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RESEARCH PAPER

Effect of steamed purple sweet potato addition on chemico-physical properties of sandwich bread

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Abstract

Purple sweet potato (PSP) has the potential to be used to prepare functional foods due to its attractive color and high anthocyanin content. With completely randomized design experiments used, the study investigated the effect of the percentage of steamed PSP (25, 29, 33 and 37% of total batch weight) on the overall quality of sandwich bread. The results showed that the added PSP significantly affected the color (L*, a* and b*) and anthocyanin content of bread. The sandwich bread with 33% PSP had the most intense purple color, and a soft structure was found with a measured hardness of 92.12 and 25.11 g force in the bread crust and the centre of the bread, respectively. The expansion ratio was 5.86 times compared with the control sample (5.47 times), and the moisture and anthocyanin content were 38.23% and 55.14 mg%, respectively. The findings of this study also suggested that the preparation of sandwiches with the addition of PSP, in addition to providing a beautiful color, also has the potential to improve overall product quality, increase fiber content (2.4%) and DPPH free radical scavenging activity (28.80%) compared to the control sample.

1. Introduction

The bread manufacturing industry in Vietnam has been growing. Today, with the population growth of the high-income group and the response to the changing consumption patterns of urban people, the use of bread, especially sandwich bread, is increasing. Sandwiches have proven to be a nutritious and practical food with flour as the main ingredient used. With the increasing development of society, improving the nutritional content and creating a variety and attractive color of bread products is a matter of concern, contributing to satisfying the needs of consumers.

Purple sweet potatoes (*Ipomoea batatas* L.) can be used in food preparation to improve nutrient content, color and taste. In particular, the high anthocyanin content in tubers gives the characteristic purple color (Khoo *et al*., 2017). PSP have also been shown to have high antioxidant properties (Curayag *et al*., 2019; Dovene *et al*., 2019), reduce coronary heart disease and stroke, carcinogenic activity and anti-inflammatory effects (Reis *et al*., 2016).

The addition of PSP to sandwiches is also a way to diversify the product, creating a product with a characteristic purple color, combined with the pleasant aroma and harmonious taste of sweet potatoes, creating new food products, and at the same time making good use of nutrients from abundant raw materials that are widely developed in Vietnam. The addition of vegetables to improve the functional and nutritional properties of bread has also been carried out in several previous studies (Danza *et al*., 2014; Mastromatteo *et al*., 2015). Bread fortified with freeze-dried vegetables was studied by Ranawana *et al*. (2016). Although the physicochemical and functional properties of bread are widely studied. However, reports of using steamed PSP added to sandwich recipes have not been studied. Therefore, this study was conducted to analyze the physico-chemical and functional properties of sandwich bread when added PSP. This work will contribute to the efficient use and enhancement of the value of local agricultural raw materials. The development of new products with nutritional value is also of great significance in improving community nutrition.

2. Materials and methods

2.1 Preparation of steamed purple sweet potato

PSP harvested from Vinh Long province has a deep

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purple color. Then they are sorted to select good quality ones, washed with clean water, peeled and cut into slices about 1 cm thick. Next, they were steamed at 100°C for 10 min and cut into small pieces the size of 1 × 1 cm.

2.2 Effect of percentage of steamed purple sweet potato added to sandwich recipe

Use the automatic Bread maker (Philips BreadMaker) to create each sandwich loaf. With a total ingredient weight of 487 g for each sandwich loaf, the quantities are fixed for ingredients used including wheat flour 261 g, yeast 1.8 g, sugar 27 g, salt 2.7 g, eggs 54 g, unsweetened fresh milk 117 g, butter 23.5 g. The steamed PSP with ratios of 25, 29, 33 and 37% (compared to the total volume of a batch) were added to the bread maker. The total time to make the sandwich was 3 hours 55 minutes at a temperature of 160ºC, including stirring, incubation and baking. The finished products were collected and analyzed for physico-chemical properties.

2.3 Chemical composition and antioxidant activity analysis

The moisture and protein content of raw materials and product were determined by AOAC (2005). Lipid content was analyzed by AOAC (1997). The carbohydrate of the sample was determined by AOAC (1980). The anthocyanin content was determined by the pH differential method, its content was expressed as cyanidin-3-glucoside equivalents according to Maran *et al.* (2015). The crude fiber content of the sample was analyzed by the standard procedure of AOAC (1990). The antioxidant activity was measured using 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical-scavenging activity, as reported by Bae and Suh (2007).

