SWEETPOTATO AS A FOOD CROP

Joko Susilo Utomo[1)]

ABSTRACT

Sweetpotato as a food crop. Sweetpotato is among the world most important, versatile and under exploited crop in many part of the world, with more than 133 million tons in world annual production and being cultivated in more than 100 countries and it ranks ninth from the viewpoint of total production as a world crops. Sweetpotato contains approximately 30% dry matter and about 80–90% is made of carbohydrate and the rest are composed by protein, lipids, minerals, fibre and vitamins. Sweetpotato is also well-known as a source of minerals and vitamin. Regardless of these general nutritional excellences, sweetpotato is underexploited food item. In attempt to enhance the utilization as food, several food items was produced. The development of ready to serve products includes candied, canned, frozen, restructured products, etc.

Keywords: Sweetpotato, production, consumption, composition, product

INTRODUCTION

Sweetpotato, Ipomoea batatas Lam., is a dicotyledonous plant belonging to the Convolvulaceae family, in which of major economic importance as a food among approximately 50 genera and over 1,000 species of this family (Woolfe 1992). The parts of the sweetpotato used for food are roots and leaves or tips. In common with other roots and tubers, sweetpotato has a high moisture content, resulting just about 30 % dry matter content which approximately 80–90% is made of carbohydrates which consist mainly starch and sugars. It is well known that sweetpotato is not only a source of energy, but also excellent sources of provitamin A and vitamin C, certain other minerals, dietary fibre and some protein (Picha 1985a, Lanier and Sistrunk 1979, Edmond and Ammerman 1978). Despite these general nutritional excellences, sweetpotato is not popular food item. In some traditional sweetpotato growing areas, production is decreasing as food consumption patterns change to imported cereal-based food. Attempts to expand the marketability of sweetpotatoes have focus on processed products, such as fries, chips and leathers (Collins and Washam-Hutsell 1987, Schwartz *et al.* 1987, Walter and Hoover 1986). Hence, the increasing of sweetpotato consumption can be obtained by convincing people of its nutritional goodness, as well as palatability, so that they will prefer it to foods of lower nutritional value (Che Man 1996).

PRODUCTION AND CONSUMPTION

The information of sweetpotato on historical trends and the global status of production and utilization are very limited. According to FAO (1990), sweetpotato is grown in 111 countries, of which 101 are classified as 'developing nations' which account for over 99% of world output. It has been estimated that sweetpotato production in developing countries is about 130 million metric tones/year, representing 34% of all roots and tubers cultivated in this region. Over 90 % of the production in developing countries is in Asia with China as the largest producer of sweetpotato in the world, accounting for 85% of global production (Huang-Jikun *et al.* 2004), and just fewer than 5% in Africa and only 5% in all the rest of the world. Sweetpotato production, in spite of a decrease in harvested area, fluctuated only a little during the 1979–1999 periods due to higher yields, which registered the highest increase around 41.5% in 21 years (CGPRT 2006).

Consumption estimates are usually derived from food balance sheets published by the FAO. Average annual per capita consumption of fresh roots for 1994–1996 is estimated by FAO (2001): Africa 9 kg, Asia 18 kg, Oceania 73 kg, Latin America 5 kg, Japan 7 kg, and USA 2 kg. The fluctuation of annual per capita consumption of fresh roots for the world, developing countries, and China from 1995 to1999 is illustrated on Figure 1. The world annual per capita consumption is lower compared with developing countries

[1] Peneliti pascapanen Balai Penelitian Tanaman Kacang-kacangan dan Umbi-umbian, Kotak Pos 66 Malang 65101, Telp. (0341) 801468, e-mail: blitkabi@telkom.net

Diterbitkan di Bul. Palawija No. 17: 19–28 (2009)

Table 1. Sweetpotato production and use as food in the world and developing countries

Year	Production (million metric tonnes)		Food (million metric tonnes)	
	World	Developing	World	Developing
1996	142.5	140.6	71.1	69.6
1997	121.8	119.9	63.4	61.8
1998	134.9	133.1	64.4	62.9
1999	146	144.3	68.6	67.2
2000	142.1	140.3	66.9	65.4
2001	143.1	141.3	67.1	65.5
2002	130.2	128.5	69.9	68.4
2003	125.4	123.6	65.8	64.2
2004	127.5	125.8	na	na
2005	129.4	127.5	na	na

Source: FAO 2006; na= not available data

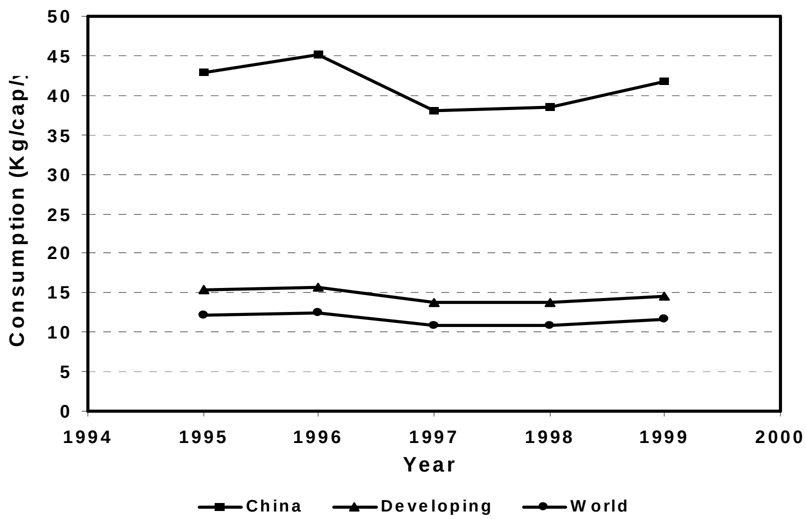

Figure 1. Evolution of annual per capita consumption of fresh sweetpotato root in China, Asia, Developing countries and the World for 1995 - 1999. (Source: FAO 2004)

