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Original Research Article

Organoleptic and Nutritional Evaluation of Antioxidant Rich Products Developed from Orange and Purple Fleshed Sweet Potato

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ABSTRACT

The orange and purple-fleshed sweet potato tubers are cheap sources of antioxidants like β-carotene and anthocyanin respectively. Use of sweet potato with 100% supplementation was found at par in terms of taste and other sensory attributes. Antioxidant rich products were developed by using fresh sweet potato as French fries, mixed vegetable and *chaat*. The aim of present study was to standardize and compare the products organoleptically as well as nutritionally for coloured sweet potato. Results revealed that POSP reported high calcium whereas orange fleshed gave higher values for protein and iron. Organoleptic attributes of PFSP french-fries showed more acceptability in all the attributes than OFSP and proved better. OFSP french-fries contributed 4.78 g protein, 15.66 g fat, 2.48 g fibre, 4.32 mg iron 92.92 mg of calcium with9, 08 mg β carotene. PFSP french-fries resulted in 4.57g protein, 15.88 g fat, 2.73 g fibre, 4.03mg iron, 105.12mg of calcium with 86.4mg anthocyanin. For mixed vegetable and *chaat* OFSP scored better having starchy and mealy taste with more colour acceptance. OFSP vegetable resulted in 4.92g protein, 5.12g fat, 2.96g fibre, 4.43mg iron 142.88 mg of calcium with 9.08 mg β carotene whereas PFSP vegetable contributed 4.52 g protein, 5.5g fat, 3.19g fibre, 4.01mg iron, 156.45 mg of calcium with 82.30mg anthocyanin. *Chaat* with OFSP resulted in 4.67 g protein, 0.56 g fat, 2.03g fibre, 4.21mg iron, 83.98mg of calcium with 7.9 mg β carotene while PFSP *chaat* contributed 4.03g protein, 0.68g fat, 2.78g fibre, 3.89mg iron, 101.47 mg of calcium with 93.12 mg anthocyanin. This study revealed that using sweet potato as base ingredient can completely replace the traditional preparations as well as contribute to antioxidant content significantly.

Key words: Sweet orange-flesh sweet potato, purple-flesh sweet potato, β carotene, anthocyanin. Organoleptical analysis, Nutrient content.

INTRODUCTION

The level of oxidative stress is determined by the balance between the rate at which oxidative damage is induced and the rate at which it is efficiently repaired and removed. The rate at which damage is caused is determined by how fast the reactive oxygen species are generated and then inactivated by endogenous defense agents called antioxidants. Unfortunately, under the present day life-style conditions many people run an abnormally high level of oxidative stress that could increase their probability of early incidence of decline in optimum body functions. The determinants of oxidative stress are regulated by an individual's unique hereditary factors, as well as his/her environment and characteristic lifestyle and food intake. Antioxidant offers protection against wide spectrum of diseases. To resist their harmful effects, the body has its own defense system with few enzymes and some nutrients.

Plant sourced food antioxidants like vitamin C, vitamin E, carotene, anthocyanin, phenolic compounds, phytates have been recognized as having the potential to reduce disease risk by thus inhibiting the oxidative mechanisms that lead to degenerative diseases conditions like atherosclerosis, diabetes, heart disease and colon cancer. [1] The main characteristics of an antioxidant are its ability to trap free radicals. Different types of natural antioxidants are present in fruits and vegetables; they have synergistic interactions that are important due to their activity and regenerative potential. [2] Correlation between glutathione oxidation and mt DNA damage and that age-associated mtDNA damage can be prevented by administration of antioxidant vitamins. [3]

Vitamin A is anti-inflammatory as it helps in reducing the severity of conditions where inflammation plays a role, such as asthma, osteoarthritis and rheumatoid arthritis. [4] Carotenoids such as lycopene and β-carotene are important biological compound that can inactivate electronically excited molecules, a process termed quenching. Vitamin C regenerates vitamin E and glutathione which acts as a substrate for several transferases, peroxidases and other enzymes that prevent or mitigate the deleterious effects of oxygen free radicals. Administration of antioxidant supplements such as a combination of vitamin A, C and E are necessary in women at high risk of developing breast cancer or after surgery or with anticancer drugs. [5]

