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Effect of antioxidant rich orange fleshed sweet potato flour on nutritional and biochemical parameters of elderly males and females

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Abstract
Consumption of b-Carotene rich orange-fleshed sweet potato in either fresh or cooked form can contribute considerably in increasing protein, iron and fiber content as well as serum retinol and glutathione levels. It had a beneficial effect on lowering the total cholesterol, triglyceride, LDL-C, VDL-C but helped in increasing the HLD-C increased after supplementation in males and females. It also lowered blood pressure. The supplemented products were found to have higher calcium content than the corresponding control sample. B-carotene and ascorbic acid content increased with the supplementation of sweet potato. Supplementation with orange-fleshed sweet potato anti-oxidant powder 20g/day for 3 months to the selected subjects revealed that after supplementation of OFSP powder, serum retinol and glutathione peroxidase increased (22.8 and 27.1%, 35.12 and 35.9% in male and female respectively). Random blood sugar reduced (13.2% in males and 9.65% in females). Blood pressure also decreased (8.86 and 16.54% in male and female in Systolic BP and 7.43 and 13.4% in male and female in Diastolic BP) with OFSP supplementation. The study concludes that supplementation of 20g OFSP significantly reduce the oxidative stress; improved the lipid profile and antioxidant status of male and female. Results of the biochemical analysis of blood, co-relates with supplementation of food with 20 percent of OFSP may be one of the factors in intervening in these aspects.

Keywords: OFSP**,** oxidative stress, β- carotene, Serum Retinol, glutathione peroxidase

Introduction

The present lifestyle conditions enforce many people to run an abnormally high level of oxidative stress that could increase their probability of early incidence of decline in optimum body functions. To resist their harmful effects, the body has its defense system with few enzymes and some nutrients. Antioxidant compounds in food play an important role as a health-protecting factor. 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. Carotenoids such as lycopene and β-carotene are important biological compounds that can inactivate electronically excited molecules, a process termed quenching. Carotenoids may also participate in reactions leading to decrease information of free radicals. Food-based approaches using these bioactive compounds when adequately implemented can be effective in controlling oxidative stress and for the improvement of health.

Vitamin A is a very powerful antioxidant that works in the body to eliminate free radicals and as an important micronutrient for maintaining normal growth, regulating cell proliferation and differentiation, controlling development and maintaining reproductive functions. Sweet potato (*Ipomea batata*) is a nutrient-rich source of β carotene 5376 µg, a good source of vitamin C 17.94-22.2 mg, magnesium 17.37-21 mg and a good source of copper, iron, potassium, folate, and dietary fiber apart from the presence of other minerals and vitamins (longvah *et al*, 2017). Sweet potato due to its high fiber content and the antioxidant property is often recognized as healthy food. Sweet potato contains important amino acids lysine. Considering complex carbohydrates, proteins, Vitamin A and C, Fe and Ca, the sweet potato ranks highest in nutritional value as compared to all other vegetables. Sweet potato is a good source of fiber which plays a favorable role in reducing blood cholesterol level (Chukwu *et al*, 2012).

Sweet potato also contains a significant quantity of the anti-oxidant nutrients β-carotene, vitamin C and vitamin E; thus, its consumption inhibits the formation of free radicals that have been implicated in the development of coronary heart disease. Besides, sweet potatoes are a good source of vitamin B6, which is needed to convert homocysteine, an intermediate product created during an important chemical process in cells called methylation, into other benign molecules and this helps to reduce the risk of stroke or heart attack (Meteljan *et al*, 2006; Lorna, *et al* 2009).

Sweet potato production in India in the year 2017-18 was reported t 1500.51MT, (Horticulture statistics Div, 2018). Sweet potato flour, a dehydrated product, can be used as a substitute for wheat flour to lower costs and as such decrease imports of wheat flour, and as an alternative market outlet for those selling the roots as raw material (Van Hal 2000). In India, pancakes, puddings, and *chapatis* are made with 50% sweet potato flour and a much wider range of products exist including doughnuts, biscuits, cookies, brownies, noodles, pies, breakfast foods, and weaning foods (Van Hal *et al*, 2000).

