Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; SP4: 321-326

Gitanjali
Department of Food and Nutrition, College of Community Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Dr. Sarla Lakhawat
Department of Food Science and Nutrition, College of Community and Applied Science, Maharana Pratap Agricultural University and Technology, Udaipur, Rajasthan, India

Correspondence
Gitanjali
Department of Food and Nutrition, College of Community Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

(Special Issue- 4)
International Conference on Food Security and Sustainable Agriculture
(Thailand on 21-24 December, 2018)

Review on orange fleshed sweet potato: A miracle crop to reduce Vitamin A deficiency

Gitanjali and Dr. Sarla Lakhawat

Abstract

Vitamin A deficiency is caused by a habitual diet that provides too little bio available vitamin A to meet physiologic needs. Orange-Fleshed Sweet Potato is now emerging as an important member of the tropical tuber crops having great possibility for being adopted as regular diet of the consumer food chain to tackle the problem of vitamin A deficiency. Apart from cheap source of energy, Orange-fleshed sweet potato is an excellent source of the β-carotene. This crop is also gaining importance as the cheapest source of antioxidant having several physiological attributes like anti-oxidation, anti-cancer and may help in protection against liver injury and coronary heart disease. Orange fleshed sweet potato is the most suiting as biofortified crop to combat micronutrient malnutrition in small and marginal farming community.

Keywords: orange fleshed sweet potato, vitamin A deficiency

Introduction

Vitamin A Deficiency is the most common cause of childhood blindness in the world (WHO, 2009) [62]. Children and pregnant women are more likely to suffer from vitamin A deficiency. The World Health Organization reported that vitamin A deficiency affects about 190 million preschool-aged children and 19 million pregnant women, mostly in Africa and South-East Asia (WHO, 2011) [60]. Nearly 44–50% of preschool children in South and Southeast Asia are affected by severe Vitamin A deficiency (Akhtar *et al*., 2013) [1]. Among the all South Asian countries, India has the highest prevalence of clinical and subclinical vitamin A deficiency, the prevalence being as much as 62% in preschool children (Suri & Kumar, 2015) [47]. In India, about 40,000 children are affected every year by blindness mainly due to the deficiency of vitamin A and nearly half of the world's micronutrient deficient people may be found in this country (National Micronutrients Status Survey 2011–12, UNICEF, GAIN, & Nutrition 2013) [31].

Inadequate intake of vitamin A at this age can lead to vitamin A deficiency that, in turn, may cause night blindness, undermine growth and immune function. This also results in increased risk of morbidity and mortality, largely from measles, diarrhoea and respiratory infections (Sommer, 2011, WHO, 2011 and WHO, 2012) [46, 60, 61]. Children are at a higher risk of intestinal infestations and infections, which may also impair absorption of vitamin A (WHO, 2014) [63]. Breast milk is the only significant source of vitamin A for infants (Sommer, 2011) [46] and infants fed little or no breast milk in early life are increasingly susceptible to infections (Akhtar *et al*., 2013) [1].

Thus, vitamin A malnutrition is a major public health concern of the developing countries and is responsible for millions of deaths annually among the young children. The nutritionists in several developing countries compelled the evidence of lack of adequate essential vitamins and minerals in the diet of many children and adults (Sommer, 2011) [46]. Unlike those in developed countries, who receive abundant preformed vitamin A (retinol) from animal foods (liver, eggs, milk and milk products), whereas poor people living in third world countries rely on cheap dark green-yellow local vegetables and fruits for vitamin A. Vitamin A deficiency is caused by a habitual diet that provides too little bio available vitamin A to meet physiologic needs, rapid growth and frequent infections. An ineffective utilization of vitamin A is also critical factors for the vitamin A deficiency (Akhtar *et al*., 2013 and WHO, 2011) [1, 60].

Food Based Strategies for Improving Vitamin A Status

Despite the considerable efforts and investments put into tablet, capsule and injection based approaches, the significant progress on supplementation programs to reduce the magnitude of vitamin A deficiency in developing countries had not occurred over the past few decades. Although, some animal foods like fish oil, liver, egg and butter, rich in vitamin (retinol) are used directly and easily by the human body, but the poor people cannot afford these expensive foods. Considerable efforts are, therefore, to be made to promote vitamin A intake through increased consumption of cheap fruits and vegetables which although do not contain vitamin A as such but do contain its precursor, the β-carotene that can be converted to vitamin A by the human body. Supplementation programs in alleviating vitamin A deficiency, thus, will be replaced in future by sustainable food based strategies (Burri, 2011) [9]. One complementary approach to reducing vitamin A deficiency and other micronutrient deficiencies is to encourage shifts toward more micronutrient-dense diets (Ruel and Alderman, 2013) [40]. Among three different approaches, namely Vitamin A supplementation programme, fortification of common foods with micronutrients and the improvement of dietary quality through diversification of foods, the dietary diversification is an important food based approach in achieving and maintaining adequate intake of micronutrient-rich foods in the context of an adequate total diet (Islam *et al*., 2016) [18]. This food based approaches requiring an inter-sectoral perspective like providing agricultural and educational inputs with an awareness of cultural, socio-economic, market and health conditions may prove to be the most sustainable of the various interventions (Black *et al*., 2008) [6].