Vitamin A is an important micronutrient for maintaining normal growth, regulating cell proliferation and differentiation, controlling development and maintaining reproductive functions. Sweet potato (*Ipomea batata*) is nutrient rich, excellent source of vitamin A 14187 IU good source of vitamin C 24 mg, magnesium 25 mg and good source of copper, iron, potassium, vitamin B6 and dietary fibre apart from the presence of other minerals and vitamins. [6] Sweet potato is a good source of fibre which plays a favourable role in reducing blood cholesterol level. [4] The purple-fleshed sweet potato anthocyanins primarily peonidins and cyanidins have important antioxidant properties and anti-inflammatory properties. Particularly when passing through our digestive tract, they may be able to lower the potential health risk posed by heavy metals and oxygen. Yield of SPF crude phenolic extract increased from 0.29 to 3.22 g/100 g SPF upon subjection to gastrointestinal pH conditions ($p < 0.05$). Total phenolic content (TPC), total flavonoid content (TFC) and antioxidant activity of SPF ($p < 0.05$) were also elevated significantly. [7] In summary, the antioxidant properties of SPF were enhanced under gastrointestinal pH conditions, suggesting that SPF possess a considerable amount of bound phenolic and other antioxidative compounds. Sweet potatoes (*Ipomoea batatas* Lam.) are highly nutritious vegetables that are rich in calories and biologically active phytochemicals such as β-carotene, polyphenols, ascorbic acid and dietary fibre. [8] Phytochemicals in sweet potato may have a significant effect on antioxidant and anticancer activities. [9]

Sweet potato production in India in the year 2013-14 was reported to be 1,087.88000 tons. [10] Sweet potato flour

(SPF), a dehydrated product, can be used as a substitute for wheat flour to lower costs and as such decrease imports of wheat flour can be used to substitute part of the wheat flour used to make *chapathis* and other baked goods. Food based approaches using these bioactive compounds when adequately implemented can be effective in controlling oxidative stress and for the improvement of health. Hence, sweet potato can be used as an easy accessible source of natural antioxidants, as a food supplement, or in the pharmaceutical and medical industries.

MATERIALS AND METHODS

Orange-fleshed sweet potatoes (OFSP) *ST14* and Purple-fleshed sweet potato (PFSP) *ST 13* were selected for present study. The sweet potato cultivars were grown at the experimental fields of the Department of vegetable Science PAU, Ludhiana. Sweet potato tubers were soaked in tap water for 15 min and then cleaned by tap water to remove adhering soil particles and other foreign debris. Different recipes were developed using complete replacement as French fries, Vegetable and *Chaat*. For *Chaat* and French Fries, fresh tubers were used. For *chaat* sweet potatoes were steamed in pressure cooker with 15 psi for not more than 2 minutes for OFSP and 3 minutes for PFSP, then peeled and cut. Both the cultivars were steamed and dried separately. The prepared products were evaluated thrice for their acceptability by a panel of 10 judges using 9 points Hedonic Rating Scale. The judges were served with three coded samples of each product with both cultivars and a control. Potato was used as control(C) for French fries, mixed vegetables and *chaat*. The orange fleshed sweet potato (OFSP) was coded as S1 and purple fleshed sweet potato (PFSP) was codes as S2. Nutritional evaluation of products was performed by analyzing proximate, [11] Vitamin C, [12] β carotene and anthocyanin [13] content. Statistical analysis was done to compare their organoleptic attributes and nutrients between both varieties of sweet potato by using ANOVA.

RESULTS AND DISCUSSION

Organoleptic Evaluation of Developed Products:

French Fries: The result presented in table 1 revealed that three samples of different products for French Fries, chaat and Vegetable with potato (C) and sweet potato (S1 and S2) were prepared. The mean scores of acceptability trials of the French Fries revealed that the sweet potato were liked moderately with an overall acceptability score of 7.54 -7.92 lower than that of Control being 8.12.The score for taste being 8.2 for control , was found to be significantly higher ($p \leq 0.05$) than the scores for the S1 . Higher score was obtained by S2 in all attributes as compared with S1 in colour, texture, taste and flavor but was non-significant as compared with S 1.However, S 2 was found at par in colour and taste with control C but were non-significant each other. These results indicate that S2 variety performs better for making French fries than S1. Orange sweet potatoes had higher visual surface moisture compared with other colored sweet potatoes whereas purple sweet potatoes had higher visual fibrousness compared with other colored cultivars. Purple sweet potatoes were perceived as more firm, dense, less moist and higher in chalkiness compared with other colored cultivars. [14]

