cooking dry matter loss (CDML) were determined as a percentage of the initial dry matter (I), i.e., the dry matter of raw fresh pastas, by using the above Eq. 1 and 2, respectively.

Texture properties of fresh pasta Texture profile of raw and boiled fresh pastas was determined using a creep meter (model RE2-33005C, YAMADEN Co., LTD., Tokyo, Japan) fitted with a 200 g load cell. Fresh pasta (5-cm long) was compressed twice up to 70% strain rate of the original thickness using a cylindrical plunger 3 mm in diameter (Type No.4 YAMADEN Co., LTD.) in a flat sample stage (Type No.1, YAMADEN Co., LTD.) and at a speed of 0.5 mm/s. Hardness, elasticity, cohesiveness, gumminess, chewiness and thickness of the fresh pasta were calculated from the resulting stress-strain curves.

Rupture properties of fresh pasta Rupture properties of raw and boiled fresh pastas were measured using a creep meter (model RE2-33005C, YAMADEN Co., LTD.) fitted with a 2000 g load cell as reported by Ito *et al*. (2012). The rupture test was determined using a wedge plunger (Type No.49, YAMADEN Co., LTD.). The 5-cm-long pasta strips were placed in the center of the sample stage (Type No.1, YAMADEN Co., LTD.) and ruptured crosswise at a speed of 5 mm/s up to 90% strain rate. Rupture force (RF), rupture deformation (RD) and rupture energy (RE) were calculated in reference to the force-deformation curves.

Color measurement and images of raw and boiled noodles Color of the raw and boiled noodles was determined using a colorimeter (CR-400, Konica Minolta Sensing, Inc., Tokyo, Japan) using the Commission International Del’Eclairage (CIE) L^*(brightness) a^* (red-green) b^*(yellow-blue) color system. Images of three noodles arranged side-by-side at 1 cm intervals were recorded with a scanner (model GT-S630, Seiko Epson Corporation, Suwa, Japan).

Sensory evaluation Quantitative descriptive analysis of PSPP-supplemented fresh pasta boiled for 3 min in terms of purple color (1-no purple to 9-extremely purple), sweet potato flavor (1-not perceivable to 9-extremely strong), sweet potato taste (1-not perceivable to 9-extremely strong), hardness (1-extremely soft to 9-extremely hard), elasticity (1-extremely low to 9-extremely high), cohesiveness (1-extremely low to 9-extremely high) and overall acceptability (1-disliked extremely to 9-liked extremely) were evaluated and compared with the control.

Statistical analysis Statistical analysis was performed using SPSS for Windows (ver. 17.0). ANOVA and Tukey’s multiple range tests were used to compare means at a 5% significance level. Pearson’s bivariate test was used to evaluate the correlation of parameters. All data except for MC, CWG, CDML, color properties and sensory evaluation were measured eight times. MC, CWG and CDML were performed 3 times and color properties were measured 10 times. Sensory evaluation was carried out by 18 panelists.

Results

Moisture content and cooking properties of fresh pasta Moisture content and cooking properties of raw and boiled fresh

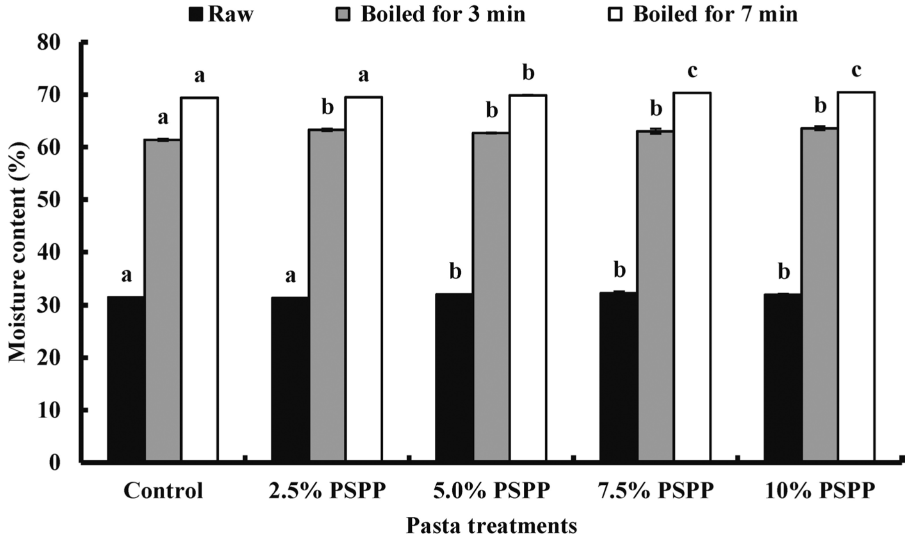

Fig. 1. Moisture content of raw and boiled noodles[1)]

[1)]Vertical bars indicate the standard deviation of each value. The data points followed by different letters within series are significantly different ($p < 0.05$).

