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Sweet potato (*Ipomoea batatas* L.): A valuable tropical tuber crop: A review

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Abstract
Tropical root and tuber crops play vital role in food security, nutrition and climate change adaptation. Root and tuber crops are essential components of diet in many countries. Tropical tuber crops comprise of major and minor (underexploited) plant species. Sweet potato is one of the nutritious, healthy and underutilized tropical tuber crops whose significance as a food is getting less. The importance of sweet potato tubers as a health food is realized now due to its nutritional composition having low glycemic index as an additional health benefits for diabetics. It is used as a new ingredient for development of gluten free products. A number of value added food products are being developed using sweet potato with functional ingredients. Sweet potato tubers could be processed into different primary products such as flour, chips, puree etc and secondary products like biscuits, pasta, noodles etc. The present article discussed about the potential benefits of sweet potato as a miracle and promising food crop.

Keywords: Sweet potato, nutrition, glycemic index, processing, pasta, bakery, gluten free

Introduction

Sweet potato (*Ipomoea batatas* L.) is the sixth important food crop and carbohydrate main source in the world and staple food source for many populations in Africa, Indonesia, Central and South America, Japan, the Caribbean, Polynesia, Hawaii and Papua New Guinea. Alone North Carolina produces 40% of the national supply in the USA (NCDA & CS, 2012) [47] According to FAO (FAO, 2011) [15] reported that sweet potato is important crop of developing countries but less important in some other countries. China is major producer of sweet potato, 80 to 85% of total production in the world followed by remaining countries in Asia and then by Africa and Latin America (Centro Internacional de la Papa, 2009) [7]. It was reported that, sweet potato is one of the most under-exploited food crops although of its nutritional benefits. In past few years, it's also known for the "food security" or "famine relief" crop particularly in developing countries (Grant, 2003) [25].

Sweet potato contains natural health promoting component having functional value for the food market, such as β-carotene, phenolic acids, anthocyanins, carbohydrates, fibers, thiamine, riboflavin, niacin, potassium, zinc, calcium, iron, vitamins A and C and high quality protein (Grace *et al.* 2014) [24]. It is also a valuable medicinal plant having anti-cancer, antidiabetic, and anti-inflammatory activities. In the face of being a carbohydrate rich food, sweet potato is also reported to have low glycaemic index (<55), suggesting its suitability as a food for diabetic people (Björck *et al.* 2000) [4]. It is predicted that diabetic population to be increase from 4% in 1995 to 5.4% by 2025, approximately 170% in developing countries particularly India ranks first, followed by China. FAO-WHO Expert Consultation recommends the increased consumption of low glycaemic foods rich in resistant starch, non-starch polysaccharides and oligosaccharides (Goni and Valentin-Gamazo, 2003) [22]. It is reported that food having low glycemic response to be use in the treatment of type 2 diabetes mellitus and in weight management (Gelencsér *et al.* 2008) [19]. Sweet potato is reported having low GI use as diabetic friendly and the component responsible to this effect have been isolated and studied from white-skinned sweet potatoes.

There are different varieties of sweet potato such as pale cream coloured, orange fleshed and purple coloured rich in phenols, β-carotene, anthocyanins etc. The high concentration of stable anthocyanins present in the purple-fleshed sweet potato tubers and leaves could be an excellent alternative to synthetic colour in food products (Truong and Avula, 2010) [68]. This variety is having anthocyanin, phenolics with antioxidant and anti-inflammatory activities (Grace *et al.* 2014) [24]. These anthocyanins are not only highly stable but also provide health-related radical-scavenging activity (Oki *et al.* 2002) [48], memory-enhancing effects (Lu *et al.* 2012) [40], and hepatoprotective activity (Zhang *et al.* 2013) [75]. Orange-fleshed sweet potato is an excellent source of β-carotene (Grace *et al.* 2014), responsible for alleviating vitamin A deficiencies and night blindness (van Jaarsveld *et al.* 2005) [71].

The consumption pattern of sweet potato tubers is found different in the world. It can be processed in diverse food products such as primary, intermediate and secondary products. It is usually consumed in its primary processed forms, such as steamed, boiled, and grilled or processed to be chip or 'kolak' (traditional food). Intermediate products of sweet potato such as flour, paste, puree, and mash (Herawati and Widowati, 2009) [29] and secondary products like pasta, noodles, spaghetti etc.

In worldwide, only one percent of total production of sweet potato enters world trade with Canada, the United Kingdom, France and the Netherlands being the major importing countries (Katan and De Roos, 2004) [33]. The USA is the largest exporter of sweet potato accounting for 35% of world trade. The other exporters are China (12%), Israel (9%), France (7%), Indonesia (6%) and Netherlands (5%). The majority of the produce used for direct consumption with small portion of produce utilize for industrial purpose and animal feed.