There are several varieties grown may be broadly categorized based on its color like white, orange, and purple which is due to the presence of phenols, β-carotene, and anthocyanin, etc. which are responsible for its nutritional value and antioxidant properties. The effect of sweet potato variety on carotenoid concentrations is very great, ranging from negligible to ≥22000 μg/100g. The anti-nutritional factor detected in sweet potato varieties includes phytates, oxalates, and tannins. However, different cooking methods may reduce inhibitory factors as compared to uncooked ones as studied by Bhandari and Kawabata (2006).

Method of consumption and cooking also plays an important role in the retention of nutrition. Red and purple-fleshed tubers show greater free radical scavenging activity than yellow and white-fleshed tubers after the cooking treatments (Perla *et al* 2012).

Materials and Methods

The present study was carried on development and supplementation of orange-fleshed sweet potato *(Ipomea batata* L.) and its effect on the health status of elderly males and females in the department of Food and Nutrition, College of Home Science, Punjab Agricultural University PAU, Ludhiana.

The sweet potato tubers ST-14 for β carotene were studied for cooking methods such as steaming and drying (making into flour) were used and their effect on nutrients was analyzed for better nutritional retention. For purpose of dehydration, the tubers of OFSP were steamed for 2 minutes since OFSP variety has been reported as starchy and mealy and were dehydrated at 60. C in the dehydrator, Vimla *et al* (2011) also found an increase in β-carotene due to boiling ranging from 84 to 90 percent. Forty male and forty female subjects between 40-60 years were selected. Selected subjects were divided into two groups C (Control) and E (Experimental) containing 20 subjects each. The subjects of group E (experimental) were provided 200g OFSP powder in a sealed poly pack at 10 days interval to be used in their diet 20 g/day for continuous 3 months. Proximate composition, anthropometric measurement, biochemical analysis, and antioxidant activity calculated. From the data obtained the mean values and standard error for each sample were calculated. The significant difference between the organoleptic scores and nutritional composition of the samples was tested using the Tukey's test and t-test. Relevant correlations were also computed.

Results and Discussion

Flakes and flour were made with dehydrated products, showed at par value of 7.88 moisture in OFSP. The protein content in the dehydrated sample was significantly high 6.06 in OFSP as compared to 4.9 g in the raw material. The fat was 1.19 in OFSP while fiber and ash content in OFSP was 2.53 and 1.69 g respectively. Carbohydrate in dehydrated OFSP was 80.65 percent against 25.63 in the raw material. The energy in dehydrated OFSP was fond 356 kcal.

A perusal of data of all the treatment for proximate analysis indicates that maximum retention of protein and carbohydrate was obtained in flour made through the dehydration process. A similar result showing 7.9 percent moisture, 76.2 percent starch, 2.4 percent ash and 1.08 percent fiber was found in SP flour by Srivastava *et al* (2012). Emmanuel *et al* (2012) also found 64.8 percent carbohydrate in flour made from OFSP. These findings are in accordance with the present study.

Effect of steaming and dehydration method on minerals, vitamins and antioxidant content on OFSP

Iron content noted 5.17 mg in raw OFSP whereas after steaming, it was 5.3mg/100g.In dehydrated flour, the iron content was 6.03mg/100g. Aywy *et al* (2013) also found that OFSP contains a high amount of iron as compared to other varieties. A moderate to high positive correlation was found between protein and iron (Tumwegamire and Kapinga (2011). The increase of iron with an increase in protein in the present study gets support from this finding. The calcium in steamed OFSP was 91.5mg/100g. In dehydrated flour, it was 145.4 in OFSP. In a similar type of experiment with different cooking methods, a significant difference in calcium content of drumstick leaves was found by Kushwaha (2011).

Vitamin C: Vitamin C was found in the raw sample; 19.02 mg/100g. The result indicates that value after steaming17.91 and dehydration 15.26mg/100g respectively showed enhance loss of vitamin C. Aywa *et al* (2013) reported that boiling significantly reduces the vitamin C content. Various processing procedures including baking, frying, and boiling are attributed to the degradation of this vitamin (Lee and Kader 2000).