and China. China also the highest per capita availability of sweetpotato for food with ranged from 38.1 to 45.2 kg, however its slight decrease into 36 to 41 kg in period of 1996–2004 (FAO 2006). As reported by CGPRT (2006) for Asia Pacific countries, the share of sweetpotato used as food from domestic supply regularly decreased from 68 to 44 %, but it was increased significantly for animal feed from 26 to more than 50%.

CHEMICAL COMPOSITION

Tuber crops are well known as source of carbohydrate composing of dry matter. Sweetpotato contains approximately 30 % dry matter and about 80–90% is made of carbohydrate. Starch, protein, fibre and ash contents were 10.3–38.71%, 0.18–5.53%, 1.77–5.49% and 2.46–5.69%, respectively (Saad 1996). Bradbury and Holloway (1988a) reported 20.1% starch, 2.38% sugar, 1.43% protein, 1.64% fibre, 0.74% ash in 164 sweetpotato samples from five South Pacific Countries. Dissimilar with other root crops, sweetpotato contains carotene that is important compound as a precursor of vitamin A (Wolfe 1992, Bradbury and Holloway 1988a, DA-EVIARC 2006).

Starch

Starch content in sweetpotato varies very greatly. Starch content in fresh sweetpotato root collected from five countries in Solomon Island varies from 17.7 to 23.4% (Bradbury and Holloway 1988a). Truong *et al.* (1986) reported that starch content varied from 42.6 to 78% (dwb) for among 18 cultivars grew in Brazilian, and 32.2–72.9% (dwb) for Filipino and American cultivars. Utomo *et al.* (2005) argued that starch content of 17 accessions from Universiti Putra Malaysia and 4 commercial cultivars were 52.79–53.75% and 53.01–53.37% (dwb), respectively.

Amylose and amylopectin are the two main polysaccharide component of sweetpotato starch. The amylose contents of sweetpotato starch granules have variously been determined as ranging from 17.5 to 38 % in cultivar from United States, Philippines, Korea and Puerto Rico (Shin and Ahn 1983, Martin and Deshpande 1985). While Utomo *et al.* (2005) reported that amylose content of sweetpotato from Malaysia was varied from 19.15 to 28.80 % (dwb).

Sugars

Sugars are one of important constituent affecting the quality of sweetpotato. Variability in total sugar of sweetpotato tubers is ranging from 0.38% to 5.64% (fwb) for cultivars from various regions of the South Pacific (Bradbury and Holloway 1988a) and from 2.9% to 5.5% (fwb) in American cultivar (Picha 1985b). On a dry weight basis, total sugar varied from 5.6% in Filipino cultivar to 38.3% in a Louisiana sample (Truong *et al.* 1986).

The major sugars occurring in raw roots are sucrose, glucose and fructose. In all cases of cultivars analyzed the concentration of sucrose exceeded that of the other sugars (Truong *et al.* 1986, Tamate and Bradbury 1985, Martin and Deshpande 1985, Picha 1985b). Glucose and fructose are the monosaccharide present in sweetpotato roots. In some cultivars the concentration of glucose is higher than that of fructose; in others they are present in approximately equal amount (Picha 1986a, 1986b, Takahata *et al.* 1996, Huang *et al.* 1999a). Maltose has also been found in low concentrations in raw roots (Bradbury and Holloway, 1988a, Truong *et al.* 1986), but Picha (1985b) and Losh *et al.* (1981) found it was absent.

Oligosaccharides

Oligosaccharides, such as raffinose, stachyose and verbascose are interesting compound to determine in connection to the poorly documented occurrence of flatulence among sweetpotato consumers, including Asian's consumer (Palmer 1982, Tsou and Yang 1984). Raw and cooked Philippines sweetpotato roots contained 0.23–0.4% cellobiose, negligible raffinose, verbascose in only trace amount and no detectable stachyose (Truong *et al.* 1986). Raffinose was reported at 0.5% of the fresh weight in baked sweetpotato (Palmer 1982). The concurrence of flatulence has been suggested as a possible factor contributing to the low acceptability of sweetpotato by consumers to increasing sweetpotato intake (Tsou and Villareal 1982).

Non-starch Polysaccharides

In addition to starch and sugar, sweetpotato also contain non-starch polysaccharides, including pectins, hemicelluloses and celluloses as well as other associated structural proteins and lignins (FAO 1990). As a group, pectic substance, hemicellulose and cellulose are classed as dietary fibre, and play a role in the nutritional value of sweetpotato (Woolfe 1992).