Sweet potato

Sweet potato (Ipomoea batatas L. Lam), the second most important root tuber and the seventh most important food crop of the world. Although, it is categorized as “poor man’s food” or “famine crop” but it has tremendous potential to contribute to a food based approach to promote food security, to alleviate poverty and to supplement as an alternative staple food for the resource poor farmers (Bovell- Benjamin, 2007) [8]. It also have a diverse range of positive attributes like high yield with limited inputs, short duration, high nutritional value and tolerance to various production stresses. These crops are said to be a native to Central America and are one of the oldest vegetables known to man (WHFoods, 2014) [48]. Asia as a whole accounts for about 78% of the world area under this crop and about 92% of the world production. India is one of the leading producers of this crop along with China, America, Brazil, Peru, Mexico and Thailand. India accounts for about 68% of the total production of South Asia followed by 27% in Bangladesh and about 5% in Sri Lanka. In India, Sweet potato is cultivated mainly in Orissa, Uttar Pradesh, West Bengal, Bihar, Karnataka, Tamil Nadu and Kerala (Mitra, 2012) [30].

Orange fleshed sweet potato

Orange fleshed sweet potato is now emerging as an important member of the tropical tuber crops. It is having a great possibility for being adopted as regular diet of the consumer food chain to tackle the problem of vitamin A deficiency. Apart from cheap source of energy, it is an excellent source of the β-carotene (Low *et al*., 2007) [23, 25] and is generally well accepted by young children (Wu *et al*., 2009 and Tumuhimbise *et al*., 2009) [67, 29, 54]. With the introduction of a large number of orange fleshed varieties having high β-carotene content ranging even up to 20-30mg per 100g (Padmaja *et al*., 2012) [35]. In addition to being rich in β-carotene, orange fleshed sweet potato contains significant amounts of protein, fat, carbohydrate, dietary fibre, zinc, potassium, sodium, manganese, calcium, magnesium, iron and vitamin C and some phytonutrients (Anita *et al*., 2006 and Mills *et al*., 2009) [2, 29]. A 100-150 g serving of boiled tubers of orange-fleshed sweet potato can supply the daily requirement of vitamin A for young children which can protect them from blindness (USAID, 2015) [55]. It is also reported that one medium sized orange fleshed sweet potato can provide about twice the β-carotene needed for the recommended daily requirement of vitamin A. The roots are usually consumed after processing like boiling, baking or making fried chips (Vimla *et al*., 2011) [58]. Because of their nutritional qualities, sweet potatoes were selected as one of the food tested for long- term space travel (Wilson *et al*., 1998). Therefore, orange fleshed sweet potato is a staple food that can provide a supply of vitamin A and energy to people in both developing and resource-poor developing countries (Low *et al*., 2009 and Mitra, 2012) [26, 30].

It is the most suiting as biofortified crop to combat malnutrition in small and marginal farming community (Kidane, 2013) [19]. Orange fleshed sweet potato tubers are also a good source of energy, easy to cultivate, vegetatively propagated, and fairly drought resistant (Hagenimana *et al*., 2001) [15]. These characteristics make orange fleshed sweet potato an excellent food security crop. These are less labor intensive than most other staple crops and can be planted over a broad range of time without considerable yield loss (Woolfe, 1992) [66]. Thus, there is a great possibility of this subsistence crop for being adopted as regular diet of the consumer food chain to supplement as an alternative staple food source for the resource poor farmers in the era of extensive population growth and nutrition crisis (Low *et al*., 2007) [23, 25].

Bioavailability of β-carotene from orange fleshed sweet potato

Bioavailability of β-carotene depends on multiple factors. Dietary fat is necessary for absorption and conversion of β-carotene to retinol (Lemmens *et al*., 2014 and Mills *et al*., 2009) [22, 29]. The retention and bioaccessibility of β-carotene determine its bioavailability (Bechoff *et al*., 2011 and Transcoso – Reyan, 2016) [4, 52]. It has been documented that maceration and heat processing improve β-carotene bioaccessibility from orange-fleshed sweet potatoes, which is probably due to rupture of microstructure of plant tissue and subsequent release of nutrients from the complex food matrix (Van- Jaarsveld *et al*., 2006, Tumuhimbise *et al*., 2009, Thakkar *et al*., 2009 and Bengtsson *et al*., 2010) [57, 29, 54, 13, 29, 51, 5].