Celiac disease (CD) is a chronic autoimmune disorder, estimated to affect approximately 1-2% of the world population and results from the dietary intolerance to gluten (Reilly and Green, 2012) [56]. Ingestion of gluten by celiac patients causes villous atrophy of the small intestine and leads to cramping, bloating, diarrhea, weight loss, vitamin and mineral deficiencies etc. (Green and Cellier, 2007) [26]. Consumption of gluten-free diet as a strict life-long strategy is the only known treatment for celiac disease, as even trace amounts of gluten could trigger immune response in the patients (Rubio-Tapia and Murray, 2010) [59]. There is higher risk of developing deficiencies of micro-nutrients (e.g., thiamine, riboflavin, niacin, iron, selenium, chromium, magnesium, folacin, phosphorus and molybdenum) in celiac patients due to lack of essential nutrients in gluten free diet (Steinman, 2007) [64]. It is difficult to develop gluten free products. Also, attempts to remove the gluten ingredient in foods may result in the loss of nutritional balance of the products (Grehn *et al.* 2001) [27]. Sweet potato flour is best alternative to wheat flour for the development of gluten free foods for celiac patients.

The present article focused on the nutritional benefits and utilization of sweet potato tuber as a potential crop for development of value added products.

Nutritional composition

Sweet potato is vegetable possessing health benefits and medicinal properties belong to the family Convolvulaceae, is large, starchy, and sweet tasting. The nutritional composition of sweet potato helps in meeting the nutritional requirements of human compromises carbohydrates, fiber, carotene, thiamine, niacin, potassium, zinc, calcium, iron, vitamin A and C etc. (Preedy *et al.* 2011) [54]. The nutritional value of fresh sweet potato roots at harvest is presented in Table 1.

It was reported that, not only tuber but leaves of sweet potato also excellent source of protein and iron as compare to tuber. The leaves are used to treat type 2 diabetes, inflammatory by Ghana and Brazil respectively (Pochapski *et al.* 2011) [53]. Sweet potato roots could be eaten as such to treat anemia, hypertension, and diabetes particularly in Kagawa and Japan (Ludvik *et al.* 2004) [41] whereas in India particularly the Monpa ethnic groups of Arunachal Pradesh, use the tubers of sweet potato as a staple food and the leaves as fish feed (Namsa *et al.* 2011) [46].

Preedy *et al.* (2011) [54] revealed that sweet potato tubers plays important role in monitoring the blood glucose level in diabetics as it is having low glycemic index, as preliminary studies on animals have revealed its ability to assist to stabilize blood sugar level and lower insulin resistance. Sweet potato also considered as an "insurance crop" as it can be grown all around the year under suitable climatic conditions. Sweet potato also known as space food because National Aeronautics and Space Administration (NASA) has preferred sweet potatoes as a special crop to be cultivated and included into the diet for astronauts on space missions due to its health benefits (Bovell-Benjamin, 2007) [5]. Sweet potato is a potential food crops could be processed into different value added products to address health problems is presented in Table 2.

Table 1: Nutritional value of sweet potato (USDA, 2009) [69]

Nutrient	Value per 100 g
Water (g)	77.28
Energy (kJ)	359.00
Protein (g)	1.57
Total lipid (fat) (g)	0.05
Ash (g)	0.99
Carbohydrate (g)	20.12
Fiber, total dietary (g)	3.00
Calcium (g)	30.00
Iron (mg)	0.61
Magnesium (mg)	25.00
Phosphorus (mg)	47.00
Potassium (mg)	337.00
Sodium (mg)	55.00
Vitamin C (mg)	2.40
Pantothenic acid (mg)	0.80
Vitamin B-6 (mg)	0.21
Vitamin A (IU)	14187

Table 2: Value added food products from sweet potato

Food products	Materials	References
Primary food products		
Dehydrated Chips	Sweet potato tubers	Dian Adi 2015 [11]; Giri *et al.* 2016 [20]
Flour	Sweet potato tubers	Giri *et al.* 2016 [20]
Composite flour	Sweet potato, cassava and potato flour	Kwame *et al.* 2017 [37]
	Sweet potato, maize starch and soybean flour	Elisa *et al.* 2017 [13]
	Sweet potato and maize flour	Samuel *et al.* 2016 [61]
	Sweet potato, unripe banana, and pigeon pea	Ehimen *et al.* 2017 [12]
	Fermented and unfermented sweet potato and wheat flour	Adams *et al.* 2017 [1]
	Orange fleshed sweet potato, cassava starch and prawn	Mbaeyi-Nwaoha and Itoje, 2016 [43]