Abbreviations: PSPP, purple sweet potato

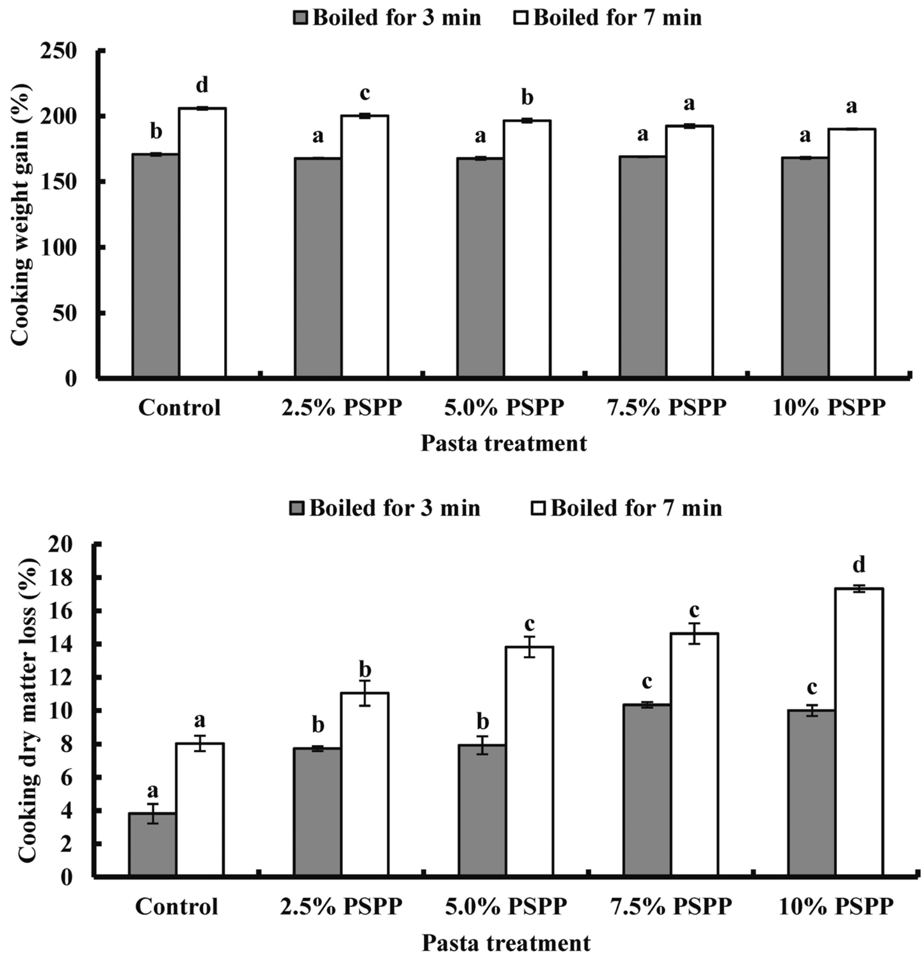

Fig. 2. Cooking properties of fresh pastas[1)]

[1)]Vertical bars indicate the standard deviation of each mean value. The data points followed by different letters within series are significantly different ($p < 0.05$).

Abbreviations: PSPP, purple sweet potato powder

pastas supplemented with PSPP are presented in Fig. 1 and 2, respectively. Figure 1 shows that the moisture content of raw fresh pastas supplemented with 5.0, 7.5 and 10% PSPP was significantly higher than the control ($p < 0.05$). Similarly, after boiling for

Table 1. Texture properties of fresh pastas supplemented with PSPP[1)]

Pasta Treatment	Raw	Boiled for 3 min	Boiled for 7 min
Hardness (N)			
Control	6.25±0.15 c, B	0.74±0.01 d, A	0.68±0.008 d, A
2.5% PSPP	4.26±0.11 b, C	0.71±0.01 c, B	0.63±0.01c, A
5.0% PSPP	3.52±0.09 a, C	0.71±0.007 c, B	0.61±0.01 c, A
7.5% PSPP	3.51±0.12 a, B	0.65±0.01 b, A	0.60±0.004 b, A
10% PSPP	3.44±0.05 a, C	0.62±0.01 a, B	0.58±0.01 a, A
Cohesiveness (-)			
Control	0.53±0.03 c, A	0.67±0.007 b, B	0.72±0.01 b, C
2.5% PSPP	0.44±0.04 b, A	0.67±0.01 b, B	0.71±0.01 b, C
5.0% PSPP	0.44±0.009 b, A	0.67±0.008 b, B	0.72±0.007 b, C
7.5% PSPP	0.41±0.005 ab, A	0.66±0.01 ab, B	0.70±0.01 ab, C
10% PSPP	0.39±0.008 a, A	0.65±0.01 a, B	0.69±0.02 a, C
Elasticity (-)			
Control	0.58±0.007 a, A	0.96±0.003 a, B	1.00±0.004 a, C
2.5% PSPP	0.68±0.008 b, A	0.95±0.006 a, B	0.99±0.005 a, C
5.0% PSPP	0.77±0.006 c, A	0.97±0.005 a, B	1.00±0.03 a, C
7.5% PSPP	0.76±0.03 c, A	0.96±0.03 a, B	1.02±0.03 a, C
10% PSPP	0.77±0.007 c, A	0.97±0.02 a, B	1.00±0.01 a, C
Gumminess (N)			
Control	3.30±0.11 d, B	0.50±0.01d, A	0.49±0.006 d, A
2.5% PSPP	1.85±0.17 c, B	0.47±0.005 c, A	0.45±0.02 c, A
5.0% PSPP	1.54±0.02 b, C	0.47±0.009 c, B	0.44±0.01 c, A
7.5% PSPP	1.43±0.06 ab, B	0.43±0.008 b, A	0.42±0.008 b, A
10% PSPP	1.36±0.04 a, B	0.40±0.02 a, A	0.40±0.01 a, A
Chewiness (-)			
Control	1.92±0.07 c, B	0.48±0.01 d, A	0.49±0.005 d, A
2.5% PSPP	1.26±0.11 b, B	0.45±0.006 c, A	0.44±0.01 c, A
5.0% PSPP	1.19±0.02 b, C	0.450.007 c, B	0.44±0.004 c, A
7.5% PSPP	1.09±0.03 a, B	0.41±0.009b, A	0.42±0.006 b, A
10% PSPP	1.04±0.03 a, B	0.39±0.01 a, A	0.40±0.008 a, A
Thickness (mm)			
Control	1.10±0.02 a, A	1.32±0.009 a, B	1.42±0.01 a, C
2.5% PSPP	1.12±0.009 ab, A	1.39±0.004 b, B	1.46±0.008 b, C
5.0% PSPP	1.13±0.09 b, A	1.39±0.02 b, B	1.47±0.01 b, C
7.5% PSPP	1.19±0.008 c, A	1.43±0.01 c, B	1.49±0.006 c, C
10% PSPP	1.19±0.007 c, A	1.45±0.009 c, B	1.53±0.007 d, C