2.4 Physical properties analysis

Bread texture was measured using Rheotex, bread loaf was sliced into 1.3 cm thick slices and placed on the texture analyser platform. The sliced bread was compressed with a cylindrical probe using 50% strain and the data was recorded. Color was determined according to the L*, a*, b* using a Colorimeter (Japan). Expansion (times) = (volume of bread after baking/ volume of dough after mixing or before baking)

2.5 Scanning Electron Microscopy

Scanning Electron Microscopy of dried bread was mounted onto brass stubs using double-sided carbon conductive adhesive tape. A gold coating (0.5 nanometers thick) was then applied under 8-9 Pa vacuum. Bulk samples were examined at 15 kV, the sample distance to the 7 cm ejection glass, 50× magnification using a JEOL model J550 scanning electron microscope (Japan).

2.6 Data analysis

Data analyses were carried out using STATGRAPHICS Centurion XV (USA). Values were expressed as mean±SD.

3. Results and discussion

3.1 Nutrient content and antioxidant activity

Proximate analysis shows that PSP grown in Vinh Long province, Vietnam have a rather high percentage of moisture, protein and anthocyanin. The moisture and protein were determined about 73.93±0.076% and 1.6±0.1%, respectively. The results obtained are slightly different from those reported by Shaari *et al*. (2021), they reported higher moisture content of fresh PSP (75.33±0.58%) and lower protein content (0.57±0.03%) compared with our data. However, Curayag *et al*. (2019) announced that the protein content in PSP was slightly higher (1.82±0.04%) than the data obtained in our study.

The PSP contains anthocyanin colour pigments. Total PSP anthocyanin content was 174 mg/100 g fresh weight. The high anthocyanin content in PSP was verified in a previous study, ranging from 19.78 mg/100 g to 158 mg/100 g (Fan *et al*., 2008; Ahmed *et al*., 2011). Kano *et al*. (2005) reported that the total anthocyanin content in PSP is 519 mg/100 g fresh weight. This difference may be due to variety, harvesting time, tuber size and growing conditions.

The high content of total anthocyanin likely was responsible for significantly high antioxidant activity. The antioxidant activity of steamed PSP was performed by DPPH radical scavenging method (1,1 diphenyl-2-picrylhydrazyl) which was evaluated (76.84±0.16%). It has been observed that steamed PSP has a rather high antioxidant activity, which if added to common foods improves nutrition and adds health benefits.

Crude fiber was determined about 4% in steamed PSP.

3.2 Effect of steamed purple sweet potato added to sandwich baking

3.2.1 Color

The addition of PSP gave the sandwich bread its own characteristic, the purple color of the bread gradually increased with the increasing content of the percentage of sweet potatoes used (Figure 1). The L* and b* values of sandwiches at the additional percentages were both significantly lower than those of the control sample (Table 1). The L* value was highest (61.29) at 25%

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addition and lowest (34.42) at 37% PSP addition. The results obtained are also consistent with the report of Lee and Park (2011), the authors concluded that increasing the percentage of sweet potatoes added from 5% to 15% in bread reduced the L* value. The product is light in color when PSP addition is 25% and darkest at 37% addition. The percentage of PSP added was 29 and 33% for the product with the beautiful color and characteristic purple color of PSP.

The a* value of bread tends to increase and is highest when adding 37% PSP (21.03). The b* value of sandwiches tended to decrease as the PSP content increased. Bread color develops late in baking, simultaneously with crust formation, and arises from such chemical processes as sugar caramelization. In this study, sandwiches were baked at 160^{o}C, and the caramelization and carbonization occur when the product surface temperature is above 150^{o}C (Asselman *et al*., 2007).