Puree	Sweet potato tubers	Fasima *et al*. 2003 [17]
	Orange fleshed sweet potato and purple fleshed sweet potato tubers	Van-Den *et al*. 2010 [70]
Flakes	Amylase treated sweet potato tubers	Grabowski *et al*. 2006 [23]
Secondary food products		
Gluten free cookies	Sweet potato, rice, sorghum and cassava flour	Giri *et al*. 2016 [20]
	Sweet potato and maize flour	Samuel *et al*. 2016 [61]
Biscuits	Orange fleshed sweet potato and wheat flour	Andualem *et al*. 2016 [2]
	Sweet potato, Idquo, acha, rdquo and pigeon pea	Anton and Charles, 2008 [3]
Crackers	Sweet potato leaves, Drum stick leaves and cassava flour	Deborah *et al*. 2011 [10]
	Sweet potato flour, cassava starch and prawn	Mbaeyi-Nwaoha and Itoje, 2016 [43]
Bread	Sweet potato, maize, soyabean flour and xanthan gum	Elisa *et al*. 2017 [13]
Flat bread	Orange fleshed sweet potato and wheat flour	Teferra *et al*. 215 [66]; Zegeye *et al*. 2015 [74]
Pan cake	Sweet potato and rice flour	Shih *et al*. 2006 [62]
Pasta	Sweet potato, soyabean flour, Arabic gum and CMC	Singh *et al*. 2004 [63]
Pasta – Fiber rich	Sweet potato flour, oat bran, wheat bran and rice bran	Jyothi *et al*. 2012 [31]
Pasta – Protein rich	Orange fleshed sweet potato, WPC, DSF and fish powder	Krishnan *et al*. 2011 [36]
Pasta-RS enriched	Sweet potato, wheat and banana flour	Jyothi *et al*. 2012 [31]; Ovando-Martinez, *et al*. 2009 [50]
Noodles	Sweet potato, cassava, arrowroot, soy, maize and sprouted cow pea flour	Sunardi *et al*. 2003 [65]
	Sweet potato and native starch	Chen, 2003 [8]
Spaghetti –Low GI	Sweet potato flour, banana starch, legume starch and fiber sources	Renjusha *et al*. 2014 [58] Renjusha *et al*. 2012 [57]
Extrudate snack (Fasting purpose)	Sweet potato flour, vari rice and unripe banana powder	Rathod and Annapure, 2016 [55]
Buns and Chapati	Orange fleshed sweet potato and wheat flour	Tilman *et al*. 2003 [67]
Cake, cookies and buns	Sweet potato and wheat flour	Salma and Ziadah, 2005 [60]
Traditional food products		
Amala- Nigeria	Sweet potato, yam and cassava flour	Yusuf *et al*. 2017 [73]
Dackere	Sweet potato and bambara groundnuts	Daidai *et al*. 2016 [9]
Gari- Nigeria	Sweet potato and cassava	Olayinka *et al*. 2016 [49]
Beverages		
Non-alcoholic Beverages	Sweet potato pulp, mango, pineapple, lemon and orange	Padmaja and Premkumar, 2012 [51]
Seldum- Ghana	Sweet potato tuber and cassava tubers	Faustina *et al*. 2016 [18]

CMC: Carboxyl methyl cellulose; WPC: whey protein concentrate; DSF: Defatted soy flour; GI: glycemic index; RS: Resistant starch

Primary food products

Dehydrated chips and flour

The purposes of dehydration of sweet potato tubers are to increase the shelf life and make it available throughout the year. Dehydrated sweet potato chips could be prepared by harvesting tubers of three and ten month's maturity. The tubers were washed free of dirt and manually peeled and sliced to round discs of approximately 5 mm thickness. The slices were sundried for 36h till the moisture content was brought down to < 10% and powdered in a hammer mill into fine flour and pass through 85 mesh sieve of BSS standard (particle size 0.177mm). The dry flour was packed in air tight containers and stored at room temperature (30±1^{0}C) for further use (Dian Adi, 2015; Giri *et al.* 2016) [11, 20]. The flow chart for preparation of sweet potato flour presented in Figure 1. It was reported that discoloration of chips is major problem associated with drying of chips due to high activity of polyphenol oxidase (PPO) and high level of phenols in roots. It was found that phenolics of sweet potato such as chlorogenic acid effectively oxidized by PPO responsible for browning of product. It could be prevented by blanching or potassium metabisulphite treatment to slices prior to drying helps to stop the activity of polyphenol oxidase. Dried chips were converted into flour and used in starch, noodles and alcohol factories in China.

Sweet potato tuber could be processed into different potential food and non-food products (Figure 2). The products such as starch and flour might be used as strategic products for upstream industries. Moreover, processing into food and non-food products also helps to reduce the post-harvest losses of tubers (Lin *et al.* 2000) [39].