[1)]Each value is the mean ± SD. The values followed by different small and capital letters within column and row, respectively, are significantly different ($p < 0.05$).
Abbreviations: PSPP, purple sweet potato powder

3 min, all PSPP-supplemented fresh pastas had significantly higher moisture content than the control ($p < 0.05$). Moreover, after boiling for 7 min, fresh pasta supplemented with 5.0, 7.5 and 10% PSPP showed significantly higher moisture content than the control ($p < 0.05$).

In terms of cooking properties, Fig. 2 shows that the cooking weight gain (CWG) of all PSPP-supplemented fresh pastas after boiling for 3 and 7 min was significantly lower than the control ($p < 0.05$). On the other hand, the cooking dry matter loss (CDML) of all PSPP-supplemented fresh pastas after boiling for 3 and 7 min was significantly higher than the control ($p < 0.05$).

Texture properties of fresh pasta Table 1 shows the texture properties of fresh pasta supplemented with PSPP. Results showed that the hardness, gumminess and chewiness of all PSPP-supplemented raw and boiled fresh pastas were significantly lower than the control. Similarly, the cohesiveness of all PSPP-supplemented raw fresh pastas was significantly lower than the control ($p < 0.05$). For fresh pasta boiled for 3 and 7 min, the cohesiveness of the 10% PSPP sample was significantly lower than the control and other treatments. Moreover, Table 1 shows that the elasticity of all PSPP-supplemented raw fresh pastas was significantly higher than the control ($p < 0.05$), while the thickness of raw fresh pasta with more than 5.0% PSPP was significantly greater than the control ($p < 0.05$). Similarly, the thickness of all boiled PSPP-supplemented fresh pastas was significantly greater than the control ($p < 0.05$). In assessing the effect of boiling on

Table 2. Rupture properties of PSPP-supplemented fresh pastas[1)]

Pasta Treatment	Raw	Boiled for 3 min	Boiled for 7 min
RF (N)			
Control	15.76±0.13 c, B	2.42±0.02 d, A	2.40±0.03 c, A
2.5% PSPP	13.44±0.18 b, C	2.32±0.04 c, B	2.14±0.06 b, A
5.0% PSPP	13.31±0.05 b, C	2.20±0.07 b, B	2.06±0.05 a, A
7.5% PSPP	13.01±0.02 a, C	2.19±0.04 b, B	2.05±0.06 a, A
10% PSPP	12.90±0.14 a, B	2.11±0.02 a, A	2.03±0.03 a, A
RE (J)			
Control	$2.25\times10^{-3}\pm4.1\times10^{-5}$ d, C	$1.11\times10^{-3}\pm1.37\times10^{-5}$ b, B	$1.03\times10^{-3}\pm6.13\times10^{-6}$ d, A
2.5% PSPP	$3.61\times10^{-3}\pm4.53\times10^{-5}$ c, C	$1.04\times10^{-3}\pm3.08\times10^{-5}$ a, B	$9.81\times10^{-4}\pm1.43\times10^{-5}$ c, A
5.0% PSPP	$3.56\times10^{-3}\pm4.92\times10^{-5}$ bc, C	$1.04\times10^{-3}\pm5.05\times10^{-6}$ a, B	$9.46\times10^{-4}\pm3.60\times10^{-6}$ b, A
7.5% PSPP	$3.51\times10^{-3}\pm1.91\times10^{-5}$ ab, C	$1.04\times10^{-3}\pm7.69\times10^{-6}$ a, B	$9.38\times10^{-4}\pm1.28\times10^{-5}$ ab, A
10% PSPP	$3.50\times10^{-3}\pm3.77\times10^{-5}$ a, C	$1.03\times10^{-3}\pm2.22\times10^{-5}$ a, B	$9.20\times10^{-4}\pm1.84\times10^{-5}$ a, A
RD (mm)			
Control	1.00±0.01 a, A	1.13±0.00 a, B	1.26±0.01 a, C
2.5% PSPP	1.00±0.00 a, A	1.21±0.02 b, B	1.29±0.00 b, C
5.0% PSPP	1.02±0.02 ab, A	1.23±0.00 c, B	1.29±0.02 b, C
7.5% PSPP	1.02±0.02 ab, A	1.23±0.01 c, B	1.29±0.02 b, C
10% PSPP	1.02±0.00 b, A	1.23±0.01 c, B	1.30±0.02 b, C