The total dietary fibre of raw sweetpotato samples from Solomon and Papua New Guinea ranged from 1.20% to 2.62% (fwb) (Bradbury *et al.* 1985a). The mean dietary fibre content (fwb) of four cooked American cultivars, calculated as the sum of pectin, hemicellulose and cellulose was 3.6% (0.97% + 0.93% + 1.7%) (Reddy and Sistrunk 1980). The total non-starch polysaccharide content of sweetpotato flesh boiled for only five minutes was 2.4 g/100 g (fwb) or 8.1 g/100 g (dwb) according to British researchers (Englyst *et al.* 1988).

Carotenoid

Carotenoid is a pigment that is responsible for the cream, yellow, orange or deep orange flesh colour of sweetpotato roots. The amount of total carotenoid present as beta-carotene is high in yellow to deep orange flesh cultivars. Some cultivars with white flesh root contain no beta-carotene and others have small quantities (Bradbury and Holloway 1988b). The carotenoid content of 17 cultivars grown in Taiwan ranged from 0.40

mg/100 g (fwb) in local cultivars and up to 24.80 mg/100 g (fwb) in cultivars introduced from the United States (Wang and Lin 1969). While Huang *et al.* (1999b) reported that orange fleshed varieties grown in Hawaii contained 6.7–13.7 mg/100 g (fwb), which was substantially lower than those reported by Bureau and Bushway (1986) for mainland USA varieties.

Anthocyanins

The purple-fleshed colour of sweetpotatoes contains high level of anthocyanin, compared to white, yellow, and orange-fleshed ones (Suda *et al.* 2003). The concentration of anthocyanin is affected by the stage of development of the root. Large roots of 300–400 g contain about 200 mg/100 g total anthocyanin (dwb), whereas those of the same cultivar weighing only 80–150 g contain about 300 mg/100 g (dwb) anthocyanin (Woolfe 1992).

Sweetpotato anthocyanins have been found to constitute a source of stable pigments, suitable for addition to beverages (Bassa and Francis 1987). The cultivar Ayamurasaki from Japan is used as a natural food colourant and the anthocyanin content of this variety is about 0.6 mg/g (Yoshinaga 1995). Anthocyanin of red sweetpotato from Peru was found highly to moderately resistant to the pH, temperature and light factors, and addition it maintained a red-violet hue for extended periods of time (Cevallos-Casals and Cisneros-Zevallos 2004).

Nitrogenous Constituent

Nitrogenous compounds collectively referred to crude protein or total protein. Sweetpotato contains a minor fraction of total protein content in dry matter compared to carbohydrates. The total protein content is on average about 5% (dwb) or 1.5% (fwb). Dickey *et al.* (1984) reported that total protein of 100 seedlings from 7 parental clones grown in America ranged from 4.38 to 8.98% (dwb) with mean 6.29%. Bradbury *et al.* (1985b) reported that ten cultivars grown in Papua contained 1.29 to 1.81% (fwb).

Non protein nitrogen (NPN) of sweetpotato includes peptides to be precipitated by reagents which coagulated true protein, free amino acids, amides and other non-polymeric nitrogen compounds. The total nitrogen in NPN of 10 high protein seedlings out of 100 seedlings grown from seven parents ranged from 22.1 to 37.7% (Dickey *et al.* 1984).

Lipids

The lipid content of sweetpotato is very low and nutritionally insignificant. Lipid concentration varies from 0.17% to 1.0% (fwb) in raw sweetpotato tuber (Haytowitz and Matthews 1984, Bradbury and Holloway 1988a). Analysis of lipid fraction for their fatty acid composition showed that palmitic acid (16:0) and linoleic (18:2) acids are most abundant in all fractions, comprising 29.3 % and 44.7% of the total lipid, respectively, (Walter *et al.* 1971). This work gives similar result to other studies, approximately equal amounts of linoleic and oleic (18:1) acids which were found in Korea sweetpotato lipids (Lee and Lee 1972). Sweetpotato lipid found containing highly unsaturated fatty acids.

Vitamin A

Sweetpotato contains high level of total carotenoids as vitamin A precursors, especially the orange flesh cultivar. In Philippine, the average vitamin A content of yellow and white-fleshed colour approximately 1,255 and 60 µg/100g (fwb), respectively (DA-EVIARC, 2006). Bangladesh Agriculture Research Institute (BARI) (2006) released four new sweetpotato cultivars in 1994 and 2004 having creamy-flesh colour contained vitamin A ranged from 700 to 1050 IU/100 g edible portion (fwb). Moreover, USDA (2001) reported that raw and cooked sweetpotato roots contained 20,063 and 17,054 IU/100 g (fwb), respectively.

Vitamin B

The range of vitamin B such as thiamin (B1), riboflavin (B2) and niacin (B3) contents in some cultivars from South Pacific were 0.04–0.12, 0.02–0.06 and 0.26–0.89 mg/100 g (fwb), respectively (Bradbury and Singh 1986). Total vitamin B6 content of raw sweetpotato was determined in Britain as 0.09 mg/100 g (fwb) (Kwiatkowska *et al.* 1989), while New Zealand samples contained 0.15 mg/100 g (fwb) (Visser and Burrows 1983). USDA (2001) reported that B1, B2, B3, and B6 content of raw sweetpotato were 0.066, 0.147, 0.674 and 0.257 mg/ 100 g (fwb) respectively.