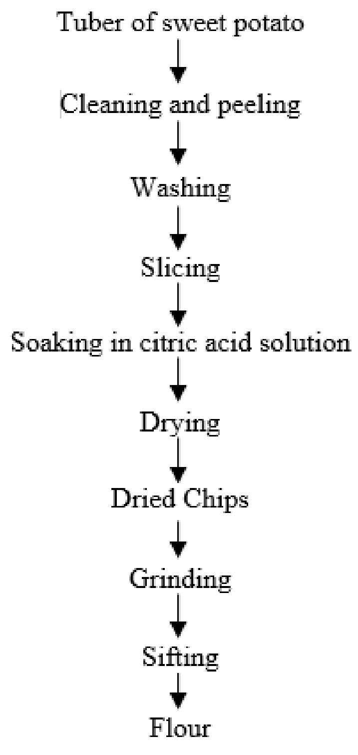
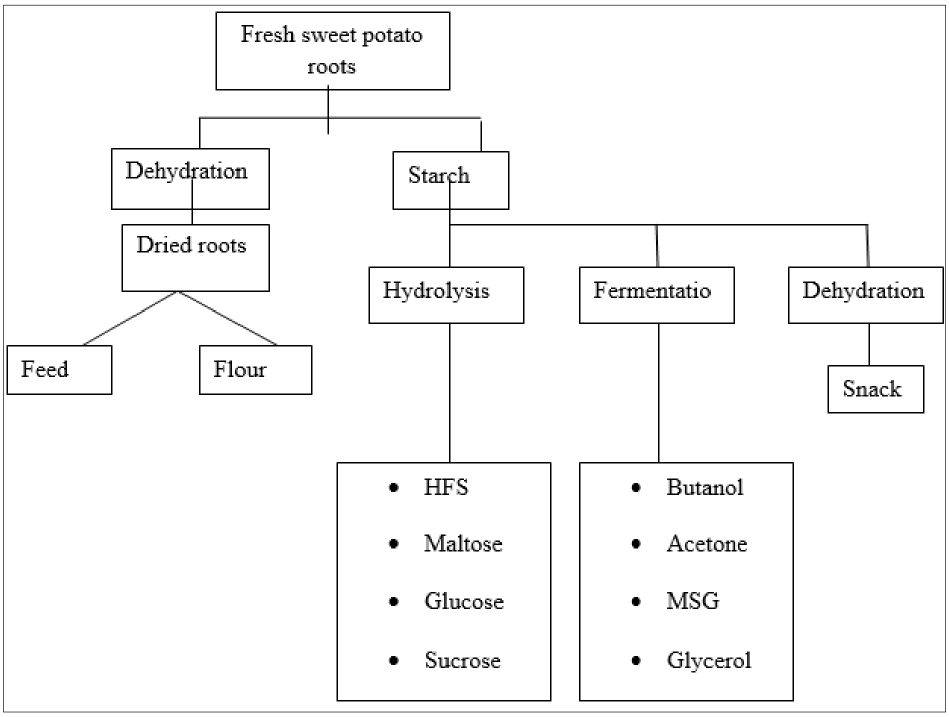


Fig 1: Scheme of sweet potato flour processing (Dian Adi, 2015) [11]



HFS: High fructose syrup; MSG: Mono sodium glutamate

Fig 2: Flow chart on the use of sweet potato as starch and flour Lin *et al.* (2000) [39]

Composite Flour

Composite flour is the blend or substitution of sweet potato flour with other flour such as wheat flour, rice flour, sorghum flour etc. This composite flour is suitable for the development of different bakery, extrudate, confectionary products etc. based on its functional properties. The significance of sweet potato composite flour has been increased particularly in tropical and subtropical countries where sweet potato is staple food to millions of people (FAO, 2015) [16], where they depends on imported wheat which leads to high prices of wheat, put financial stress on low income people. So, there is need to investigate the possibility of supplementing wheat flour with flour from relatively cheap and easy-to-produce root tuber, such as cassava, potato and sweet potato. These composite flour blends could be reduce the demand of import wheat and could meet the demand of production of pasta, noodles, bread, cookies etc. From various studies it was found that wheat flour could be supplemented up to 20 percent with root tuber flour such as sweet potato, cassava and potato without compromising the nutritional and sensory quality of products (Kwame *et al.* 2017) [37].

Sweet potato flour can easily be used as a substitute for wheat flour in different baked products such as biscuits, cookies, cake, muffins, bread etc. and can also be used for its high carotene content. It was reported that the addition of orange-fleshed sweet potato in buns, chapattis, and mandazis greatly increased the content of total carotenoids in these products. Addition of various proportion of sweet potato flour in wheat flour can increase the nutritive values in terms of fiber and carotenoids. This also helps in lowering the gluten level and prevent from celiac disease (Tilman *et al.* 2003) [67].

Cakes and cookies could be made with 50% sweet potato flour-wheat flour mixes. Cookies could be made by substituting 60% and muffins by 57% wheat flour whereas 100% wheat flour replacement with sweet potato flour was possible in cookies. Buns were made by incorporating 20% sweet potato flour containing 7.5mg/100g β-carotene to wheat flour supplemented with 6% gluten and 4% bread softener and it was sensory satisfactory by panel members (Salma and Zaidah, 2005) [60].