Mixed Vegetable: Samples of vegetable were prepared using potato for Control and sweet potato S1 and S2 mixed with other vegetables. The results revealed that the higher scores for the colour, appearance, flavor, texture and taste was obtained by S1 ranging from 7.2 to 7.5 with an overall acceptability score of 7.28 which was liked very much , followed by S 2 with an overall acceptability score of 6.28. The lowest score for acceptability was found in colour and appearance i.e. 6.1 which were liked moderately. The Control vegetable had highest overall acceptability score of 8.18 than of S1 and S2. The scores for colour (8.20), appearance (8.20), texture (8.20), taste (8.30) and flavor (8.0) of C was highest followed by S1 (7.20), (7.20), (7.50), (7.30), (7.20) and S2 (6.10), (6.10), (6.30), (6.30), and (6.60) respectively. There was significant difference among all three samples in terms of appearance, flavor and overall acceptability. S1 achieved insignificant higher score for colour and taste over S2. Vegetable (*kandamula sabji)* developed with sweet potato was extremely liked by the community people in Odisha. [15] This may be contributing to the fact that there was a significant treatment effect for color Orange sweet potatoes (the most common type encountered in the U.S.A.) received higher appearance liking scores as compared with yellow or purple cultivars. [14]

Chaat: Three samples of *chaat* were prepared using potato for Control and sweet potato S1 and S2. The results revealed that the highest scores for the color, appearance, flavour, texture and taste was obtained by S1 ranging from 8.1 to 8.4 with an overall acceptability score of 8.24 which was liked extremely, followed by C and S2 which had an overall acceptability score of 7.98 and 7.42 respectively. The S1 was found superior in terms of texture and overall acceptability over Control but were none significantly different. There was no significant difference for the appearance and colour among all three but Control and S1scored better than S2 in terms of taste, texture, flavor and overall acceptability.

Table 1.1: Organoleptic Analysis of French Fries

Level	Appearance	Colour	Texture	Taste	Flavour	Overall Acceptability
C	$8.40^{a}\pm0.51$	$8.00^{a}\pm0.94$	$8.00^{a}\pm0.66$	$8.20^{a}\pm0.42$	$8.00^{a}\pm0.66$	$8.12^{a}\pm0.38$
S1	$7.50^{b}\pm0.52$	$7.90^{a}\pm0.31$	$7.30^{a}\pm0.94$	$7.50^{b}\pm0.85$	$7.50^{a}\pm0.97$	$7.54^{b}\pm0.32$
S2	$7.90^{ab}\pm0.31$	$8.00^{a}\pm0.00$	$7.90^{a}\pm0.73$	$8.20^{a}\pm0.42$	$7.60^{a}\pm0.69$	$7.92^{ab}\pm0.32$

Tukey's test has been applied for different parameters at different levels. Values followed with different superscripts are significant ($p\leq0.05$).

Table 1.2: Organoleptic analysis of Mixed vegetable.

Level	Appearance	Colour	Texture	Taste	Flavour	Overall Acceptability
C	$8.20^{a}\pm0.42$	$8.20^{a}\pm0.63$	$8.20^{a}\pm0.63$	$8.30^{a}\pm0.48$	$8.00^{a}\pm0.81$	$8.18^{a}\pm0.37$
S1	$7.20^{b}\pm0.63$	$7.20^{b}\pm0.63$	$7.50^{a}\pm0.85$	$7.30^{b}\pm0.48$	$7.20^{b}\pm0.63$	$7.28^{b}\pm0.36$
S2	$6.10^{c}\pm0.87$	$6.10^{b}\pm0.87$	$6.30^{b}\pm0.48$	$6.30^{b}\pm0.67$	$6.60^{c}\pm0.69$	$6.28.23^{c}\pm0.33$

Tukey's test has been applied for different parameters at different levels. Values followed with different superscripts are significant ($p\leq0.05$).