Health Benefits of Orange Flesh Sweet Potato

There are a surprising number of nutrients responsible for the health benefits of orange fleshed sweet potato tuber. Among these some are antioxidants, anti-inflammatory nutrients and blood sugar-regulating nutrients (Whfoods, 2014) [48]. Being rich in β-carotene, the orange fleshed sweet potato is gaining importance as the cheapest source of antioxidant having several physiological attributes like anti-oxidation, anti-cancer and may help in protection against liver injury and coronary heart disease (Choi *et al*., 2009, Mei *et al*., 2010 and Grace *et al*., 2015) [12, 28, 14].

Antioxidant Nutrients

Orange Fleshed Sweet Potato contains a wealth of orange-hued carotenoid pigments. In many countries, sweet potatoes are available on a virtual year-round basis and their ability to provide an antioxidant nutrient like beta-carotene makes them a standout antioxidant food (Han *et al*., 2007) [16]. Recent research shown that during the digestion process, while passing through digestive tract, phytonutrients present in these crops may be able to lower the free oxygen radicals heavy metals toxicity (Han *et al*., 2007 and Xie *et al*., 2010) [16, 68]. That risk reduction might be important not only for individuals at risk of digestive tract problems but for all persons wanting to reduce the potential risk caused by the presence of heavy metal residues in their diet. The Storage proteins i.e., sporamins present in sweet potato also have some important antioxidant properties (Ozaki *et al*., 2010) [33]. These storage proteins produced by sweet potato plants, whenever they are subjected to physical damage. Their ability to help the plants heal from this damage is significantly related to their role as antioxidants (Chang *et al*., 2010) [10]. Especially when sweet potato is being digested inside of our gastrointestinal tract, we may get some of these same antioxidant benefits (Filla *et al*., 2009) [13].

Anti-Inflammatory Nutrients

The colour-related pigments (carotenoids, anthocyanin etc.) present in sweet potato are equally valuable for their anti-inflammatory health benefits. In animal studies, activation of nuclear factor-kappa B (NF-kB), activation of inducible nitric oxide synthase (iNOS) and cyclooxygenase-2 (COX-2) and formation of malondialdehyde (MDA) have all be shown to get reduced by consumption of either sweet potato or its colour-containing extracts(Hwang *et al*., 2010) [17].

The colour-related sweet potato phytonutrients also have their impact on fibrinogen (Ludvik *et al*., 2008) [27]. Balanced amounts of fibrinogen, thrombin and fibrin are a key part of the body's health and its ability to close off wounds and stop loss of blood. However, excess amounts of these clotting-related molecules may sometimes pose a health risk. In animal studies, excess fibrin in the central nervous system has been associated with increased demyelination process in neurons and can also trigger unwanted inflammation in nerve tissues (Zhang *et al*., 2009) [70]. In preliminary animal studies, intake of sweet potato coloured extracts has been shown in reduction of inflammation and also simultaneous reduction of fibrinogen levels (Wang *et al*., 2010 and Mei *et al*., 2010) [59, 68, 28].

Hypoglycaemic effect

These tubers have their ability to potentially improve blood sugar regulation in type 2 diabetes persons in spite of their medium glycemic index (Ozaki *et al*., 2010 and Bahado *et al*., 2006) [33, 3]. Recent research has also shown that sweet potatoes extracts can significantly increase the blood adiponectin levels in persons having type 2 diabetes (Ludvik *et al*., 2008) [27]. Adiponectin is a protein hormone produced by fat cells of body, and it serves as an important modifier of insulin metabolism. These tubers has high fiber, antioxidant nutrients like Vitamin A, Vitamin C, zinc and other micronutrients like potassium, magnesium, iron and Vitamin B, which help in diabetes management and prevention of other complications such as heart attacks and stroke(Han *et al*., 2007) [16].

Other Potential Health Benefits

One of the more challenging nutrient groups provided by sweet potato is the resin glycosides, called batatins (including batatin I and batatin II) (Yin *et al*., 2008) [69]. But, recently researchers discovered a related group of glycosides in sweet potato called batatosides (including batatodide III, batatoside IV, and batatoside V) (Philpott *et al*., 2009) [37]. In labotarory studies, most of these sweet potato glycosides have been shown to have antibacterial and antifungal properties (Noda and Horiuchi, 2008) [32]. But, to what extent these resin glycosides in sweet potatoes can provide a health benefit to human is not yet clear.