β-carotene: The present result showed that in β-carotene in OFSP was 8.30 and 8.27 mg/100 g in steamed and dehydrated flour as compared to 10.3 mg in fresh tubers indicating 85, 78 and 80% retention respectively. Mitra (2012) found that β-carotene content in variety ST-14 (OFSP) was 9.74 mg/ 100g with retention of 87.22 percent with different processing methods. Emmanuel *et al* (2012) found that boiling and steaming of roots seemed to result in better retention of all trans-β-carotene than roasting and dehydration.

Phenols: After applying the steaming process a significant increase ($p \leq 0.01$) in total phenol was observed in both the cultivars of sweet potato. The phenolic acid content increased up to 105.7 in OFSP mg/100g with a 37.5 percent increase respectively. Dehydration showed a 25.8 percent decrease in OFSP. The phenolic content was estimated at 570.03 mg/100g as compared to control. Rautenbach *et al* (2010) observed an increase in the total phenolic content in four sweet potato cultivars after thermal processing (boiling for 20 min), and the increases varied between 21.1% and 79.1%., Bellail1 *et al* (2012) indicated that all home processing methods resulted in a significant increase ($P \leq 0.05$) in the phenolic content of the flesh tissues.

DPPH Activity: In raw sweet potato DPPH it was 61.48 in OFSP. After steaming, DPPH increased to 69.84 in OFSP. In the dehydrated product, it was 43.93% in OFSP. The results of the current study showed that antioxidant activity measured in fresh samples of ST-14 (OFSP) 61.48% inhibition. Steaming showed the highest inhibition i.e. 69.28% whereas, dehydration showed lowest viz. 43.93% in OFSP. Retention of β carotene content in ST-14 (OFSP) was 85% by steaming followed by dehydration 79.67% with an increase in antioxidant activity. There appeared a positive correlation between the β carotene ($r = 0.97$-0.99, p level ≤ 0.01) with DPPH capacity indicating that this may be used as an indicator for the antioxidant activity of sweet potato roots which showed a maximum increase by steaming process. Lachman and Hamouz (2005) found that total antioxidant activity depends on the amount of phenolic acid, carotenoids, and anthocyanins in the tuber. The antioxidant capacity may be associated with the ability of carotenoids to quench oxygen. According to Bellail *et al* (2012), thermal processing significantly ($P \leq 0.05$) increased the total phenolic content, as well as individual phenolic acids and antioxidant capacity.

Nutrient intake pattern before and after supplementation of OFSP powder

The study revealed a significant decrease of 5.85 and 8.73 percent intake of energy and carbohydrates, in the female experimental group but significant increase in intake of protein, fat, and fiber as 16.83, 16.34 and 17.98 percent respectively was noticed. A significant increase of 12.38 and 11.98 percent was noticed in iron and calcium intake. An increase in uptake of β carotene and vitamin C 40.5 and 14.5 percent respectively were recorded.

Like in females, after supplementation male group also showed a significant decrease of 5.85 and 14.07 percent noticed in the uptake of energy and carbohydrate. Protein intake was increased significantly by 4.5 percent, while fat consumption was reduced to 31.5 percent. A significant increase in intake of fiber (15.4), iron (9.9%), calcium (6.48%), β carotene (46.5%) and vitamin C (14.83%) was noticed.

Anthropometric measurement of the subjects before and after supplementation of antioxidant rich OFSP powder

Anthropometric profiles like height, weight, BMI, MUAC, TSFT, WHR were taken for subjects and presented in Table. 1

Height

The mean height of the female subjects was 161.37 cm in control (C) and 162.2 in experimental (E). Chaddha, 2006 reported the height of vegetarian and non-vegetarian women was 157 and 158 cm. Kaur, 2007 reported the mean height of women to be 157 cm.

Weight

The mean weight in C female was 72.82 kg while in group E it was 73.5 kg after supplementation.