[1)]Each value is the mean ± SD. The values followed by different small and capital letters within column and row, respectively, are significantly different ($p < 0.05$).
Abbreviations: PSPP, purple sweet potato powder; RF, rupture force; RE. rupture energy; RD, rupture deformation

texture, results showed that the hardness, gumminess and chewiness of all boiled fresh pastas were significantly lower than the raw fresh pasta ($p < 0.05$). On the other hand, the elasticity and cohesiveness of boiled fresh pasta were significantly higher than the raw fresh pasta ($p < 0.05$). Furthermore, the elasticity and cohesiveness of fresh pasta boiled for 7 min were significantly higher than the fresh pasta boiled for 3 min in all treatments ($p < 0.05$). The boiled fresh pasta was significantly thicker than the raw fresh pasta ($p < 0.05$); and the fresh pasta boiled for 7 min was significantly thicker than that boiled for 3 min ($p < 0.05$) (Table 1).

Rupture properties of fresh pasta Table 2 shows that the rupture force (RF) and rupture energy (RE) of all PSPP-supplemented raw and boiled fresh pastas were significantly lower than the control ($p < 0.05$). On the other hand, the rupture deformation (RD) of raw fresh pasta supplemented with 10% PSPP was significantly higher than the control and raw fresh pasta supplemented with 2.5% PSPP ($p < 0.05$). Similarly, the RD of all PSPP-supplemented boiled fresh pastas was significantly higher than the control ($p < 0.05$).

In assessing the effect of boiling on rupture properties, results showed that the RF of boiled fresh pasta was significantly lower than the raw fresh pasta ($p < 0.05$). The RE of boiled fresh pasta was significantly lower than the raw fresh pasta ($p < 0.05$); while the RE of fresh pasta boiled for 7 min was also significantly lower than for samples boiled for 3 min in all treatments ($p < 0.05$). On the other hand, the RD of boiled fresh pasta was significantly higher than the raw fresh pasta ($p < 0.05$); while the RD of fresh pasta boiled for 7 minutes was significantly higher than for samples boiled for 3 min in all treatments ($p < 0.05$).

Color properties of fresh pasta Table 3 shows the color properties of raw and boiled fresh pastas. Results showed that the L* value of raw and boiled fresh pastas differed significantly from each other and was inversely proportional to the PSPP concentration ($p < 0.05$). For the effect of boiling on pasta color, results showed that the L* value of all boiled fresh pastas and those supplemented with PSPP was significantly higher than the raw fresh pasta ($p < 0.05$). Moreover, the L* value of fresh pasta boiled for 7 min was significantly higher than for samples boiled for 3 min in all treatments ($p < 0.05$).

In terms of the a* value, Table 3 shows that the control was the lowest among all treatments ($p < 0.05$). The a* value of raw fresh pasta was proportional to the PSPP content, and treatments differed significantly from each other, except for 7.5 and 10% PSPP ($p < 0.05$). Similarly, the a* values of fresh pasta boiled for 3 and 7 min differed significantly from each other, and were proportional to PSPP concentration ($p < 0.05$). For the effect of boiling, results showed that the a* values of the control, 2.5 and 5.0% PSPP fresh pasta boiled for 3 min were significantly lower than the raw fresh pasta ($p < 0.05$); meanwhile the a* value of 10% PSPP boiled for 3 min was significantly higher than that of raw fresh pasta. Moreover, the a* values of all PSPP-supplemented fresh pastas boiled for 7 min were significantly lower than for the pasta boiled for 3 min.

Furthermore, Table 3 shows that the b* values of raw fresh

Table 3. Color properties of fresh pastas supplemented with PSPP[1)]

Pasta Treatment	Raw	Boiled for 3 min	Boiled for 7 min
L* value			
Control	78.18±0.96 e, A	78.03±0.34 e, A	79.24±0.36 e, B
2.5% PSPP	56.25±0.41 d, A	60.25±0.49 d, B	63.94±0.59 d, C
5.0% PSPP	46.56±0.57 c, A	51.11±0.48 c, B	55.43±0.33 c, C
7.5% PSPP	41.32±0.50 b, A	45.53±0.74 b, B	49.79±0.70 b, C
10% PSPP	38.61±0.58 a, A	41.06±0.62 a, B	46.53±0.76 a, C
a* value			
Control	-2.30±0.22 a, B	-3.59±0.04 a, A	-3.61±0.03 a, A
2.5% PSPP	15.04±0.33 b, C	9.62±0.33 b, B	5.89±0.22 b, A
5.0% PSPP	19.48±0.60 c, C	16.36±0.18 c, B	11.10±0.33 c, A
7.5% PSPP	21.52±0.53 d, B	21.14±0.43 d, B	16.40±0.62 d, A
10% PSPP	21.77±0.36 d, B	22.37±0.59 e, C	18.08±0.45 e, A
b* value			
Control	22.41±0.89 e, C	13.77±0.23 e, B	11.75±0.27 e, A
2.5% PSPP	1.16±0.08 d, B	0.67±0.20 d, A	1.10±0.12 d, B
5.0% PSPP	-4.88±0.10 c, B	-5.36±0.12 c, A	-4.92±0.10 c, B
7.5% PSPP	-7.12±0.10 b, C	-8.69±0.16 b, A	-8.43±0.09 b, B
10% PSPP	-8.19±0.13 a, C	-10.71±0.09 a, A	-10.41±0.16 a, B