3.2.2 Hardness

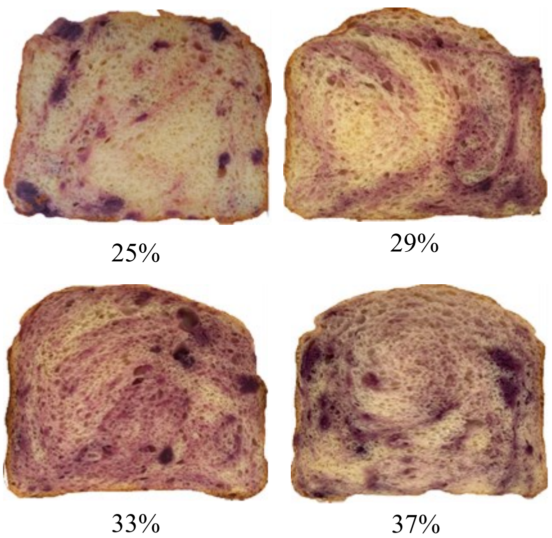

Figure 1. Sandwich slices with different percentages of purple sweet potato additions.

Table 1. Effect of percentage of purple sweet potato supplement on color of sandwich bread.

Percentage of PSP	L*	a*	b*
0	69.75^{e}	6.75^{a}	23.4^{d}
25	61.29^{d}	12.49^{b}	17.23^{c}
29	54.10^{c}	17.21^{c}	16.46^{c}
33	44.62^{b}	20.33^{d}	13.13^{b}
37	34.42^{a}	21.03^{d}	8.14^{a}

Mean values with different superscripts within the same column are statistically significantly different ($P \leq 0.05$).

The added PSP had the potential to change the texture of the sandwich. Stiffness is the force required to deform a sample to a certain extent (Szczesniak, 2002) and the stiffness of a sandwich can be expressed through shear force (Wang *et al*., 2012).

The hardness of the sandwich bread was different between the control sample (without PSP addition) and the samples with different percentages of PSP added. The highest value of firmness of the crust and in the center of the sandwich were determined respectively 235.52 and 71.12 g force (control sample) and the lowest value were 82.10 and 20.35 g force (the crust and in the center, respectively) for the sandwich supplemented with 37% PSP. Increasing the percentage of PSP, the firmness of the crust and the inside of the sandwich were reduced. This is probably due to PSP containing a high water content (73.93% as mentioned above) which has increased the amount of water in the dough mass. With 25% of PSP added, the dough does not have enough moisture to expand, so the inner structure becomes tight and non-porous, and the crust is still dry. In contrast, the addition of 37% PSP made the sandwich structure very soft. Liu *et al*. (2016) reported that water absorption and degree of softening increased with the increasing addition of potato flour in mixed flour (10 to 35%). Sandwiches are often appreciated when the structure has the right softness.

3.2.3 Expansion of sandwich bread

The expansion is a parameter that characterizes the quality of sandwich bread, which is determined by the increase in the volume of the bread. The expansion is influenced by the ingredients and processing specifications (Scheuer *et al*., 2015; Solagi *et al*., 2017). The analytical results showed that the expansion of sandwich bread was significantly different between the control sample and the samples with different percentages of PSP added (as described in Table 2 and Figure 2).

The fermentation property of the dough significantly affects the quality of the sandwich. The maximum dough height comprehensively reflects the air-generating capacity and air-holding capacity of the dough, which is positively correlated with the volume of the bread. The results showed that the dough height increased with an

Figure 2. Different expansion of sandwich bread (no PSP supplement – left side and the PSP supplemented 33% - right side).

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Table 2. Firmness of sandwich bread according to different percentages of purple sweet potato addition.

% of PSP addition	Firmness (g force)		Expansion (times)	Moisture content (%)	Anthocyanin (mg/100 g)
	Bread crust	In the center			
0	235.52^{d}	71.12^{e}	5.47^{a}	35.52^{a}	0.00
25	175.11^{c}	44.26^{d}	5.52^{b}	36.22^{b}	37.42^{a}
29	121.32^{b}	34.67^{c}	5.76^{c}	37.13^{c}	46.23^{b}
33	92.24^{a}	25.11^{b}	5.86^{d}	38.23^{d}	55.14^{c}
37	82.10^{a}	20.35^{a}	5.74^{c}	39.19^{e}	59.11^{d}

Mean values with different superscripts within the same column are statistically significantly different ($P \leq 0.05$).

increasing amount of steamed PSP, in which the highest value was achieved with 33% steamed PSP added (5.86 times) and the lowest value (5.47 times) when the PSP addition was 25%. With a percentage of PSP of 25%, the dough has the lowest moisture content, the crust will be dry, and the fermentation time will be longer, resulting in a slow increase in the bread volume. However, the addition of a higher content of PSP (37%) caused the dough to be too mushy, relatively slow crust formation during baking, poor shape retention and reduced expansion. Therefore, adding PSP 33% was most suitable in the case of steamed PSP used. The obtained results are in agreement with the study of Nindjin *et al.* (2011), who showed that with the addition of yams from 10 to 40%, the volume of the bread increased and the expansion tended to decrease in increasing the yam content up to 50%.