Food uses of orange fleshed sweet potato

Orange fleshed sweet potato can be termed as a "three in one" tuber, as it integrates the qualities of cereals (high starch), fruits (high content of vitamins, pectins, etc.) and vegetables (high content of vitamins, minerals, etc.). These tubers are extensively eaten after boiling, baking and roasting by Asian and South East Asian population. The beneficial effects of these ingredients have been appropriately put to use by converting the roots into a number of intermediary food products like jam, jelly, soft drinks, pickles, fried chips, bakery items sauce, candies, etc. (Singh *et al*., 2008, Padmaja *et al*., 2012 and Sindi *et al*., 2013) [45, 35, 44]. Orange fleshed Sweet potato has been processed into a dry cubes type food product. They are prepared after peeling, slicing into long pieces, soaking them in 2% (w/v) potassium metabisulphite solution and cooking in a 60° Brix syrup containing 0.8-1.0% citric acid. This is then dried and packed (Truong, 1987) [53]. Sweet potato contains water-soluble pectin, which enables its use in making jams and jellies (Truong, 1987) [53]. Pickles have been also made from orange fleshed varieties in Bangladesh, Philippines and also in India (Padmaja and Premkumar 2002 and Tan *et al*. 2005) [34, 49].

Orange fleshed Sweet potato based composite flours have been used in many countries for making small baked goods like cakes, cookies, biscuits, buns, muffins, doughnuts etc (Salma and Zaidah, 2005, Low and Van- Jaarsvald, 2008, Laurie *et al*., 2012 and Teferra *et al*., 2015) [41, 24, 20, 50]. French fry type products have been also prepared from sweet potato in Thailand (Reungmaneepaitoon *et al*. 2005) [39]. Ready to eat and Ready to cook breakfast food and snacks have also been made from orange fleshed sweet potato tubers (Lee, 2005) [21].

Curd is a popular food item for the Asians and is generally made from milk. Orange fleshed Sweet potato varieties were used to prepare curd having high nutritive value. The β-carotene rich variety yielded curd with a carotene content of 2.6 mg per 100g (Ray *et al*. 2005) [38]. The sensory evaluation of these curd also gave high scores for taste, aroma and texture (Panda and Ray, 2007) [36]. Orange fleshed Sweet potato tubers are dehydrated and converted into flour to increase the shelf life of stored tubers and also its further use in starch, pasta, noodle and alcohol factories (Wiersema *et al*. 1989 and Chen, 2003) [64, 11]. Orange fleshed Sweet potato flour was also attempted as a replacer of flour and starch in making of candy (Samsiah *et al*., 2005) [42]. These crops flour can also be utilized to make gulab jamun by mixing it with refined wheat flour and milk powder (Padmaja and Premkumar, 2002) [34]. The high quality puree made from Orange fleshed Sweet potato is used directly as a baby food or used for mixing various food items like patties, flakes, reconstituted chips, etc. (Bouwkamp, 1985 and Woolfe, 1992) [7, 66]. Puree making also ensures round the year availability and better storage life. Restructured sweet potato sticks were made from cooked and mashed orange fleshed sweet potato using extrusion technology (Utomo *et al*. 2005) [56].

Non-alcoholic beverage has been also prepared from orange fleshed variety of sweet potato by mixing the cooked and mashed pulp of sweet potato with pulp of ripe mango or fruit juices from orange, lemon, pineapple etc. in India (Padmaja and Premkumar 2002) [34].

Conclusion

However, a large number of consumers are not aware about nutritional importance of this crop. It is possible only when low cost diverse technologies for value added products from orange fleshed sweet potato will be developed. Thus, there is a great possibility of this subsistence crop for being adopted as regular diet of the consumer food chain to supplement as an alternative nutritious food source for the resource poor farmers in the era of extensive population growth and nutrition crisis. In addition to the promotion of orange-fleshed sweet potato in household diets, the nutrition education regarding the function and importance of vitamin A in the diet could improve the vitamin A status to combating night blindness, the major public health concern in unprivileged areas.