Table 1: Anthropometricparameters of subjects before and after supplementation

	(n=20)			(n=20)		
	Females	**Females**	**Standard range**	**Males**	**Males**	**Standard range**
	C	E		C	E	
Height(cm)	161.37	162.2		173	174.5	
Weight (Kg)			60			
Before	72.82	73.5		76.12	77.5	60-65Kg
After	72.76	72.65		76.23	77.06	
%change	0.08	1.15		0.14	0.56	
t value	NS	0.91		1.05^NS^	1.05^NS^	
BMI (Kg/m^2)			18.5-24.99[1]			18.5-24.99[1]
Before	27.69	27.94		26.24	25.8	
After	27.6	27.62		26.28	25.6	
% change	0.32	1.07		0.15	0.77	
T value	NS	5.45**		NS	3.92**	
MUAC (cm)						
Before	31.85±1.11	32.99±0.37	29.3[2]	31.5±0.77	30.79±0.54	32[2]
After	32.19±0.51	31.05±0.41		30.61±0.78	29.00±0.40	
% change	1.10	5.80		2.90%	5.80	
t-value	NS	5.52**		16.34**	6.2**	
TSFT (mm)						
Before	18.5±0.29	19.03±0.19	16.5[2]	23.10±0.44	23.13±0.44	12.5^
After	17.9±0.35	17.46±0.32		22.62±0.54	21.61±0.46	
% change	3.20	8.20		2.07	6.48	
t-value	3.43^NS^	4.67**		1.12 ^NS^	3.32**	
WHR						
Before	0.83±0.01	0.85	<0.80^	0.856±0.07	0.866±0.07	0.8-1.0^
After	0.82±0.01	0.83		0.842±0.05	0.836±0.01	
% change	1.20%	1.10%		1.63%	3.46%	
t-value	1.02 ^NS^	1.73 ^NS^		4.86**	6.05**	

Values are mean ±SE **Significant at 1% level of significance *Significant at 5% level of significance NS-Non significant # ICMR (2010) [1]Anonymous (2005) [2]Jelliffe ^Ghafoorunissa and Krishnaswamy (2007)

Anthropometric measurement of female subjects of E group revealed slightly less decrease (1.15%) in weight but a significant decrease in BMI (1.07%) was noticed after supplementation. The BMI obtained before and after supplementation was higher than the standard value (WHO 1995). A significant decrease of 5.8 percent in the MUAC experimental group after supplementation was noticed. A significant reduction in MUAC may be due to supplementation of fiber-rich antioxidant OFSP powder which gave a high satiety effect. The data revealed that the mean TSFT after supplementation in the E group decreased to 8.20 percent. Reduction in MUAC and TSFT may be due to loss in weight caused by food supplementation and regular exercise. The reduction in WHR (1.10%) was non-significant lower in the group of female E but significant change was noticed in the male group (3.46%). WHR is a stable and highly reliable measure and significantly co-related with fat distribution.

Biochemical profile

Data regarding blood pressure of females and male subjects in E group after supplementation showed a decrease of 2.68 and 8.86 percent in systolic blood pressure and 13.3 and 7.43 percent diastolic blood pressure, indicating a positive intervention of OFSP supplementation. High fiber with high anti-oxidant properties of OFSP might have influenced the blood pressure. Sandhu *et al* 2005 also reported a significant decrease in systolic blood pressure from 135.6 to 124.0mm/hg as a result of nutrition intervention.

Table 2: Blood pressure of the subjects before and after supplementation

Blood pressure (mm/Hg)	Female (n-40)		Male (n-40)		Standard range
	Control	Experimental	Control	Experimental	
Systolic Bp (mm Hg)					120[@]
Before	128.1	145.75	141.5	149.5	
After	128.34	121.63	141.49	136.25	
% change	0.18	16.54	-	8.86	
t value	NS	2.68*	NS	5.18**	
Diastolic Bp (mm Hg)					80[@]
Before	84.85	92.86	87.87	95.34	
After	84.97	80.5	87.9	88.25	
% change	0.14	13.3	-	7.43	
t value	NS	3.12**	NS	4.72**	

[@]Raghuram *et al* (2007) Values are mean ±SE **Significant at 1% level of significance *Significant at 5% level of significance NS-Non significant

Random blood Sugar

The data regarding random blood sugar level revealed that after three months of supplementation with OSFP, it decreased significantly to a twin 9.5 percent in females and 13 percent in males.