Contrary to this study, the dough height was found to reduce with the increase in the amount of purple potato flour or potato flour addition (Liu *et al*., 2016; Liu *et al*., 2020). The cause is thought to be that PSP flour has destroyed the gluten network structure of the flour and reduced its stability of the flour. Thus, in our study, the steamed (instead of powdered) PSP supplement was shown to be superior in sandwich processing.

3.2.4 Moisture content

The analysis results showed that the moisture content of the sandwich bread increased significantly when the steamed PSP was added. The lowest value was 35.52% (control sample) and the highest value was 39.19% in the percentage of PSP supplemented with 37%. This result is quite consistent with the report of Lee and Park (2011), that PSP contains a lot of starch that increases water absorption and swelling. In this study, the starch in the PSP has gone through the steaming process, so the starch granules have absorbed a certain amount of moisture, so when added to the dough, it also provides an extra part of the PSP's moisture.

3.2.5 Anthocyanin content

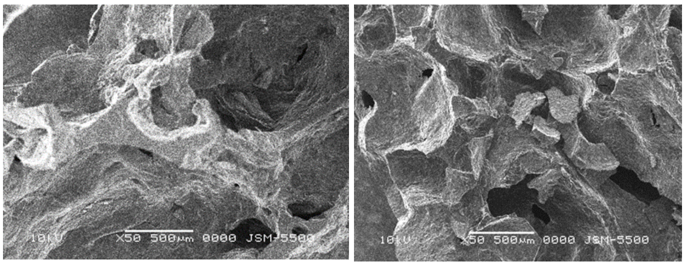
Anthocyanin content also varies with the percentage of added PSP in the recipe. The sandwich bread with the percentage of PSP added at 25% exhibited the lowest anthocyanin content (37.42 mg/100 g) and the highest value was found (59.11 mg/100 g) at the added PSP of 37%. This result is also consistent with Tamaroh and Sudrajat (2021) who showed that when increasing the percentage of added yams, the anthocyanin content also increased in bread products. The higher the percentage of PSP added, the more pronounced the characteristic purple color of the bread and the darker the bread color due to anthocyanin pigments.

Sandwich bread supplemented with PSP improved nutritional value, creating a fancy purple color. The addition of PSP also healthily improved the quality of sandwiches. Anthocyanin in food support antioxidant is anti-aging, increase resistance, stabilize blood vessels, fight inflammation, limit the growth of cancer cells and cure diabetes (Khoo *et al*., 2017). It could be seen that the anthocyanin content in the sandwich bread was quite high with the percentage of PSP used.

3.2.6 Scanning Electron Microscopy

The knowledge of the microstructure of food products can provide important data for understanding their quality on macro scale. Acquired images can help analyze the texture or integrity of food products (Gorinstein *et al*., 2004). SEM images show that many starch granules have lost their shape due to gelatinization and are embedded in the protein matrix (Figure 3), the binding force between the protein matrix and starch granules is also different for large and small starch granules evenly dispersed in both samples. The control image clearly illustrates the gluten network and crosslinking with starch granules (Figure 3a). However, the breadth micrograph with the addition of PSP (Figure 3b) shows protein-coated regions deposited on the starch granules, which appear to be irregular structures dispersed in a discontinuous protein matrix. The interaction of gelatinized starch with the gluten network was clearly observed in the PSP-added bread sample but not in the control sample. The starch and gluten crosslinking regions show that the starch granules are tightly bound to each other or adherent to the gluten network. However, after baking, the starch granules were broken and it was difficult to distinguish between the two samples. It was also observed that small holes appeared clearly on the surface of the sandwich with PSP added, probably because the amount of steamed PSP that was gelatinized and added filled the voids and made for bread retain more water after baking. This was also noted, the moisture content of bread with 33% addition of PSP was higher than that of bread without an addition.