[1)]Each value is the mean ± SD. The values followed by different small and capital letters within column and row, respectively, are significantly different ($p < 0.05$). Abbreviations: PSPP, purple sweet potato powder; L* , degree of lightness or darkness; a*, degree of redness or greeness; b*, degree of yellowness or blueness

pasta differed significantly from each other and were inversely proportional to PSPP concentration ($p < 0.05$). A similar trend can be observed among fresh pasta treatments boiled for 3 and 7 min ($p < 0.05$). For the effect of boiling, results showed that the b* values of all treatments boiled for 3 min were significantly lower than the raw fresh pasta ($p < 0.05$); meanwhile the b* value of control fresh pasta boiled for 7 min was significantly lower than that boiled for 3 min ($p < 0.05$). Moreover, the b* values of all fresh pastas supplemented with PSPP and boiled for 7 min were significantly higher than the fresh pasta boiled for 3 min ($p < 0.05$).

Ultimately, the same color change can be observed in the images of raw and boiled fresh pasta; wherein increasing PSPP concentration resulted in a darker, more purple fresh pasta (Fig. 3). In addition, boiling of fresh pasta for 3 and 7 min resulted in a lighter color.

Sensory properties of boiled fresh pasta Figure 4 shows the quantitative descriptive evaluation of fresh pasta boiled for 3 min in terms of purple color, sweet potato flavor, sweet potato taste, hardness, elasticity, cohesiveness and overall acceptability. Results showed that the purple color of boiled fresh pasta increased significantly in proportion to PSPP concentration ($p < 0.05$). Figure 4 also shows that the 2.5 and 5.0% PSPP-supplemented fresh pastas were perceived to have significantly higher sweet potato flavor than the control, but were significantly lower than the 7.5 and 10% PSPP-supplemented fresh pasta ($p < 0.05$). On the other hand, the sweet potato taste of fresh pasta significantly increased in proportion to PSPP concentration ($p < 0.05$). Hardness of all PSPP-supplemented fresh pastas was evaluated to be significantly softer than the control ($p < 0.05$). All fresh pasta treatments did not show significantly different elasticity and cohesiveness values ($p < 0.05$). Furthermore, Fig. 4 shows that the overall acceptability of 2.5 and 5.0% PSPP-supplemented fresh pasta was significantly different and both were significantly less acceptable than the control and 10% PSPP-supplemented fresh pasta ($p < 0.05$). Ultimately, 7.5% PSPP showed the highest overall acceptability among the fresh pasta treatments ($p < 0.05$).

Discussion

Moisture content and cooking properties of fresh pasta The higher moisture content of raw 5.0, 7.5 and 10% PSPP-supplemented fresh pasta than the raw control can be attributed to the contents of intrinsic sugar and 54% damaged starch of PSPP as previously reported by Santiago *et al.* (2015), which may have contributed to its higher water holding capacity (Park and Baik, 2002). Similarly, the significantly higher moisture content of all PSPP-supplemented fresh pastas boiled for 3 min, and of 5.0, 7.5 and 10% PSPP supplemented fresh pastas boiled for 7 min compared to the corresponding boiled control fresh pasta can be attributed to the higher water absorbing capacity, because of