Vitamin C

Vitamin C is the one of vitamin found in sweetpotato fresh root. Sweetpotato from Papua New Guinea were reported to contain as much as 64 mg/100 g edible portion (Farnworth 1973). Total ascorbic acid in four samples from Solomon Island varied from 19.8 to 32.9 mg/100 g (fwb) (Bradbury and Singh 1986). Moreover, Bradbury and Holloway (1988a) calculated the amount of ascorbic acid and dehydroascorbic acid in sweetpotato tubers from nine countries was 24 mg/100g.

Vitamin E

Vitamin E in sweetpotato determined in the form of tocopherol ranging from 0–10 mg/100 g (fwb) determined by several researchers (Hirahara and Koike 1989). Raw New Zealand sweetpotato roots were reported to contain 0.75 mg tocopherol/ 100 g (fwb) (Visser and Burrows 1983), while Haytowitz and Matthews (1984) found that the white-fleshed colour sweetpotato contained approximately 4.56 mg/100 g (fwb).

Polyphenolics

The sweetpotato has a number of different compounds known collectively as polyphenolics, the oxidation of which by free oxygen is catalyzed by enzymes called polyphenol oxidases (Woolfe 1992). This reaction produces quinines which either polymerize directly or combine with amino acids and amino group in proteins to form dark coloured (brown) compounds. This leads to unpleasant appearance and loss of quality of both the fresh root and final product. Walter and McCollum (1979) reported the phenolics content of seven cultivars ranged from 14 to 51 mg/100 g (fwb).

Minerals

The ash content of sweetpotatoes averages approximately 1% of the fresh root weight or about 3–4% of the dry weight (Woolfe 1992). Table 2 shows the mineral composition of sweetpotato root.

The greatest amount of element in sweetpotato is K, followed by P, Ca or Mg. Na may be higher concentration than Ca. Other elements are present as shown by various analysis are Fe, Cu, Mn, Zn, S, and Cl. In addition, B, Cd, Ni and Pb, Hg, Se, and Si may be present. Other, less extensively investigated trace elements reported to have beneficial effects in human include copper, chromium, manganese, selenium and molybdenum (National Research Council 1980). At approximately 0.5 mg/kg (fwb) the fluoride content of sweetpotato roots was higher than that of other roots and tubers (Venkateswara and Mahajan 1990).

SWEETPOTATO FOOD PRODUCTS

Sweetpotato is an important crop in the world. It is nutritious source of complex carbohydrate, dietary fibre, energy, vitamins, and minerals. The basic method of cooking roots used in all areas are baking or roasting, boiling, steaming, and frying (Woolfe 1992). Considerable research has been devoted of sweetpotato cooked or product such as baked (Reddy and Sistrunk 1980, Collins *et*

Table 2. Mineral composition of raw sweetpotato roots (mg/100 g, fwb).

Mineral	South Pacific SP. roots	General		
	Mean a	Ranges a	Mean b	Ranges b
Ca	29	7.5–74.5	24	17–34
P	51	41.0–70.0	41	28–54
Mg	26	18.4–35.7	20	14_23
Na	52	13.8–84.0	21	13–30
K	260	129–382	396	342–488
Fe	0.49	0.16–0.94	0.69	0.59–0.86

Notes: Adapted from: Bradbury & Holloway 1988a.
a = Mean and ranges of 164 samples from 5 South Pacific countries (Bradbury & Holloway 1988a)
b = Mean and range (Lopez *et al.* 1980; Monro *et al.* 1986; Ohtsuka *et al.* 1984).

al. 1995), French fried or strip or chips (Walter and Hoover 1986, Schwartz *et al.* 1987, Walter *et al.* 1992, Walter *et al.* 1993, Utomo *et al.* 2008), canned (Lanier and Sistrunk 1979), patties (Hoover *et al.* 1983, Walter and Hoover 1984), edible sheet or leather (Collins and Washam-Hutsell 1987, Che Man 1996), and other cooked and frozen products (Damir 1989, Wu *et al.* 1991, Valetudie *et al.* 1999).

Baked Sweetpotato

Baking is the simplest method of preparing food, which is usually place the sweetpotato root in the baking instrument until the skin is charred. In baking, carbohydrates constituent affect not only firmness but also mouthfeel which includes smoothness, coarseness and consistency (Hamann *et al.* 1980). The starch in sweetpotato root is converted during baking into maltose and dextrins (Picha 1985b, Picha 1986a). Maltose was most abundant sugar in bake root since it was not found in raw sweetpotato root (Picha 1985b), and about 99% of the converted starch accumulated as maltose. Beside dextrin and maltose, sugars include sucrose, fructose and glucose, are also important factor in baking process. There was an increase in the concentration of sugars during baking (Reddy and Sistrunk 1980, Losh *et al.* 1981, Damir 1989)

Boiled and Steamed Sweetpotato

Similar to baked sweetpotato, boiled and steamed sweetpotato have similar characteristics of the starch degradation term. However, boiled generally produces less sweet and moist than those which have been baked, as boiling more rapidly raises the temperature of the flesh to that at which the enzyme are inactivated, and less starch is hydrolyzed (Walter and Hoover 1984). Boiling and steaming have been found to increase the moisture content of sweetpotato roots by about 4% and 2%, respectively (Bradbury *et al.* 1988).