3.2.7 Chemical composition of sandwich bread (with and without purple sweet potato addition)



(a) (b)

Figure 3. Scanning electron micrograph of sandwich bread (50×); (a) without addition of PSP; (b) with the addition of 33% PSP.

The chemical composition of the finished product was analyzed and presented in Table 3.

The analysis results showed that the protein content of the control sample was 11.9% and the sandwich added with PSP was 10.5%. The protein content of PSP bread was reduced compared to the control sample because PSP has a low protein content (1.6%) compared to wheat flour (9.5-13.5%) (Salehifar *et al*., 2010) so when added slightly reduced the protein content of the finished product. This result is similar to the report of Okorie (2012) for bread made from a mixture of sweet potato and flour.

The carbohydrate and lipid content were also slightly reduced in the PSP-fortified bread. This result is similar to previous studies (Okorie, 2012; Nindjin *et al*., 2011) with purple yam. Amandikwa *et al*. (2015) also reported a decrease in total carbohydrate intake with the addition of sweet potatoes to sandwiches. However, the PSP-supplemented sandwich had higher moisture content and water activity than the control sample (as discussed). High water activity shows that this is a difficult product to store, so only high-quality cakes should be used within 3 days (stored at room temperature 25±2°C).

Table 3. Chemical composition of the finished product.

Chemical composition	Sandwich bread without PSP addition	Sandwich bread with 33% PSP addition
Protein (%)	11.9±0.48	10.5±0.15
Carbohydrate (%)	48.48±0.03	47.66±0.06
Lipid (%)	3.10±0.18	2.62±0.2
Moisture (%)	35.52±0.11	38.33±0.09
Water activity (a_w)	0.94±0.1	0.95±0.1
Fiber (%)	1.45±0.02	2.40±0.05
DPPH%	19.10±0.10	28.80±0.2

Values are presented as mean±standard deviation

In addition, with high fiber content and antioxidant activity, PSP sandwich products have improved functions that are good for consumers' health. The antioxidant activity of sandwich bread with PSP addition was about 28.8% with a concentration of 33% steamed PSP added, the content of anthocyanins that contribute to antioxidant activity. The results for the antioxidant activity of sandwich bread were determined. Larief *et al*. (2018) studied sponge bread from wheat flour and white rice flour substituted with 30% purple yam flour and showed antioxidant activity of DPPH free radical binding of 26.9%. Another latest study by Curayag *et al*. (2019) showed that the substitution of 20% of PSP flour increased antioxidant activity with the antioxidant activity of DPPH free radical binding of 10.14%. The antioxidant activity of bread with purple yam flour substitution ranged from 23.43 to 49.70% as presented by Tamaroh and Sudrajat (2021).

The substitution of steamed PSP had a significantly increased anthocyanin level, fiber, color and antioxidant activity of sandwich bread whereas the protein and carbohydrate of the sample were reduced. A special feature in this study was that the volume expansion of sandwich bread increased when using steamed PSP, which overcomes the disadvantage of the bread, which is the low expansion when using PSP powder as in previous studies. The results suggested that the addition of steamed PSP could be an effective way of enhancing the technological and nutritional of sandwich bread (Figure 4). Based on these findings, all forms of PSP can be a natural colourant, a potential functional food ingredient, and can become a superior source for the production of foods with health benefits. This also showed a new use of PSP in the bread industry, effectively utilizing local resources and national agribusiness.

Figure 4. Sandwich bread with steamed PSP supplement.

Conflict of interest

The authors declare no conflict of interest.

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References

Ahmed, M., Akter, M.S. and Eun, J.B. (2011) Optimization conditions for anthocyanin and phenolic content extraction form purple sweet potato using response surface methodology. *International Journal of Food Sciences and Nutrition*, 62(1), 91–96. http://doi.org/10.3109/09637486.2010.511167.

Amandikwa, C., Iwe, M.O., Uzomah, A. and Olawuni, A.I. (2015). Physico-chemical properties of wheat-yam flour composite bread. *Nigerian Food Journal*, 33(1), 12-17. https://doi.org/10.1016/j.nifoj.2015.04.011

AOAC. (1980). Official Methods for computation of carbohydrates and energy. 14th ed. Washington, DC, USA: AOAC.