Functional properties of composite flour

The functional properties of composite flour play an important role in food products preparation such as water absorption capacity, oil absorption capacity, density etc. Most of the workers reported that as the level of sweet potato flour increased in composite flour, there is increase in water absorption capacity, bilk density, dispersibility. Incorporation of sweet potato flour improved the functional properties and make composite flour suitable for preparation of value added products. Elisa *et al.* (2017) [13] prepared composite flour using sweet potato flour, maize starch and soybean flour blends in different proportions such as 60:20:19.5; 50:30:19.5; 40:40:19.5; 50:20:29.5; 40:20:29.5; and 30:40:29.5 and xanthan gum at 0.5% was added to each blend. Oil absorption index was not significantly different among the six blends of composite flour and wheat flour. When sweet potato meal was partially replaced (from 10 to 90%) with soya meal there was decreased water absorption capacity and bulk density.

When maize flour was replaced with sweet potato flour at 10–100%. The water binding capacity increased from 0.9–1.7 and the starch swelling power decreased from 10.1–5.3 at 95°C with increase in sweet potato flour content in the flour mixture. Similarly, bulk density and dispensability also decreased in the flour (Samuel *et al.* 2016) [61].

The blend of unripe cooking banana, pigeon pea and sweet potato flour were investigated. Dispersibility, bulk density, water, and oil absorption capacities of the blends increased as the level of sweet potato flour and banana flour increased. This flour blends are desirable for preventing malnutrition in Nigeria and developing new food formulations (Ehimen *et al.* 2017) [12].

Adams *et al.* (2017) [1] investigated that, the use of fermented sweet potato flour with wheat flour resulted to change in functional properties of blend as compare to unfermented sweet potato flour with wheat flour. Fermentation of sweet potato flour improved the foaming capacity, (2.00% to 8.00%), emulsion capacity (23.66% to 25.72%) and least gelation (6.00% to 10.00%).

Gluten free composite flour enriched with prawn along with cassava starch, pink and orange fleshed sweet potato were prepared for the production of gluten free crackers for celiac (Mbaeyi-Nwaoha and Itoje, 2016) [43]. It was reported that the starch had WAC (1.85-2.19%), OAC (1.85-2.04%), BD (68.96-72.44 g/ml), and SC (5.60-5.75%).

Sweet potato puree

It is primary processed products which is directly used as infant food or used for mixing different food products such as patties, flakes, reconstituted chips etc. The sweet potato tubers of undesirable size and shape which have less market value could be processed to puree. Some workers made good quality puree from orange and cream fleshed sweet potatoes of any size or shape. The process for production of puree involved cooking of roots, peeling followed by mashing and modified method includes adding of commercial alpha-amylase to portion of puree to carryout partial hydrolysis of starch. Enzyme treatment improves the rheological characteristics of puree. Fasina *et al.* (2003) [17] studied the thermal and dielectrical properties of sweet potato puree with temperature range of 50-80^{0}C. Sweet potato puree prepared under aseptic conditions included flash heating at 123^{0}C have shelf life up to 9 months.

There are multiple uses of sweet potato puree and powders in food industry. These can be used as thickening and gelling agents to impart desired textural properties, and enhance the nutritional values, antioxidant activity as well as natural color (e.g. orange and purple) of numerous food products. Moreover, purees and powders also used as functional ingredients as alternatives to wheat products for individuals diagnosed with celiac disease and incorporated in low glycemic index foods for diabetics. Sweet potato purees and dehydrated forms high in β-carotene (orange fleshed varieties) and anthocyanin (purple fleshed varieties) can be used as functional ingredients to impart desired textural properties and phytonutrient content in processed food products (Van-Den *et al.* 2010) [70].

Sweet potato flakes

Sweet potato flakes is a dehydrated product which helps to extent shelf life of perishable roots and can be reconstituted to mashed sweet potato or incorporated into different food products preparation such as bakery product etc. The improved technology includes treatment of puree with alpha amylase enzyme to hydrolyzed starch and subjected to drum drying. Curing of tubers and storage affect the amount of amylase required to produce acceptable flakes. The pre-heating of sweet potato puree for 2-6 min helped to activate the endogenous amylases for conversion of starch to sugars. The partly cooked puree introduced to second steam injector, at 200^{0}F for the activation of amylases followed by drum dried to obtain dehydrated flakes. The good quality sweet potato powder was prepared by treating puree with amylase enzyme followed by spray drying (Grabowski *et al.* 2006) [23].

Secondary food products

Cookies

Cookie-type biscuits are extensively demanded due to their long shelf life and crisp texture (Mareti *et al.* 2010) [42]. Cookies are made usually from wheat flour with additives such as sugar, chocolate chips, peanut butter etc. (Kaushal *et al.* 2013) [35]. Functional cookies have been attempted by different researchers using several types of alternative non-wheat flours such as buckwheat flour, cassava flour, quinoa flour etc. (Mishra *et al.* 2015) [45]. Gluten-free cookies have been developed from rice, corn, buckwheat and potato flours (Mishra *et al.* 2015) [45]. India is one of the largest biscuit producers (Kar *et al.* 2012) [34]. Sweet potato flour based gluten free cookies suitable for celiac patient were developed using sweet potato flour (40-60%), rice flour (20-25%), sorghum flour (15-20%) and cassava flour (5-15%). Minerals content in sweet potato flour based gluten free cookies was higher than maida based cookie. Gluten free cookies prepared with sweet potato flour showed the maximum crude fiber content as compared to maida based cookie. Results indicated that gluten free cookies for can be prepared using sweet potato flour 60% with rice flour 20%, sorghum flour 15% and cassava flour 05% (Giri *et al*. 2016) [20]. The study was conducted by Samuel *et al.* (2016) [61] to develop gluten free cookies using sweet potato and maize flour blends. Substitution of maize flour with sweet potato flour was done at 10–100%. The sensory evaluation revels that the overall qualities of cookies containing 40% of sweet potato flour were found satisfactory by panel members.