Other products made using boiling method of sweetpotato roots are candies, jam and sweets. The basic method of candies product: sweetpotato is boiled with an equal weight of sugar, a little vanilla for flavour and either natural pectin content of sweetpotato or added agar is used to produce a pasty or gelled mass. Sweetpotato roots also appropriate for jam making as it contains suitable content of water-soluble pectin with gelling properties similar to that of apple pectin (Winarno 1982). The Philippines sweetpotato jam process consisted of cooking a mixture of 20.7 % sweetpotato, 45% sugar, 34% water, and 0.3% citric acid until a solid content of 68 Brix obtained.

Fried Sweetpotato

The popular frying products of sweetpotatoes are French fried-type product or strip and chip. The major problem of development the quality of those products is discolouration, which arises from the formation of grey discolouration caused by the oxidase reaction of polyphenol group's enzymes and also the non-enzymatic browning, that result when reducing sugars condensed with amino groups. Several methods have been developed to eliminate the constraints due to get good quality of the product. Hoover and Miller (1973) used sodium acid pyrophosphate blanch treatment to eliminated graying in the production of high quality chips. Walter and Hoover (1986) and Schwartz *et al.* (1987) modified previous method for producing French fried type products.

Flavour and texture of French fried are other quality factors while the lack or loss of crispiness is the main problem in chips making. The increase of desirable flavour is due to an increase in sugars and other undefined flavour component (Hamann *et al.* 1980). Textural properties are dependent on the way in which structural component of food are arranged. The difficulty of managing the firmness produces inconsistency textural properties of the products. Walter *et al.* (1992) and Walter *et al.* (1993) controlled the firmness through managing the pH of sweetpotato tissue using acid and base media. Base mediated firmness retention was effective on strips and could be easily adapted to many types of products.

Dehydrated Sweetpotato Products

Dehydration of sweetpotato has been traditionally practiced in many developing countries. The flour production was developed in several developing countries and the process including peeling, shredding, pressing to remove some of moisture, drying and then milling (Winarno 1982, Guedes 1986). Sweetpotato flour is used usually as a partially substitution of wheat flour in bread making. The possibility of utilizing wheat-sweetpotato composite flour in breads and other bake goods has been investigated in several countries includes Egypt, Ghana, India, Korea, Philippines and the West Indies. Most researchers found 10–15% substitution the most acceptable in these terms.

An excellent sample of dehydrated sweetpotato product is sweetpotato cubes. On reconstruction, the cubes are cooked with rice, coconut milk, brown sugar and vanilla to make a fruit soup called quinata'an which is traditional Philippines dish. This product has also been developed in India as quick-cooking convenient vegetable or in soup mixes (Truong 1990). A product resembling dried fruit has been developed from orange-fleshed roots (Truong 1987).

Sweetpotato flake is the dehydrated product that produced in large scale processor. The standard process of flake using drum drying procedure has been investigated since sixties (Manlan *et al.* 1985). Flakes can be reconstituted into mashed sweetpotato or incorporate into variety of other product such as pies, pasties, cakes etc. The production of high quality flake includes preprocess or pre-heating process due to inactivating enzyme discolouration and reduction of peeling time and dehydration process.

Restructured Products

A food product fabricated by combining sweetpotato puree with other ingredient and moulding the resultant formulation into a patty-type has been developed. This product is typically called restructured product. This is because a major reason for the lack of sweetpotato products in the marketplace those processors have not been able to develop products of consistence quality (Hoover *et al.* 1983, Walter and Hoover 1984).

Many reports on various aspects in production of sweetpotato puree have been published, however a few accounts of restructured sweetpotato products (Hoover *et al.* 1983, Walter and Hoover 1984). Truong and Walter (1994) developed the sweetpotato puree restructured with cellulose derivates, and then Truong *et al.* (1995) developed a restructured baked sweetpotato product in which sweetpotato puree was texturized using an alginate-calcium gelling system. Previous attempts to control the textural properties of conventional sweetpotato French fries have included partial dehydration (Walter and Hoover 1986, Schwartz *et al.* 1987) and temporary modification of tissue (Sylvia *et al.* 1997). Patties preparation process was describe by Hoover *et al.* (1983). Utomo *et al.* (2008) developed restructured sweetpotato stick in which sweetpotato puree was prepared by blanching the sliced sweetpotato and texturized the puree using 5 % sweetpotato flour. Baked sweetpotato can be made through restructured process as described by Truong and Walter (1994)

Other Products

The natural sweetness of sweetpotato tubers and the addition of further sugar gives a variety of candied products, jam and sweets. Those products are particularly popular in Mexico, Argentina, China and Japan (Horton 1988, Wiersema *et al.* 1989). Non alcoholic beverages from high beta-carotene sweetpotato cultivars, possessing a nutritional comparable with or superior to fruits drink have been formulated (Truong and Fementira 1990). The colour of the beverages varied according to the colour of the roots, ranging from yellow to orange or pinkish-purple (Truong 1987). The major anthocyanin of sweetpotato was reported as a potential colourants in beverages production (Bassa and Francis 1987). Other traditional non-alcoholic sweetpotato beverage 'dolo' is also popular in Cameroon (Numfor and Lyonga 1987).

Sweetpotato can be used as a raw material of vinegar. The starch requires initial hydrolysis to sugars before alcoholic fermentation by yeast can take place. The next step, oxidation of the alcohol to acetic acid is carried out by acetic acid bacteria. Vinegar processed from a high beta-carotene cultivar has been commercialized in Japan (Woolfe 1992).