AOAC. (1990). Official Methods of Analysis for crude fiber. 15th ed. Washington, DC, USA: AOAC.

AOAC. (1997). Official Methods of Analysis for fat (crude) or ether extract in flour (AOAC 920.85, 3rd rev). 16th ed. Gaithersburg, Maryland, USA: AOAC.

AOAC. (2005). Official Methods of Analysis for ash, moisture in flour (AOAC 929.09). 18th ed. Arlington, USA: AOAC.

Asselman, A., Van Straten, G., Boom, R.M., Esveld, D.C. and Van Boxtel, A.J.B. (2007). Quality prediction of bakery products in the initial phase of process design. *Innovative Food Science and Emerging Technologies*, 8(2), 285-298. https://doi.org/10.1016/j.ifset.2007.01.006

Bae, S.H. and Suh, H.J. (2007). Antioxidant activities of five different mulberry cultivars in Korea. *LWT-Food Science and Technology*, 40(6), 955-962. https://doi.org/10.1016/j.lwt.2006.06.007

Curayag, Q.A.L., Dizon, E.I. and Hurtada, W.A. (2019). Antioxidant activity, chemical and nutritional properties of raw and processed purple-fleshed sweet potato (*Ipomoea batatas* Lam.). *Cogent Food and Agriculture*, 5(1), 1662930. https://doi.org/10.1080/23311932.2019.1662930

Danza, A., Mastromatteo, M., Cozzolino, F., Lecce, L., Lampignano, V., Laverse, J. and Del Nobile, M.A. (2014). Processing and characterization of durum wheat bread enriched with antioxidant from yellow pepper flour. *LWT-Food Science and Technology*, 59 (1), 479-485. https://doi.org/10.1016/j.lwt.2014.06.001

Dovene, A.K., Wang, L., Bokhary, S.U.F., Madebo, M.P., Zheng, Y. and Jin, P. (2019). Effect of cutting styles on quality and antioxidant activity of stored fresh-cut sweet potato (*Ipomoea batatas* L.) cultivars. *Foods*, 8(12), 674. https://doi.org/10.3390/foods8120674

Fan, G., Han, Y., Gu, Z. and Chen, D. (2008). Optimizing conditions for anthocyanins extraction from purple sweet potato using response surface methodology (RSM). *LWT-Food Science and Technology*, 41(1), 155-160. https://doi.org/10.1016/j.lwt.2007.01.019

Gorinstein, S., Pawelzik, E., Delgado–Licon, E., Yamamoto, K., Kobayashi, S., Taniguchi, H. and Trakhtenberg, S. (2004). Use of scanning electron microscopy to indicate the similarities and differences in pseudocereal and cereal proteins. *International Journal of Food Science and Technology*, 39(2), 183-189. https://doi.org/10.1046/j.0950-5423.2003.00773.x

Kano, M., Takayanagi, T., Harada, K., Makino, K. and Ishikawa, F. (2005). Antioxidative activity of anthocyanins from purple sweet potato, *Ipomoera batatas* cultivar Ayamurasaki. *Bioscience, Biotechnology and Biochemistry*, 69(5), 979-988. https://doi.org/10.1271/bbb.69.979

Khoo, H.E., Azlan, A., Tang, S.T. and Lim, S.M. (2017). Anthocyanidins and anthocyanins: Colored pigments as food, pharmaceutical ingredients, and the potential health benefits. *Food and Nutrition Research*, 61(1), 1361779. https://doi.org/10.1080/16546628.2017.1361779

Larief, R., Dirpan, A. and Theresia. (2018). Purple yam flour (*Dioscorea alata* L.) processing effect on anthocyanin and antioxidant capacity in traditional cake "bolu cukke" making. *IOP Conference Series: Earth and Environmental Science,* 207, 012043. https://doi.org/10.1088/1755-1315/207/1/012043

Lee, S.M. and Park, G.S. (2011). Quality characteristics of bread with various concentrations of purple sweet potato. *Korean Journal of Food and Cookery Science*, 27(4), 1-16. https://doi.org/10.9724/kfcs.2011.27.4.001

Liu, X., Yang, L., Zhao, S. and Zhang, H. (2020). Characterization of the dough rheological and steamed bread fortified with extruded purple sweet potato flour. *International Journal of Food Properties*, 23(1), 765-776. https://doi.org/10.1080/10942912.2020.1733600