Table 3: Random blood sugar of the subjects before and after supplementation

Random Blood sugar level (mg/dl)	Female (n-40)		Male (n-40)		Standard range
	Control	Experimental	Control	Experimental	
Before	131.77	128.25	116.36	145.25	140-200 mg/dl[@]
After	132.31	115.87	117.05	125.75	
% change	0.4	9.65	0.59	13.2	
t value	NS	1.2*	NS	2.24*	

Value represents Mean ±SE ** Significance at 1% level * Significance at 5% level of significance NS-Non significant [@]Srilakshmi (2011)

Lipid profile

Biochemical estimation of blood for lipid profile revealed that cholesterol level decreased significantly with a mean value of 4.93 and 3.56 in female and male subjects respectively in E group who obtained 3 months of OFSP supplementation. The subjects of the same group showed a significant decrease of 3.48 and 4.7 percent in females and males respectively in triglycerides. HDL-C increased 3.48 percent in females and 4.7 percent in male showing a high degree of increase. Decrease in LDL-C up to a level of 4.63 and 1.9 percent was recorded in females and males. The decrease in value in females was significant but in males, it was non-significant. VLDL-C also decreased significantly to 3.4 and 4.6 percent in males and females.

Serum retinol level of subjects before and after supplementation

Estimation of blood for antioxidant level revealed that there was an increase of 27.11 and 22.8 percent serum retinol level in females and males of E group respectively supplemented with OFSP. It was a non-significant change in the final observation in the female group. But in the E group of females, the final mean value of increased from 721.38 to 917ng/dl. These values were under the standard range of 300-1200 ng/dl for adults.

Table 4: Serum retinol level of subjects before and after supplementation

Serum Retinol (ng/ml)	Female (n-40)		Male (n-40)		Standard range
	Control	Experimental	Control	Experimental	
Before	690.89	721.38	665.34	668.75	300-1200ng/ml
After	691.04	917	665.89	821.63	
% change	0.02	27.11	0.08	22.8	
t value	NS	8.81**	NS	6.45**	

Value represents Mean ±SE ** Significance at 1% level of significance * Significance at 5% level of significance

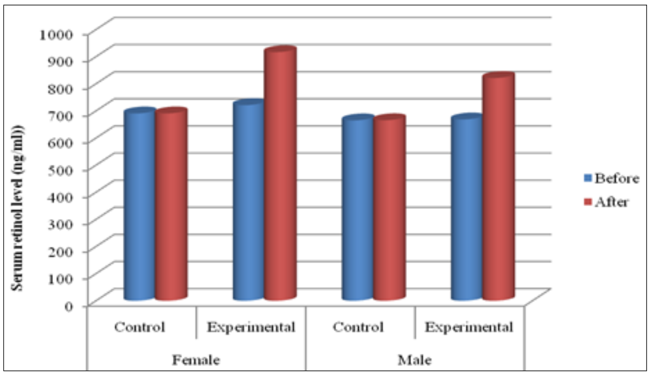

Fig 1: Serum retinol level of subjects before and after supplementation

Effect of OFSP supplementation on Glutathione Peroxidase

GPx value in OFSP supplemented subjects of group E, increased to 35.9 and 35.12 percent in female and male respectively as shown in Table (5). Results of the biochemical analysis of blood, co-relates with supplementation of food with 20 percent of OFSP which may be one of the factors in intervening in these aspects. Signorelli *et al* 2006 reported a low level of GPX in elderly women. Kushwaha 2011 found an increased effect of GPX after supplementation b carotene-rich moringa and amaranth powder.