REFFERENCES

Bangladesh Agriculture Research Institute (BARI). 2006. Tubers crops. Download from http://www.bari.gov.bd/commodity_achievement/tubercrops2.htm on 1 march 2006.

Bassa, I.A. and Francis, F.J. 1987. Stability of anthocyanin from sweet potatoes in a model beverage. J of Food Sci. 52(6): 1753–1754.

Bradbury, J.H., Beatty, R.E., Bradshaw, K. Hammer, B., Holloway, W.D., Jealous, W., Lau, J., Nguyen, T and Singh, U. 1985a. Chemistry and nutritive value of tropical root crops in the South Pacific. Proc. of Nutrition Soc. Aust. 10: 185–188.

Bradbury, J.H., Hammer, B., Nguyen, T. Anders, M. and Millar, J.S. 1985b. Protein quantity and quality and trypsin inhibitor content of sweet potato cultivars from the highland of Papua New Guinea. J of Agric. Food Chem. 33(2): 281–285.

Bradbury, J.H. and Singh, U. 1986. Thiamin, riboflavin and nicotinic acids contents of tropical root crops from the South Pacific. J of Food Sci. 51(6): 1563–1564.

Bradbury, J.H. and Holloway, W.D. 1988a. Chemical composition of root crops in: Bradbury and Holloway, (eds). Chemistry of tropical root crops: significance for nutrition and agriculture in the pacific. ACIAR Monograph No. 6. Canberra. p:1–88.

Bradbury, J.H. and Holloway, W.D. 1988b. Chemistry of tropical root crops: Significance for nutrition and agriculture in the Pacific. ACIAR Monograph Serial. No. 6, Canberra.

Bradbury, J.H., Bradshaw, K., Jealous, W., Holloway, W.D. and Phimpisane, T. 1988. Effect of cooking on nutrient content of food tropical root crops from South Pacific. J of Sci. Food Agric. 43: 333–342.

Bureau, J.L. and Bushway, R.J. 1986. HPLC determination of carotenoids in fruits and vegetables in the United States. J of Food Sci. 51: 128–130.

Cevallos-Casals, B.A. and Cisneros-Zevallos, L. 2004. Stability of anthocyanin-based aqueous extract of Andean purple corn and red-fleshed sweet potato compared to synthetic and natural colorants. Food Chemistry. 86: 69–77.

CGPRT. 2006. Domestic supply and consumption patterns of coarse grains, pulses, roots and tuber crops in Asia and the pacific. CGPRT Centre Monograph No. 45. p: 90.

Che-Man, Y.B. 1996. Development and evaluation of a snack food from sweet potato. ASEAN Food J. 11(3): 114–119.

Collins, J.L. and Washam-Hutsell, L. 1987. Physical, chemical, sensory and microbiological attributes of sweet potato leather. J of Food Sci. 52(3): 646–648.

Collins, J.L. Liao, J.Y. and Penfield, M.P. 1995. Chemical, physical and sensory attributes of formed and frozen, baked sweetpotato. J of Food Sci. 60(3): 465–467.

DA-Eastern Visayas Integrated Agricultural Research Center (DA-EVIARC).2006. Plant industry production guide on sweetpotato. Download from http://www.da.gov.ph/sweetpotato on 11 September 2006

Damir, A.A. 1989. Effect of heat penetration during cooking on some physico-chemical properties and microstructure of sweet potatoes. Food Chem. 34: 41–55.

Dickey, L.F., Collins, W.W., Young, C.T. and Walter, W.M. 1984. Root protein quantity and quality in a seedling population of sweet potatoes. Horticulture Sci. 19(5): 689–692.

Edmond, J.B. and Ammerman, G.R. 1978. Sweet potato: production, processing, marketing. Wesport, CT. AVI Publ. 334p

Englyst, H.N., Bingham, S.A. Runswick, S.A., Collinson, E. and Cummings, J.H. 1988. Dietary fibre (non-starch polysaccharides) in fruits, vegetables and nuts, J of Human Nutr and Dietetic. 1(4):247–286.

FAO. 1990. Roots, tubers, plantains and bananas. Food and Agriculture Organization of The United Nations. Rome. 198p.

FAO. 2001. FAO data. Download from http://www. fao.org/es/esc/esce/ESCB/roots/swtope.html on 9 January 2001.

FAO. 2004. FAO data. Download from http://www.fao.org/es/esc/esce/ESCB/roots/swtope.html on 17 January 2004.

FAO. 2006. FAO data. Download from http://www.fao.org/es/esc/esce/ESCB/roots/swtope.html on 5 June 2006.

Hamann, D.D., Miller, N.C. and Purcell, A. 1980. Effects of curing on the flavor and texture of baked sweet potato. J Food Sci. 45:992.

Haytowitz, D.B. and Matthews, R.H. 1984. Composition of food: vegetables and vegetable product. Human Nutrition Information Series, USDA Agriculture Handbook. No. 8–11. Washington DC.

Hoover, M.V. and Miller, N.C. 1973. Process for producing sweet potato chips. Food Tech. 27: 74, 76, 80.

Hoover, M.W., Walter, W.M. and Giesbrecht, F.G. 1983. Method of preparation and sensory evaluation of sweet potato patties. J of Food Sci. 48: 1568–1569.

Horton, D. 1988. Trip Report: Argentina. International Potato Centre. Lima, Peru.