Biscuits

Biscuits enriched with pro vitamin A and energy was developed by Andualem *et al.* (2016) [2] through incorporation of OFSP and altering baking time and temperature. The biscuits were developed by incorporating 30% OFSP flour to wheat flour and baked at 200°C for 12 and 15 min and at 220°C for 9 and 12 min. The developed biscuits found high in β-carotene (0.54- 6.01 µg/g), crude protein (9.88-11.06%), and crude fiber (0.17-2.68%).

Biscuits were produced using composite flour blends of ldquo; acha and rdquo; pigeon pea and sweet potato flour. It showed that the overall qualities of samples containing 65% ldquo; acha and rdquo, 20% pigeon pea and 15% sweet potato and 75% ldquo; acha and rdquo;, 20% pigeon pea and 5% sweet potato were found most satisfactory by panelists (Mbaeyi, 2015) [44]. Addition of sweet potato flour and fiber fractions to white wheat flour significantly reduced the pasting properties. However, the addition of sweet potato flour and starch resulted in biscuits of similar firmness as the control biscuits (Anton and Charles, 2008) [3].

Crackers

The gluten free crackers for celiac patients were developed using *Moringa oleifera* and *Ipomoea batatas.* Butter and cream crackers were made from 100% cassava flour and 100% sweet potato flour using 100% wheat flour as the control. It was found that the β-carotene levels of the leaves ranged from 4.76 mg/100g to 11.54 mg/100g for the sweet potato leaves. Phenolic content ranged from 3.16% to 6.92% for sweet potato leaves and 1.51% for *Moringa oleifera* (Deborah *et al.* 2011) [10]. Similarly, crackers were formulated using varying proportions (100%, 90:10%, and 80:20%) of prawn and starch. Moisture (2.41-5.63%), protein (2.68-19.64%), fat (3.71-13.62%), carbohydrate (56.48-87.34%), ash (0.07- 4.24%), crude fiber (0.56-3.43%) and pH (5.46-8.23) were obtained. These crackers were also found rich in mineral such as Na, Ca, Zn, Fe, Cu, Mg and Se (Mbaeyi-Nwaoha and Itoje, 2016) [43].

Bread

Bread was developed from composite flour blends containing sweet potato flour, maize starch and soybean flour in different proportions like: 60:20:19.5; 50:30:19.5; 40:40:19.5; 50:20:29.5; 40:20:29.5; and 30:40:29.5 and 0.5% xanthan gum in each blend. The composite flour with the proportion of sweet potato flour 40%, maize starch 40%, soybean flour 19.5% and xanthan gum 0.5% yielded bread with highest sensory qualities (Elisa *et al.* 2017) [13].

β-carotene enriched flat bread was attempted by Teferra *et al*. (2015) [66] using orange fleshed sweet potato to combat the vitamin A deficiency particular in children of Ethiopia. The vitamin A (µg RAE) content of the control bread was observed to be zero. Among the flat breads samples in which OFSP flour was incorporated, the vitamin A content was highest (269.63µg RAE) for the sample supplemented with 35% of orange fleshed sweet potato flour. It was investigated that maize flour based flat bread enriched with 35% OFSP could be used to prevent vitamin A deficiency for lactating mothers (Zegeye *et al.* 2015) [74].

Pancakes

Generally, gluten-free pancakes were prepared using rice flour. The study was carried out to prepare gluten free pancake in which rice flour replaced with various amounts, at 10, 20 and 40%, of sweet potato flour. Regarding the nutritional properties of the rice-sweet potato pancakes there was only significant difference in the β-carotene content, which increased from 5.2 to 236.1 mg/g when sweet potato flour was incorporated, from 0 to 40%, into the rice pancake formulation (Shih *et al*. 2006) [62].

Pasta

Pasta is famous food mostly liked by consumer as a convenient and nutritionally palatable. It is origin in Italy (Petitot *et al.* 2009) [52]. Traditionally pasta is made from semolina particularly from durum wheat which provides the desired texture and cooking quality to the product but wheat proteins are lacks in lysine and threonine leading to low biological value for the product. To improve the nutritional value of pastas in terms of protein quality, various workers attempted fortification of pasta with various protein sources such as legume flours, cheese, soy proteins, mustard protein isolate and gluten meal (Petitot *et al.* 2009) [52]. The sweet potato flour could be utilized for preparation of noodles and pastas (Limroongreungrat and Huang, 2007) [38].