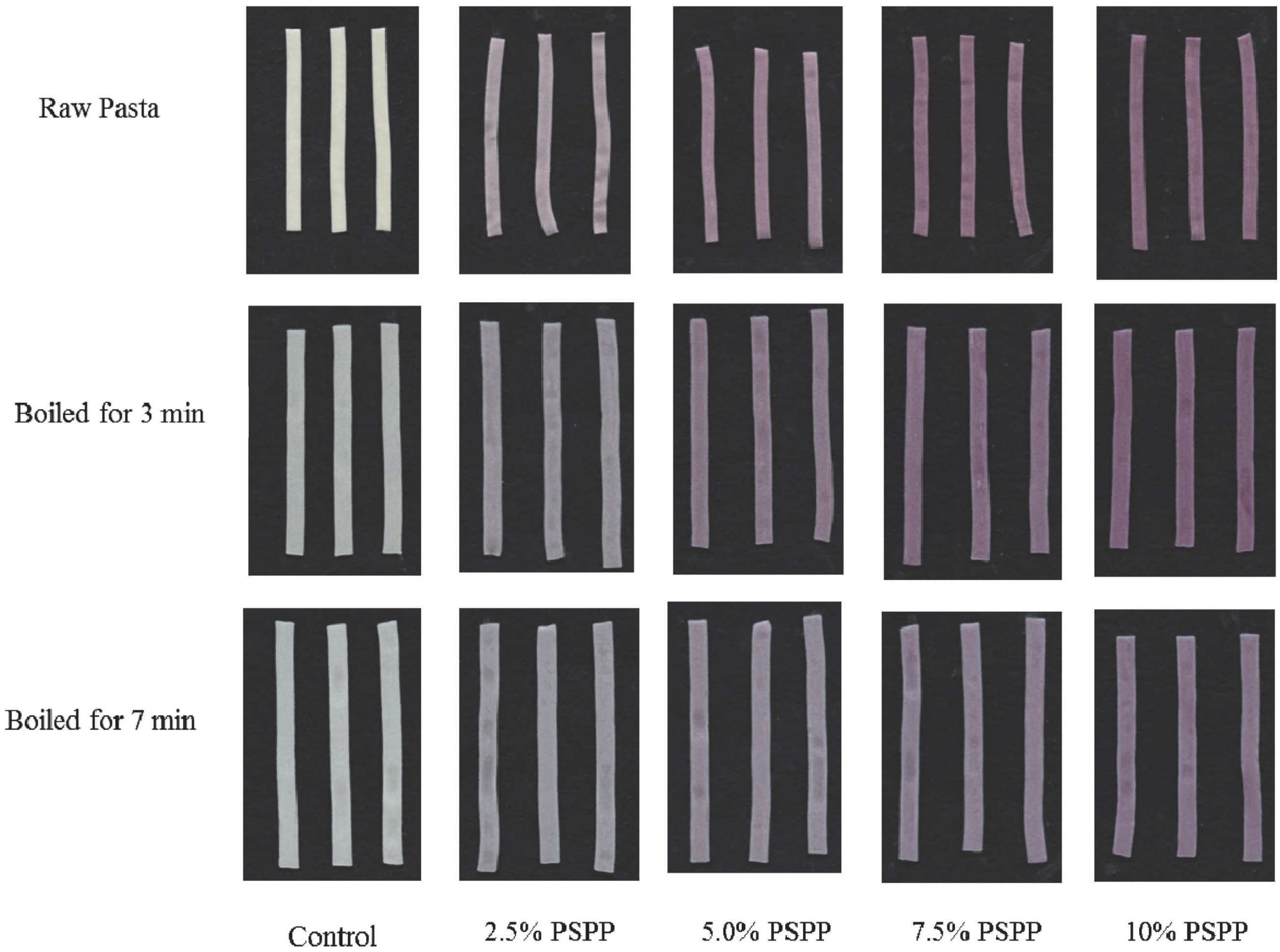

Fig. 3. Images of raw and boiled fresh pasta[1)]
[1)]Abbreviations:PSPP,purple sweet potato powder

PSPP's intrinsic sugar and damaged starch contents (Park and Baik, 2002).

On the other hand, the lower CWG of PSPP-supplemented fresh pasta compared to the control, and the inverse relationship between CWG and PSPP concentration can be attributed to the loss of dry matter during cooking or boiling. This observation is supported by the high or significant inverse correlation of the CWG of PSPP-supplemented fresh pasta with their CDML, with correlation coefficients of −0.667 and −0.985 ($p < 0.01$) for fresh pasta boiled for 3 and 7 min, respectively ($p < 0.01$). These observations indicate the solubility of the high sugar, damaged starch and anthocyanin contents of PSPP-supplemented fresh pasta in water during boiling (Hatcher *et al.* 2002). The same decrease in CWG and increase in cooking weight loss was observed by Li *et al.* (2012) with the increasing proportion of yam flour added to salted noodles. Moreover, the increase in cooking weight loss or CDML is related to the decrease in gluten protein content (Hou *et al.* 2013).

Texture properties of fresh pasta The significantly lower hardness, cohesiveness, gumminess and chewiness of raw PSPP-supplemented fresh pasta than the control may be attributed to the high gelatinized and damaged starch content of PSPP, resulting in weaker starch-protein interactions (Oh *et al.* 1985). The softer texture of raw PSPP-supplemented fresh pasta can be also related to its higher moisture content, as evidenced by the rather high inverse correlation between the hardness, cohesiveness, gumminess and chewiness of raw fresh pasta and moisture content, with Pearson's correlation coefficients of −0.695, −0.624, −0.656 and −0.632, respectively. Correspondingly, the significantly higher MC of PSPP-supplemented raw fresh pasta may have contributed to its softer texture (Kojima *et al.* 2004).

Similar high or significant inverse correlation between hardness, cohesiveness, gumminess and chewiness of fresh pasta boiled for 3 and 7 min and moisture content was observed, with correlation coefficient ranges of −0.807 to −0.589 and −0.924 ($p < 0.05$) to −0.835, respectively. Ultimately, this softer texture can be attributed to the high water absorbing capacity of the supplemented PSPP, resulting in a higher moisture content. On the other hand, the significantly higher elasticity of raw PSPP-supplemented fresh pasta than the raw control can be attributed to the gelatinized starch of the supplemented PSPP, which acts as binder between starch particles, compensating for the lack of gluten and reinforcing the elasticity (Wieser, 2007; Chillo *et al.* 2009). The significantly greater thickness of raw fresh pasta supplemented