Huang, Y.H., Picha, D.H., Kilili, A.W. and Johnson, C.E. 1999a. Changes in invertase activities and reducing sugar content in sweetpotato stored at different temperatures. J of Agric. Food Chem. 47: 4927–4931.

Huang, Y.H., Tanudjaja, L. and Lum. D. 1999b. Content of alpha-, Beta-carotene and dietary fibre in 18 sweetpotato varieties grown in Hawaii. J of Food Composition and Analysis. 12: 147–151.

Huang-Jikun., Song Jun, Qiao-Fanbin and Fuglie, K.O. 2004. The sweetpotato economy of China with new estimates of sweetpotato utilization. *In*: Fuglie, K.O. and Hermann, M. (eds). Sweetpotato post harvest research and development in China. Proc. of an International Workshop held in Chengdu, Sichuan, PR China, Nov. 7–8, 2001. Bogor, Indonesia: International Potato Center (CIP).

Lanier, J.J. and Sistrunk, W.A. 1979. Influence of cooking method on quality attributes and vitamin content of sweet potatoes. J of Food Sci. 44(2): 374–376, 380.

Lee, Y.W. and Lee, S.R. 1972. A study on the systematic analysis of lipids from sweet potatoes (In Korean). Korean J of Food Sci and Tech. 4(4): 309–316.

Lopez, A., William, H.L. and Cooker, F.W. 1980. Essential elements in fresh and canned sweet potato. J of Food Sci. 45(3): 675–678.

Losh, J.M., Phillips, J.A., Axelson, J.M. and Schulman, R.S. Sweet potato after baking. 1981. J of Food Sci. 46: 283–286, 290.

Manlan, M., Matthews, R. F., Bates, R. P. and O'Hair, S. K. 1985. Drum drying of tropical sweet potatoes. J of Food Sci. 50(3): 764–768.

Martin, F.W. and Deshpande, S.N. 1985. Sugar and starches in non-sweet sweetpotato compared to those of conventional cultivars. J of Agric. Univ. Puerto Rico. 69(3): 401–406.

Mason, R.L. 1982. Sweet potato canning investigations. Food Tech. Australia. 34(12): 574–576.

Monro, J.A., Holloway, W.D. and Lee, J. 1986. Elemental analysis of fruit and vegetables from Tonga. J of Food Sci. 51(2): 522–523.

National Research Council. 1980. Recommended daily allowances. 9th edition. National Academy of Scis. Washington, DC.

Ohtsuka, R., Kawabe, T., Inaoka, T., Suzuki, T., Hongo, T., Akimichi, T. and Sugahara, T. 1984. Composition of local and purchased foods consumed by the Gidra in Lowland Papua. Ecology and Food Nutr. 15: 159–169.

Palmer, J.K. 1982. Carbohydrate in sweet potato. In: Villareal, R.L. and Griggs, T.D. (eds.). Sweet potato. Proc. of the First Internat. Symp. AVRDC. Shanhua. Tainan. Taiwan. p: 137–138.

Picha, D.H. 1985a. Crude protein, minerals, and total carotenoids in sweet potatoes. J of Food Sci. 50(6): 1768–1769.

Picha, D.H. 1985b. HPLC determination of sugar in raw and baked sweet potatoes. J of Food Sci. 50(4): 1189–1190.

Picha, D.H. 1986a. Sugar content of baked sweet potatoes from different cultivars and length of storage. J of Food Sci. 51(3):c845, 846, 848

Picha D.H. 1986b. Carbohydrate changes in sweetpotatoes during curing and storage. J of Am. Soc. Hort. Sci. 111: 89–92.

Reddy, N.N. and Sistrunk, W.A. 1980. Effect of cultivar, size, storage and cooking method on carbohydrates and some nutrition of sweet potato. J of Food Sci. 45(3): 682–684.

Saad, M.S. 1996. Genetic and variability of starch, protein, fibre and ash in sweetpotatoes from Malaysia. Selected Research Papers July 1994–June 1995. SAPPRAD. Philippines. Vol. 2: Sweetpotato: 203–210.

Schwartz, S.J., Walter W.M. Jr., Carrol, D.E., and Gierbretch, F.G. 1987. Chemical, physical, and sensory properties of a sweet potato french-fry type products during frozen storage. J of Food Sci. 52(3): 617–619.

Shin, M.S., and Ahn, S.Y. 1983. Physicochemical properties of sweetpotato starches. J of Korean Agriculture Chemistry Society. 26(2): 137–142.

Suda, I., Oki, T., Masuda, M., Kobayashi, M., Nishiba, Y. and Furuta, S. 2003. Review: Physiological functionality of purple-fleshed sweetpotatoes containing anthocyanins and their utilization in foods. JARQ. 37(3): 167–173. http://www.jircas.affrc.go.jp. Accessed 1 march 2006.

Sylvia, K.W., Walter, W.M.Jr., and Giesbrecht, F. G. 1997. Alkali-processed sweetpotato French fries. J of food quality. 20:17–30.

Takahata, Y., Noda, T. and Sato, T. 1996. Relationship between acid invertase activity and hexose content in sweet potato storage roots. J of Agric. Food Chem. 44: 2063–2066.

Truong, V.D., Bierman,C. J. and Marlet, J. A. 1986. Simple sugar, oligosaccharides, and starch determination in raw and cook sweet potato. J of Agric. Food Chem. 34(3): 421–425.