Liu, X.L., Mu, T.H., Sun, H.N., Zhang, M. and Chen, J.W. (2016). Influence of potato flour on dough rheological properties and quality of steamed bread. *Journal of Integrative Agriculture*, 15(11), 2666-2676. https://doi.org/10.1016/S2095-3119(16)61388-6

Maran, J.P., Sivakumar, V., Thirugnanasambandham, K. and Sridhar, R. (2015). Extraction of natural anthocyanin and colors from pulp of jamun fruit. *Journal of Food Science and Technology*, 52 (6), 3617-3626. https://doi.org/10.1007/s13197-014-1429-0

Mastromatteo, M., Danza, A., Lecce, L., Spinelli, S., Lampignano, V., Laverse, J. and Del Nobile, M.A. (2015). Nutritional and physicochemical characteristics of wholemeal bread enriched with pea flour. *International Journal of Food Science and Technology*, 50(1), 92-102. https://doi.org/10.1111/ijfs.12636

Nindjin, C., Amani, G.N. and Sindic, M. (2011). Effect of blend levels on composite wheat doughs performance made from yam and cassava native starches and bread quality. *Carbohydrate Polymers*, 86(4), 1637-1645. https://doi.org/10.1016/j.carbpol.2011.06.076

Okorie, S.U. and Onyeneke, E.N. (2012). Production and quality evaluation of baked cake from blend of sweet potatoes and wheat. *Journal of Natural and Applied Sciences*, 3(2), 171–177.

Ranawana, V., Campbell, F., Bestwick, C., Nicol, P., Milne, L., Duthie, G. and Raikos, V. (2016). Breads fortified with freeze-dried vegetables: quality and nutritional attributes. Part II: breads not containing oil as an ingredient. *Foods*, 5(3), 62. https://doi.org/10.3390/foods5030062

Reis, J.F., Monteiro, V.V.S., de Souza Gomes, R., do Carmo, M.M., da Costa, G.V., Ribera, P.C. and Monteiro, M.C. (2016). Action mechanism and cardiovascular effect of anthocyanins: a systematic review of animal and human studies. *Journal of Translational Medicine*, 14, 315. https://doi.org/10.1186/s12967-016-1076-5

Salehifar, M., Ardebili, M.S. and Azizi, M.H. (2010). Effect of wheat flour protein variations on sensory attributes, texture and staling of Taftoon bread. *Food Science and Technology*, 30, 833-837. https://doi.org/10.1590/S0101-20612010000300041

Scheuer, P.M., Luccio, M.D., Zibetti, A.W., de Miranda, M. Z. and de Francisco, A. (2016). Relationship between instrumental and sensory texture profile of bread loaves made with whole-wheat flour and fat replacer. *Journal of Texture Studies*, 47(1), 14-23. https://doi.org/10.1111/jtxs.12155

Shaari, N., Shamsudin, R., Nor, M.Z.M. and Hashim, N. (2021). Quality attributes of Malaysia purple-fleshed sweet potato at different peel condition. *Agronomy*, 11(5), 872. https://doi.org/10.3390/agronomy11050872

Solagi, I., Shaikh, N., Marri, A., Soomro, A. and Khaskheli, S. (2017). Loaf characteristics and sensory properties of whole wheat bread fortified with sorghum and rice flour. *Journal of Basic and Applied Sciences,* 13*,* 606–610. https://doi.org/10.6000/1927-5129.2017.13.97

Szczesniak, A.S. (2002). Texture is a sensory property. *Food Quality and Preference*, 13(4), 215-225. Http://doi.org/10.1016/S0950-3293(01)00039-8

Tamaroh, S. and Sudrajat, A. (2021). Antioxidative characteristics and sensory acceptability of bread substituted with purple yam (*Dioscoreaalata* l.). *International Journal of Food Science,* 2021, Article ID 5586316. https://doi.org/10.1155/2021/5586316

Wang, N., Maximiuk, L. and Toews, R. (2012). Pea starch noodles: Effect of processing variables on characteristics and optimisation of twin-screw extrusion process. *Food Chemistry*, 133(3), 742-753. https://doi.org/10.1016/j.foodchem.2012.01.087