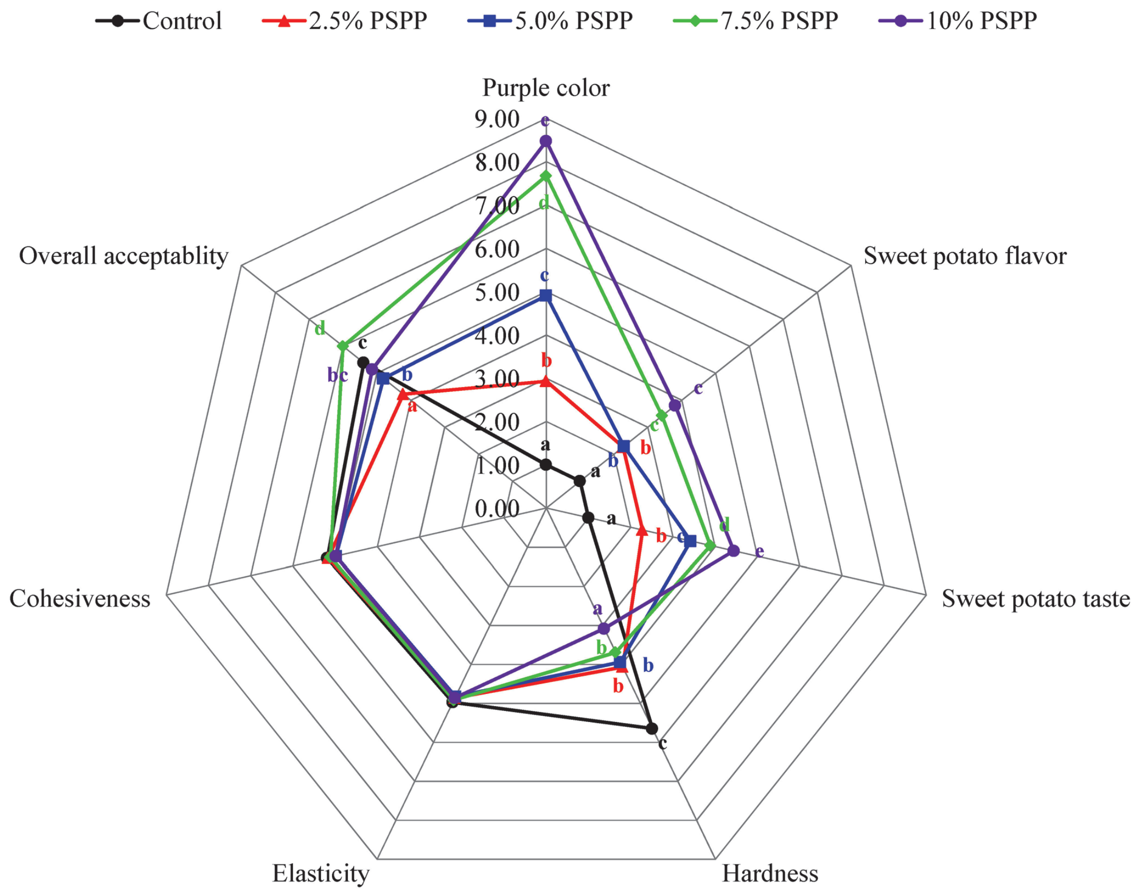

Fig. 4. Sensory properties of boiled fresh pasta supplemented with PSPP[1)]
[1)]The data points followed by different letters within each evaluating term are significantly different ($p < 0.05$).
Abbreviations: PSPP, purple sweet potato powder
Quantitative descriptive analysis scale: purple color, 1-no purple to 9-extremely purple; sweet potato flavor, 1-not perceivable to 9-extremely strong; sweet potato taste, 1-not perceivable to 9-extremely strong; hardness, 1-extremely soft to 9-extremely hard; elasticity, 1-extremely low to 9-extremely high; cohesiveness, 1-extremely low to 9-extremely high; overall acceptability, 1-disliked extremely to 9-liked extremely

with more than 5.0% PSPP compared to the control can be explained by the high gelatinized starch content of PSPP. Moreover, the significantly greater thickness of boiled PSPP-supplemented fresh pasta indicates greater swelling and water absorption, which is related to the high sugar and damaged starch content of PSPP (Oh *et al.* 1983; Hatcher *et al.* 2002; Park and Baik, 2002).

Boiling resulted in softer texture of fresh pasta, related to water absorption and starch gelatinization (Ishida *et al.* 2003). Moreover, boiling resulted in significantly greater elasticity and cohesiveness, attributable to the gelatinization of the starch component of the fresh pasta, and provided a sticky and paste-like structure. Boiling of fresh pasta for 7 min resulted in a higher degree of starch gelatinization, which explains its significantly higher elasticity and cohesiveness than the fresh pasta boiled for 3 min.

Rupture properties of fresh pasta The significantly lower RF and RE of all raw PSPP-supplemented fresh pastas and higher RD of 10% PSPP compared to the control indicates that PSPP-supplementation results in a softer texture. This was evidenced by the high or significant correlation of RF ($r = 0.983$, $p < 0.01$) and RE ($r = 0.985$, $p < 0.01$), and the inverse correlation of RD ($r = -0.808$) of raw fresh pasta with hardness. Correspondingly, the significantly higher MC of PSPP-supplemented raw fresh pasta may have contributed to its lower RF and RE and higher RD (Fig. 1). This is verified by the considerably high or significant inverse correlation of RF and RE, and direct correlation of RD with MC of raw fresh pasta, showing correlation coefficients of −0.599, −0.589 and 0.941 ($p < 0.05$), respectively.

Similarly, the significantly lower RF and RE, and higher RD of all boiled PSPP-supplemented fresh pastas confirm the softer texture compared to control. This relates to the rather high or significant correlation of RF ($r = 0.876$ ($p < 0.05$) − 0.967 ($p < 0.01$)) and RE ($r = 0.688$ to 0.989 ($p < 0.01$)) and inverse correlation of RD ($r = -0.688$ to −0.9525 ($p < 0.05$)) with the hardness of boiled fresh pasta. Moreover, the RF ($r = -0.680 - -0.779$) and RE ($r = -0.500 - -0.777$) showed a rather high inverse correlation, whereas RD ($r = 0.496 - 0.645$) directly and considerably correlated with the MC of boiled fresh pasta. Hence, these show that the rupture properties of fresh pasta are influenced by the moisture content, which is related to the high water absorbing capacity of PSPP (Fig. 1).