Table 1: Organoleptic Analysis of *Chaat*

Level	Appearance	Colour	Texture	Taste	Flavour	Overall Acceptability
C	$7.90^{a}\pm0.31$	$7.90^{a}\pm0.56$	$8.00^{ab}\pm0.66$	$8.00^{a}\pm0.47$	$8.10^{a}\pm0.56$	$7.98^{ab}\pm0.38$
S1	$8.20^{a}\pm0.63$	$8.40^{a}\pm0.51$	$8.10^{a}\pm0.73$	$8.20^{a}\pm0.63$	$8.30^{a}\pm0.48$	$8.24^{a}\pm0.39$
S2	$7.70^{a}\pm0.94$	$7.90^{a}\pm1.10$	$7.10^{b}\pm0.99$	$7.20^{b}\pm0.78$	$7.20^{b}\pm0.48$	$7.42^{b}\pm0.40$

Tukey's test has been applied for different parameters at different levels. Values followed with different superscripts are significant ($p\leq0.05$).

Nutritional Analysis of Coloured Sweet Potato Products:

French fries: The proximate composition of control (potato), S1 (OFSP) and S2 (PFSP) french fries revealed that as in (table 2.1) S1 possessed higher percentage of protein, 4.78g whereas S2 showed higher values for fibre and ash being 2.73, 1.11 per cent. Fat content was much higher in potato chips than sweet potato chips. A linear relationship found between dry matter content in raw sweet potato tubers and the level of oil uptake. [16] Sweet potato tubers with 23-25% dry matter content gave crisps containing between 21% and 32% of oil, while the fat contents of crisps from potatoes having similar dry matter content were 36% and more, indicating that potato chips absorbs more fat than sweet potato chisps. Thus, S2 was found to be better for french fries as already showed in sensory analysis due to its fibre content. Vitamin C did not show much difference among three. A wide range varying between 9.23 to 44.93 mg/ 100 g of sweet potato chips was noticed. [17] Iron content was higher, 4.32 mg in S1 whereas calcium was higher in S2 having 105.12mg as shown in (table2.2). β carotene was found 9.08 mg/100g in S1 while anthocyanin content was 86.4mg/100g in S2. Antioxidant activity measured by DPPH showed the highest % inhibition in PFSP french fries 51.21 followed by 47.49 and 33.65% inhibition respectively.

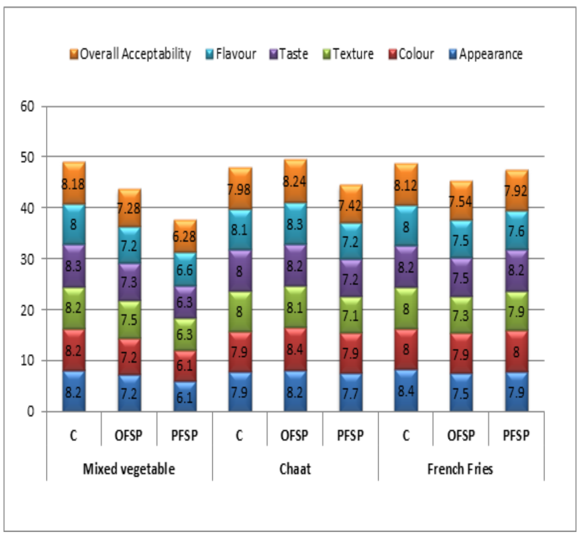

Fig. 1 Organoleptic analysis of different products

Mixed Vegetable: The proximate composition (table 2.1) of vegetable (C) and vegetable supplemented with fresh sweet potato S1 and S2 revealed that the moisture content ranged between 2.8 to 3.2%. The protein content of control was found to be 2.2 g which was lower than S1, 4.92 and S2 being 4.52 per cent. The fat content of vegetable was found approximately equal in all the treatments that are 5.12, 5.5 and 5.95% in S1, S2 and C, respectively. The fibre content in C, S1 and S2 were found 2.22, 2.96 and 3.19 percent respectively while ash content was 1.69, 1.89 and 2.26 per cent respectively. The values for carbohydrate, was 84.84g in C followed by 82.33g in S2 and 81.91g in S1. Energy showed slight variation 401.71, 393.40 and 395.50 Kcal in C, S1 and S2 respectively. Iron (table2.2) was significantly high in test samples 4.43mg and 4.01 mg in S1 and S2 respectively while calcium showed high value of 156.45mg and 142.88mg for S2 and S1 respectively. Vitamin C (table 2.3) was present in S1 and S2 having 29.68 and 28.37mg /100g. S1 showed β carotene as 9.08 mg compared to 0.9mg in Control and 0.83 mg S2. Anthocyanin content found was 82.30mg/100g. Antioxidant activity measured by DPPH showed the highest % inhibition in PFSP vegetable followed by OFSP and control being 53.30, 46.50 and 38.85% inhibition respectively.