The consumption of food containing dietary fiber provides health benefits to reduce the risk of lifestyle diseases. Dietary fiber rich functional sweet potato pasta were prepared using dietary fiber sources like oat bran, wheat bran, and rice bran. Sweet potato pasta fortified with these fiber sources improved the crude protein content to 5–10% in the pasta. Two varieties of sweet potato roots were used by Jyothi *et al.* (2012) [31] such as Sree Arun and Sree Kanaka. The level of fortification of fiber into pasta was 10 and 20% and all fiber fortified pastas shows slow starch digestibility as compare to control pastas. The retention of resistant starch (RS) in pastas from Sree Arun was 38-49% and Sree Kanaka was 39-55% whereas control pasta was only 14-17%. The high fiber content with high RS made sweet potato pastas ideal for diabetic and obese people.

Sweet potato flour pasta was developed with soy flour, water, arabic gum and carboxy methyl cellulose (CMC). It was concluded that, the maximum sensory score (33.8), minimum solids loss (16.6%) and maximum texture hardness (5616 g) were identified at 674 g/ kg sweet potato flour, 195 g /kg water, 110 g /kg soy flour, 10.6g /kg Arabic gum and 10.1 g /kg CMC levels (Singh *et al.* 2004) [63]. High-protein pasta was developed by Krishnan *et al*. (2011) [36] from cream and orange-fleshed sweet potato varieties using functional ingredients like whey protein concentrate (WPC), defatted soy flour (DSF), and fish powder (FP). It was found that WPC gave high quality pasta with strong starch-protein network formation, and low *in vitro* starch digestibility. Hydrocolloides are widely used in food industry to modify the dough quality, to affect on pasting properties of starch and dough rheology. These are also used in gluten free mixes. The polymeric structure of gums enables their use as gluten-substitutes (Gómez *et al.* 2007) [21]. It was reported that these gums helps to reduce the starch digestibility, also behaves similar to dietary fiber in food (Briani *et al.* 2006) [6]. Due to its properties, hydrocolloides are used in bakery products such as cake, cookies, bread manufacturing (Gómez *et al.* 2007) [21]. Various hydrocolloides (gums) such as guar gum, xanthan gum, locust bean gum and partially hydrolyzed guar gum were used for the development of functional pasta from sweet potato flour. Jyothi *et al*. (2014) [32] studied the effects of these hydrocolloids on overall quality of sweet potato flour pasta. The level of fortification of gums was 1% to 3% in pasta Fortification of gums in pasta reduced the starch digestibility. Sweet potato pasta with 1% hydrocolloid helps to reduce starch digestibility, improved swelling index and textural properties, suitable for diabetic and obese people.

Noodles are famous dish likes by consumers as convenient and tasty food. Many workers reported that the use of wheat flour could substituted with other flours up to some extent, such as sweet potato flour, sweet potato composite flour, cassava flour, arrowroot and soybean composite flour, modified arrowroot starch, maize flour and cowpea sprout flour (Sunardi *et al.* 2003) [65].

Sweet potato is known as low GI food and various workers developed pasta and spaghetti from sweet potato flour (Limroongreungrat and Huang, 2007; Jyothi *et al.* 2012; Jyothi *et al.* 2011) [38, 30-31]. Sweet potato spaghetti with low GI was attempted using starches such as banana or legumes and fiber sources (Renjusha *et al.* 2014; Renjusha *et al*. 2012) [58, 57]. Starch noodles are very favorite food in China, Philippines, Korea and Thailand but it have low nutritional and functional value because starch is the only ingredient in the preparation of food and has dietary fiber content of 2–3% (Jyothi *et al.* 2012) [31]. There is need to fortify starch noodles or pasta with resistance starch due to its health benefits to control obesity and diabetics. Resistant starch enriched pasta has been reported from wheat, banana and sweet potato (Jyothi *et al.* 2012; Ovando-Martinez *et al.* 2009) [31, 50].

It was reported that the consumption of low GI food rich in fiber reduce the risk of obesity, diabetes and heart disease (Gelencser *et al.* 2008) [19]. NUTRIOSE is a source of resistance starch used in formulation of functional foods having low glycemic index (GI). NUTRIOSE is a partially hydrolyzed starch from wheat or corn which is reported to be rich in dietary fiber (Guerin-Deremaux *et al.* 2011) [28].

Chen, (2003) [8] studied the properties of sweet potato starch and their application in noodles making. These noodles were made by gelatinizing 5% sweet potato starch with water and mixing with 95% native starch. The mixture was made into dough at 40ºC and extruded into trips of 1.5cm diameter followed by hot water and cold water treatment and then frozen at 5ºC for 8h followed by drying. Fortification of defatted soy flour (DSF) in sweet potato flour would improve the protein and dietary fiber content of noodles. Similarly, use of orange fleshed sweet potato noodles increased the β-carotene (5.0mg/100g) as compared to wheat flour base noodles (0.2mg/100g).