The significantly lower RF and RE, and higher RD of boiled fresh pasta indicates a softer texture, attributable to starch gelatinization and water absorption during boiling (Ishida *et al.* 2003). Furthermore, the significantly lower RE and higher RD of fresh pasta boiled for 7 min compared to that boiled for 3 min can be related to the higher degree of gelatinization and water absorption.

Color properties of fresh pasta PSPP-supplementation resulted in a darker, bluer and redder color of the raw and boiled fresh pasta, as indicated by the significant decrease in L* and b* values, and increase in a* value (Table 3), respectively. As also shown in Fig. 3, the darker, bluer and redder purple color of PSPP-supplemented fresh pasta is due to the dark purple anthocyanin pigments of PSPP, with L*, a* and b* values of 52.70 ± 1.35, 21.86 ± 0.51, −8.13 ± 0.33, respectively (data not shown) (Kano *et al*. 2005; Montilla *et al.* 2011).

On the other hand, boiling resulted in lighter colored fresh pasta, shown by the significantly higher L* value compared with the raw fresh pasta. Boiling of the control fresh pasta also resulted in a greener color, as indicated by the significantly lower a* value compared with the raw control fresh pasta. Boiling for 3 min significantly decreased the degree of redness of 2.5 and 5.0% PSPP fresh pasta, as evidenced by the lower a* value compared to the raw pasta; while for 10% PSPP-supplemented fresh pasta, the degree of redness was intensified after boiling for 3 min. The significant decrease in b* value of the control and 2.5% PSPP samples boiled for 3 min indicates a lower degree of yellowness than the raw fresh pasta. Conversely, the decrease in b* value of 5.0, 7.5 and 10% PSPP after boiling for 3 min indicates a higher degree of blueness compared with the raw fresh pasta. Ultimately, the significantly higher L* and b* values, and lower a* value of all PSPP-supplemented fresh pastas boiled for 7 min compared to 3 min signify a lower degree of darkness, blueness and redness, respectively. This lighter and less purple color of fresh pasta boiled for 7 min indicates leaching of water-soluble anthocyanins due to the longer boiling time.

Sensory properties of boiled fresh pasta PSPP-supplementation significantly affected the purple color of fresh pasta boiled for 3 min. The fresh pasta was assessed as having no purple color for the control to an extremely strong purple color for the 10% PSPP-supplemented fresh pasta. Meanwhile, the 2.5, 5.0 and 7.5% PSPP were evaluated as having a slight, moderate and very strong purple color, respectively.

Sweet potato flavor was not perceivable in the control, whereas, it was barely perceivable in the 2.5 and 5.0% PSPP. Moreover, sweet potato flavor was slightly perceivable in the 7.5 and 10% PSPP samples. On the other hand, the panelists evaluated the sweet potato taste of the fresh pasta as ranging from not perceivable for the control to moderately perceivable for the 10% PSPP. The 2.5, 5.0 and 7.5% PSPP fresh pastas were rated to have barely, slightly and slight-moderately perceivable sweet potato taste, respectively.

The hardness of the control fresh pasta was rated as slightly hard, whereas, the 2.5, 5.0 and 7.5% PSPP were evaluated as slightly soft. The 10% PSPP was judged to be soft fresh pasta. All fresh pastas were perceived to have moderate elasticity and cohesiveness. The panelists' perception of sample hardness differed greatly among all samples, showing considerable correlation with the hardness measurements obtained by creep meter, with correlation coefficients of 0.857.

The panelists slightly disliked the 2.5% PSPP, whereas the control, 5.0%, and 10.0% PSPP were neither liked nor disliked. Ultimately, the 7.5% PSPP was liked slightly and perceived as the most acceptable among all of the fresh pasta treatments. These results generally agree with the report of Li *et al.* (2012), in which the overall acceptability of cooked salted noodles supplemented with purple yam flour was not significantly different from the control.

Conclusion

PSPP-supplementation improved the water holding and absorbing capacities of fresh pasta, resulting in a softer texture, as evidenced by the inverse correlation of moisture content with hardness, rupture force and rupture energy. Moreover, PSPP provides a high amount of gelatinized starch, resulting in a softer and more elastic raw fresh pasta. Also, PSPP provides a dark purple color that is attributable to its intrinsic anthocyanin content.

On the other hand, sensory evaluation showed that PSPP-supplementation results in fresh pasta with a slight to extremely strong purple color, barely to slightly perceivable sweet potato flavor, barely to moderately perceivable sweet potato taste, slightly soft to soft firmness, and moderate elasticity and cohesiveness. Furthermore, in overall acceptability, the 5% and 10% PSPP were neither liked nor disliked along with the control, whereas the 7.5% PSPP showed slightly higher acceptability. These results indicate that PSPP-supplementation gives rise to acceptable fresh pasta, potentially leading to the increased utilization of PSPP in noodle processing. However, further research is needed to establish the effects of PSPP-supplementation and boiling on starch-gluten interactions, anthocyanin retention, and antioxidant properties of fresh pasta.

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