Chaat: The moisture content of control *chaat* preparation (C) was found to be 3.6% as compared with the test sample S1 being 4.36 and S2 being 3.45 per cent (table 2.1) . The amount of protein in S1 was 4.67% while it was 4.03% in S2 .Though S1 showed better protein content than S2 but they were at par while both were significantly superior over control C. No amount of fat was added to the preparation but presence of 0.56 to 0.68 percent of fat in the result may be due to fat present in the samples itself. The fibre, 2.78% and ash content, 1.16 % in S2 of was higher than S1 being 2.03% for fibre and 1.14% for ash. The results for the carbohydrate content of C and S2 were 92.13 and 88g followed by 87.24 in S1. Energy value for control preparation was 379 kcal/100g while for S2 it was 374 kcal followed by S1, 373 Kcal per 100 g. Significant difference was found in calcium content (table2.2) between S1 and S2 having 83.9 in S1 and 101.47 mg 1n S2 which was 3.7 and 4.5 times higher than control. Vitamin C showed high percentage in both the test samples of *chaat* 35.06 mg for S2 and 32.84 mg for S1 which is higher than C being 26.26mg/100g. Content of β carotene found in S1 was 8.80 mg and anthocyanin in S2 was 93.12mg/100g. DPPH activity resulted in 73.00 in PFSP showed highest antioxidant activity, followed by 59.36 in OFSP and 36.70 % inhibition in control *chaat.*

High positive correlation between the total anthocyanin content and its antioxidant activity found by [18] Results) clearly demonstrated that cyanidin based anthocyanins were closely related to DPPH radical scavenging activity in sweet potato storage roots. [19] The lowest antioxidant activity in potato with yellow or white fleshed tubers followed by red-fleshed varieties. It was higher 4.34 times in red fleshed and in even more 5.03 times higher in purple-fleshed varieties. [20]

Table 2.1 Proximate Composition of developed products using Sweet potato fresh/flour/flakes (on dry weight basis g/100g)

Products	Moisture (g)	Protein (g)	Fat (g)	Fibre(g)	Ash(g)	CHO(g)	Energy (Kcal)
French Fries							
C	$2.6^{b}\pm0.19$	$1.71^{b}\pm0.07$	$16.46^{a}\pm0.49$	$2.41^{a}\pm0.48$	$0.64^{a}\pm0.04$	$76.18^{a}\pm2.95$	459.7
S1	$3.3^{a}\pm0.12$	$4.78^{a}\pm0.17$	$15.66^{a}\pm0.10$	$2.48^{a}\pm0.06$	$0.84^{b}\pm0.05$	$73.78^{a}\pm0.49$	455.18
S2	$2.96^{ab}\pm0.04$	$4.57^{a}\pm0.01$	$15.88^{a}\pm0.01$	$2.73^{a}\pm0.04$	$1.11^{c}\pm0.06$	$72.75^{a}\pm0.36$	452.20
Mixed Veg							
C	$3.1^{a}\pm0.37$	$2.2^{b}\pm0.14$	$5.95^{a}\pm0.90$	$2.22^{b}\pm0.39$	$1.69^{c}\pm0.23$	$84.84^{b}\pm16.06$	401.71
S1	$3.2^{b}\pm0.22$	$4.92^{a}\pm0.28$	$5.12^{a}\pm0.06$	$2.96^{a}\pm0.01$	$1.89^{b}\pm0.01$	$81.91^{a}\pm2.15$	393.40
S2	$2.8^{c}\pm0.08$	$4.52^{a}\pm0.22$	$5.5^{a}\pm0.20$	$3.19^{a}\pm0.26$	$2.26^{a}\pm0.11$	$82.33^{a}\pm2.01$	395.50
Chaat							
C	$3.6^{b}\pm0.16$	$1.82^{b}\pm0.03$	$0.37^{a}\pm0.08$	$1.22^{c}\pm0.27$	$0.86^{a}\pm0.22$	$92.13^{a}\pm5.89$	379.13
S1	$4.36^{a}\pm0.31$	$4.67^{a}\pm0.10$	$0.56^{a}\pm0.19$	$2.03^{b}\pm0.07$	$1.14^{ab}\pm0.13$	$87.24^{b}\pm1.12$	372.68
S2	$3.45^{b}\pm0.09$	$4.03^{a}\pm0.65$	$0.68^{a}\pm0.04$	$2.78^{a}\pm0.07$	$1.16^{a}\pm0.19$	$88.00^{b}\pm4.35$	374.24