Truong, V.D. 1987. New development in processing sweet potato for food. Paper presented at an International Sweetpotato Symposium, 20–26 May, ViSCA. Baybay. Leyte.

Truong, V.D. 1990. Development of small scale technology for dehydrated sweetpotato cubes for traditional food preparations. In: Tropical root and tuber crops changing role in a modern world. Proceeding of the Eight Symposium of the International Society for Tropical Root Crops. 30 October – 5 November 1988. Bangkok.

Truong, V.D. and Fementira, G.B. 1990. Formulation, consumer acceptability and nutrient content of non-alcoholic beverages from sweet potato. In: Tropical Root and Tuber crops changing role in modern world. Proceeding of the Eight Symposium of the International Society for Tropical Root Crops. 30 October – 5 November 1988. Bangkok.

Truong, V.D. and Walter, W.M.Jr. 1994. Physical and sensory properties of sweetpotato pure texturized with cellulose derivatives. J of Food Sci. 59: 1175–1180.

Truong, V.D., Walter, W.M.Jr., and Giesbrecht, F.G. 1995. Texturization of sweetpotato puree with alginate: effect of tetrasodium pyrophosphate and calcium sulfate. J of Food Sci. 60: 1054–1059.

Tsou, S.C.S. and Villareal, R.L. 1982. Resistance to eating sweet potato. p: 39, 42, 43 *In* Villareal, R.L. and Griggs, T.D. (eds.). Sweet potato. Proceedings of the First International Symposium. AVRDC. Shanhua. Tainan. Taiwan.

Utomo, J.S., Che Man, Y, Rahman, R.A. and Saad, M.S. 2005. Physical and chemical characterization of 21 sweetpotato cultivars. p: 193–196. *In* Shamsudin, Z., Omar, D., Sale, G., Shamsudin, M.N., Mohd-Soom, M.A., Mohd-Jelan, Z.A., Mohd-Shariff, A.R., Kamaruddin, M.S., Akmar, S.N.A., How, T.W., Abd-Rhashid, R.A.T.S., Ishak, C.F., Ahmed. O.H. and Ishak. S.N. (eds). Agriculture congress 2004: Innovation towards modernized agriculture. Faculty of Agriculture, University Putra Malaysia.

Utomo, J.S., Che Man, Y.B., Rahman, R. A. and Saad, M.S. 2008. The effect of shape, blanching methods and flour on characteristics of restructured sweetpotato stick. International J of Food Sci and Tech. 43: 1896–1900.

USDA. 2001. Nutrient database for standard reference: Sweetpotato. USDA. pp: 3.

Valetudie, J-C., Gallant, D.J. Bouchet, B., Colonna, P and Champ, M. 1999. Influence of cooking procedures and biochemical changes in sweet potato. Starch/starke 51.Nr.11–12, S. p: 389–397.

Venkateswara, Rao, K. and Mahajan, C.L. 1990. Fluoride content of some common South Indian food and their contribution to fluorosis. J of Food Agric. 51(2): 275–279.

Walter, W.M.Jr, Hansen, A.P. and Purcell, A.E. 1971. Lipid of cured Centenial sweet potato. J of Food Sci. 36(5): 795–797.

Walter, W.M.Jr. and McCollum, G.K. 1979. Use of chromatography for analysis of sweet potato phenolics. J of Agric. Food Chem. 27(5): 938–941.

Walter, W.M.Jr. and Hoover, M.W. 1984. Effect of Preprocessing storage condition on the composition, Microstructure, and acceptance of sweet potato patties. J of Food Sci. 49: 1258–1261.

Walter, W.M.Jr. and Hoover, M.W. 1986. Preparation, evaluation, and analysis of a french-fry-type product from sweet potato. J of Food Sci. 51(4): 967–970.

Walter, W.M.Jr., Fleming, H.P. and McFeeters, R.F. 1992. Firmness control of sweetpotato French fry-type product by tissue acidification. J of Food Sci. 57(1): 138–142.

Walter, W. M. Jr., Fleming, H. P. and McFeeters, F. T. 1993. Base-mediated firmness retention of sweetpotato products. J of Food Sci. 58(4): 813–816.

Wang, H. and Lin, C.T. 1969. The determination of the carotene content of sweetpotato parental varieties and their offspring. J. Agric. Assoc. China. 65:1–5.

Wiersema, S.G., Hesen, J.C. and Song , B.F. 1989. Report on a sweet potato postharvest advisory visit to the People's Republic of China, 12–27 January 1989. International Potato Center. Lima, Peru.

Winarno, F.G. 1982. Sweet potato processing and by product utilization in the tropic In Villareal, R. L. and Griggs, T. D. (eds.) Sweet potato. Proceeding of the First International Symposium. AVRDC. Shanhua. Tainan. Taiwan. p: 373–384.

Woolfe, J.A. 1992. Sweet potato: an untapped food resource. Cambridge University Press. Cambridge. 643 p.

Wu, J.Q., Schwartz, S.J. and Carroll, D.E. 1991. Chemical physical and sensory stabilities of prebaked frozen sweet potato. J of Food Sci. 56(3): 710–713.

Yoshinaga, M. 1995. New cultivar "Ayamurasaki" for colourant production. Sweetpotato research Front. 1:2.