Sweet potato was processed also into vermicelli. Sweet potato flour was prepared from white fleshed sweet potato slices treated with 0.1% sulfur dioxide to avoid browning, drying, powdering and sieving. Vermicelli was developed by substituting 50% maida with sweet potato flour by extrusion method. Also protein fortified vermicelli was attempted by adding 10%, 20% and 30% of green gram, black gram and defatted soy flour (DSF) into mix. It was found that protein content could be increased upto 8% in gram added sweet potato mix and 14% in DSF blended mix. It was found that, the experts scored highest to vermicelli contains 50% sweet potato flour with 35% maida and 15% DSF which provides protein 11.53% and energy value of 307 kcal/100g.

Extrudate snacks

Fasting is vital part of the tradition and culture of Indian. Most of the fasting people would prefer to eat vari rice, sago, tubers and fruits. Indian people like to have vari rice khichadi, sabudana (sago) vada, sweet potato kheer, potato vada and fruit juices made traditionally at home during fasting. The demand for nutritious and tasty, healthy snacks were increased. Among these, expanded product has gained preference of both consumers and producers (Ernoult *et al.* 2002) [14]. The ready to eat extrudate snacks for fasting purpose were developed from vari rice, sweet potato and unripe banana powder. The blend of vari rice, sweet potato and unripe banana powder in the ratio of (40:40:20) extruded at 180 °C die temperature, screw speed of 170 rpm with 16 % moisture content was most acceptable by panel members (Rathod and Annapure, 2016) [55].

Traditional products

A traditional fermented food product of Nigeria is *Amala* prepared from sweet potato, yam and/or cassava flour. Yusuf *et al*. (2017) [73] evaluated the acceptability of *amala* produced from orange-fleshed sweet potato using traditional and modified methods of fermentation.

Dackere is a dranular and traditional food product produced generally from cereals or tuber flours including corn, cassava, millet, sweet potato. *Dackere* is lacks in protein so to make it protein sufficient, Daidai *et al.* (2016) [9] developed *dackere* from sweet potatoes and bambara groundnuts blended flour which is rich in protein. The protein content of sweet potato–bambara *dackere* blend was found increased from 5.7% to 12.1% due to fortification with bambara groundnut flour. Similarly, *Gari* is a fermented food product of Nigeria prepared particularly from cassava roots. Sweet potato roots were included into cassava for the production of quality *gari.* It was examined that the addition of sweet potato significantly improved the nutritional value of cassava-sweet potato *gari* (Olayinka *et al*. 2016) [49].

Non alcoholic beverages

A non-alcoholic beverage was developed from sweet potato similar to fruity type beverage. It was developed using mashed sweet potato with sugar, citric acid and ascorbic acid. Generally, orange fleshed sweet potato produced beverage with good aroma and color. Padmaja and Premkumar, (2002) [51] attempted to prepare nonalcoholic beverage from sweet potato mashed pulp with mango, pineapple, lemon, orange etc. Non-alcoholic beverages (NAB) are mostly produced from fruits, dairy, cocoa etc. Seldum is the NAB prepared mainly from roots and tubers. It's having great demand in Ghana. A study was reported to produce NAB from cassava and sweet potato roots. The formulations were prepared as cassava roots: sweet potato roots - 100:0%, 90:10%, 70:30%, and 50:50%. The sensory evaluation showed that, panel members had good preference with 50:50% formulations (Faustina *et al*. 2016) [18].

Nutritive value of sweet potato leaves

Sweet potato leaves has not been much used as a human food though rich source of vitamins, minerals and protein. These leaves are used as vegetable in some part of world. It contains high antioxidants particularly phenolic compounds. This phenolic compound includes caffeocylquinic acid derivatives having antimutagenic effect (Yoshimoto *et al.* 2005) [72]. Leaves also attributed high content of lutein to the extent of 29.5mg/100g which has eye protection effect.

Conclusions

The present article concluded that the sweet potato is tropical tuber crop which is underutilized though having nutritional health benefits such as good source of starch, vitamins, minerals and also having low glycemic index, high content of β carotene, anthocyanine, phenolic compounds, antioxidants etc. These health benefits properties of sweet potato could be a very good vehicle to address the health related problem like diabetics, celiac disease. It also serves as a food security crop. The natural colorant and antioxidant present in orange and purple fleshed sweet potatoes can be used for developing functional foods. There is further research needed to develop the functional food products from sweet potato which are gluten free, suitable for diabetics, with low glycemic index. There is need to explore the health benefits of sweet potato for development of industrial based food products which could address the specific health related problems. Available evidences suggested that, the nutritional benefits of orange fleshed and purple fleshed sweet potato is not recognized potentially from the researchers and consumers, which also need further efforts.

Conflict of interest

Authors declare that there is no conflict of interest.

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