N=3 ,mean ± sd, superscripts are significant at ($p\leq0.05$)

Table 2.2 Vitamins Minerals content of developed products using Sweet potato fresh/flour/flakes (on dry weight basis mg/100g)

Products	Iron(mg)	Calcium(mg)
French Fries		
C	$0.64^{c}\pm0.04$	$18.33^{c}\pm0.13$
S1	$4.72^{a}\pm0.14$	$92.92^{b}\pm1.58$
S2	$4.03^{b}\pm0.06$	$105.12^{a}\pm0.24$
Mixed Veg		
C	$1.74^{c}\pm0.02$	$32^{c}\pm17.40$
S1	$4.93^{a}\pm0.13$	$142.88^{b}\pm5.95$
S2	$4.11^{b}\pm0.11$	$156.45^{a}\pm3.87$
Chaat		
C	$1.81^{b}\pm0.04$	$22.46^{b}\pm1.48$
S1	$4.41^{a}\pm0.30$	$83.98^{a}\pm4.35$
S2	$4.97^{a}\pm0.28$	$101.47^{a}\pm0.72$

n=3 mean ± sd superscripts are significant at ($p\leq0.05$).

Table 2.3 Vitamins and antioxidant content of developed products using Sweet potato flour/flakes (on dry weight basis mg/100g)

Products	Vitamin C(mg)	β-carotene (mg)	Anthocyanin(mg)	DPPH (% inhibition)
French Fries				
C	$10.82^{b}\pm0.60$	0.17±0.05	0	33.65±0.12
S1	$27.57^{a}\pm0.67$	8.84±0.74	0	47.49±0.14
S2	$27.85^{a}\pm1.07$	0	86.4±1.13	51.21±0.13
Mixed Vegetable				
C	$25.84^{c}\pm14.22$	0.9±0.02	0	38.85±0.42
S1	$29.68^{a}\pm1.37$	9.08±0.74	0	46.50±0.22
S2	$28.37^{b}\pm0.94$	0.83±0.03	82.30±0.15	53.30±2.41
Chaat				
C	$26.26^{b}\pm3.51$	0.07±0.04	0	36.70±0.64
S1	$32.84^{a}\pm0.97$	8.80±0.36	0	59.36±0.05
S2	$35.06^{a}\pm1.96$	0	93.12±0.98	73.00±2.07

Tukey's test has been applied for different parameters at different levels. Values followed with different superscripts are significant ($p\leq0.05$).

CONCLUSION

Study conducted on sensory and nutritional content of coloured sweet potato revealed that all products developed with sweet potato contain high protein and iron than in potato as control. Fibre and calcium content was higher in PFSP than OFSP and potato. A significant increase in β carotene was observed in all of the developed OFSP products with the addition of either fresh or dehydrated sweet potato flour or flakes. Incorporation of 40% sweet potato flour yielded approximately similar results compared with wheat flour cookies with improved nutritional value and texture and showed the peculiar characteristics (moisture, protein, ash, fiber and fat) of sweet potato flour. [21]

High calcium content reported in the study may be attributed to the varietal differences, soil and agropractices. [22] A separate analysis with only OFSP varieties (N = 32 clones) studied revealed that there are positive correlations between β-carotene and minerals. [23] It was also found a moderate negative correlation between β-carotene and carbohydrate. Results of this study revealed a possibility of fresh as well as dehydrated sweet potato with orange and purple flesh colour could be a better nutritional substituent food for commercially available food industries. Consumption of β-Carotene rich orange-fleshed sweet potato in either fresh or cooked form can contribute considerably in increasing dietary protein, iron and fibre content as well as serum retinol and glutathione levels. The supplemented products were found to have higher calcium content than the corresponding control sample. β- carotene and ascorbic acid content increased with the supplementation of sweet potato in all the products. Thus, natural colourant and antioxidant present in orange and purple flesh sweet potatoes can be used for developing functional foods.

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