Table 5: Glutathione level of subjects before and after supplementation

Random GPx level (units/g Hb)	Group I (Control)		Group II (Experimental)		Standard range# (GPX units/g Hb)
	Control	Experimental	Control	Experimental	
Before	74.63	74.75	86.14	85.98	Deficit <60
After	75.02	116.75	86.03	132.45	Low/Marginal 61-100
% change	0.5	35.9	0.12	35.12	Marginal 101-130
t value	NS	6.9**	NS	9.88**	Adequate > 130

Value represents Mean ±SE ** Significance at 1% level of significance * Significance at 5% level of significance # Ransel Technical Brief (Randox Laboratories)

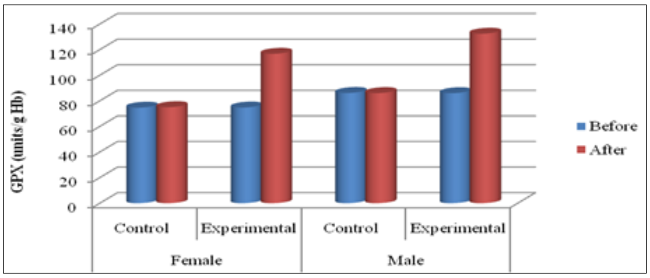

Fig 2: Glutathione level of subjects before and after supplementation

Bhor *et. Al.* (2004) studied the decrease in GPx activity correlates with the increase in lipid peroxidation**.** It could be the result of the restoration of GSH levels depleted due to oxidative stress, by increased synthesis, uptake from the circulation. The intestinal GPx detoxifies dietary lipids before they enter the circulation (Halliwell *et al* 2000).

Discussion

In the study, protein intake was increased significantly by 4.5 percent, while fat consumption was reduced to 31.5 percent. A significant increase in intake of fiber (15.4), iron (9.9%), calcium (6.48%), β carotene (46.5%) and vitamin C (14.83%) was noticed. In sweet potato storage roots, β-carotene is located in cell protoplasts in lipid droplets or bound to a protein that is released during cooking, thereby enhancing bioavailability (Kopsell and Kopsell 2006). An increase in HDL and a significant decrease in LDL relates that sweet potato is a good source of fiber which plays a favorable role in reducing blood cholesterol levels (Chukwu *et al* 2012). A Study in the Philippines by Trinidad *et al* (2013) revealed that sweet potato and cassava increased HDL-C and decreased LDL-C in humans with moderately raised serum glucose and cholesterol. Data regarding random blood sugar level revealed that after three months of supplementation with OSFP, it decreased significantly to a twin 9.5 percent in females and 13percent in males. A similar study showed by Olowu *et al* (2012) that *Ipomea batata* has a profound oral hypoglycemic effect, which was possibly mediated via increased peripheral glucose utilization, thus, justifying its local use in the management of a suspected diabetic patient. A study done by Ludvik *et al* (2004) confirms the beneficial effects of Caiapo (sweet potato) on plasma glucose as well as cholesterol levels in patients with type 2 diabetes. Girodon *et al* (1997) also reported that low dose supplementation with vitamins and minerals was able to normalize biological nutrient status as early as six months of treatment. Also, data indicated that antioxidant defense in elderly subjects was improved with low doses of vitamin C, vitamin E and β-carotene as studied through a functional test utilizing red blood cells challenged in vitro with free radicals. Huang *et al* (2004) found phytochemicals in sweet potato may have a significant effect on antioxidant and anticancer activities. Additionally, the antioxidant activity was directly related to the total amount of phenolics and flavonoids found in the sweet potato extracts. The additive roles of phytochemicals may contribute significantly to the potent antioxidant activity and the ability to inhibit tumor cell proliferation in vitro. Hence, sweet potato can be used as an easily accessible source of natural antioxidants, as a food supplement, or in the pharmaceutical and medical industries. Orange-fleshed sweet potatoes have emerged as one of the most promising plant sources of β-carotene, the pro-vitamin A (Hagenimana and Low J (2000)).

Conclusion

Consumption of b-Carotene rich orange-fleshed sweet potato in either fresh or cooked form can contribute considerably in increasing dietary protein, iron and fiber content as well as serum retinol and glutathione levels. Supplementation of OFSP 20g /day flour significantly changed the lipid profile, serum retinol, Glutathione peroxidase. It had a beneficial effect on lowering the total cholesterol, triglyceride, LDL-C, and VDL-C but helped in increasing the HLD-C. It also lowers blood pressure. After reviewing the observations, it is concluded that the steaming and dehydration process can retain the better antioxidant activity of the β-carotene in orange-fleshed sweet potato. Antioxidant-rich OFSP powder certainly had a positive effect on the health status of males and females.

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