References

1. Akhtar S, Ahmed A, Randhawa MA, Atukorala S, Arlappa N, Ismail T. Prevalence of vitamin A deficiency in Soth Asia: Cause, outcomes, and possible remedies. Journal of Health Population and Nutrition. 2013; 31:413-423.
2. Anita BS, Akpan EJ, Okon PA, Umoren IU. Nutritive and anti-nutritive evaluation of sweet potatoes (Ipomoea batatas) leaves. Pakistan Journal of Nutrition. 2006; 2:166-8.
3. Bahado- singh PB, Wheatley *et al*. Food processing methods influence the glycaemic indices of some commonly eaten West Indian carbohydrate-rich foods. Br J Nutrition. 2006; 96:476-481.
4. Bechoff A, Poulaert M, Tomlins KI, Westby A, Menya S, Young S *et al.* Retention and bioaccessibility of b-carotene in blended foods containing orange-fleshed sweet potato flour. Journal of Agricultural and Food Chemistry. 2011; 59:10373-10380.
5. Bengtsson A, Brackmann C, Enejder A *et al*. Effects of Thermal Processing on the in Vitro Bioaccessibility and Microstructure of Beta- Carotene in Orange-Fleshed Sweet Potato. J Agric Food Chem. 2010. [Epub ahead of print].
6. Black RE, Allen LH, Bhutta ZA *et al*. Maternal and child undernutrition: global and regional exposures and health consequences. Lancet. 2008; 371:243-260
7. Bouwkamp JC. Sweet Potato Products: A Natural Resource for the Tropics, CRC Press, City, 1985, 271.
8. Bovell-Benjamin AC. Sweet potato: a review of its past, present, and future role in human nutrition. Advanced Food Nutrition Research. 2007; 52:1-59.
9. Burri B. Evaluating sweet potato as an intervention food to prevent vitamin A deficiency. Comprehensive Review Food Science Food Safety. 2011; 10:118-130.
10. Chang WH, Huang YF, Yeh TS *et al*. Effect of purple sweet potato leaves consumption on exercise-induced oxidative stress, and IL-6 and HSP72 levels. J Appl Physiol. 2010, 23. [Epub ahead of print].
11. Chen Z. Physicochemical properties of sweet potato starches and their application in noodle products. PhD thesis, Wageningen University, the Netherlands, 2003, 145.
12. Choi JH, Choi CY, Lee KJ *et al.* Hepatoprotective effects of an anthocyanin fraction from purple-fleshed sweet potato against acetaminophen-induced liver damage in mice. J Med Food. 2009; 12:320-6.
13. Filla ML, Thakkar SK, Kim JY. In vitro bioaccessibility of beta-carotene in orange fleshed sweet potato (Ipomoea batatas, Lam.). J Agric Food Chem. 2009; 25(57):10922-7.
14. Grace MH, Truong AN, Truong VD, Raskin I, Lila MA Yencho. Novel value added uses for sweet potato juice and flour in polephenols and protein enriched functional food ingredients, Food Science and Nutrition. 2015; 3:415-424.
15. Hagenimana V, Low J, Anyango M, Kurz K, Gichuki ST, Kabira J. Enhancing vitamin A intake in young children in Western Kenya: Orange-fleshed sweet potatoes and women farmers can serve as key entry points. Food and Nutrition Bulletin. 2001; 1(22):370-87.
16. Han KH, Matsumoto A, Shimada K *et al*. Effects of anthocyanin-rich purple potato flakes on antioxidant status in F344 rats fed a cholesterol-rich diet. Br J Nutrition. 2007; 98:914-921.
17. Hwang YP, Choi JH, Yun HJ *et al*. Anthocyanins from purple sweet potato attenuate dimethylnitrosamine-induced liver injury in rats by inducing Nrf2-mediated antioxidant enzymes and reducing COX-2 and iNOS expression. Food Chem Toxicol. 2010; 8:117-126.
18. Islam SN, Nusrat T, Begum P, Ahsan M. Carotenoids and b-carotene in orange fleshed sweet potato: A possible solution to Vitamin A deficiency, Food Chemistry. 2016; 199:628-631.
19. Kidane G, Abegaz K, Mulugeta A, Singh P. Nutritional analysis of vitamin A enriched bread from orange fleshed sweet potato and locally available wheat flour at samre woreda, Nothern Ethiopia, Current research in nutrition and food science. 2013; 1:49-53
20. Laurie SM, Van Heerden SM. Consumer acceptability of four products made from beta-carotene-rich sweet potato" African Journal of food science. 2012; 6:96-103.
21. Lee SY. Extruded products from sweet potato-from breakfast food to snacks. In: 2nd International Symposium on Sweet Potato and Cassava, Kuala Lumpur, Malaysia, 14-17 June, 2005, 219-220
22. Lemmens L, Colle I, Buggenhout SV, Palmero P, Loey AV, Hendrickx M. Carotenoid bioaccessibility in fruit- and vegetable-based food products as affected by product (micro) structural characteristics and the presence of lipids: A review. Trends in Food Science & Technology. 2014; 38:125-135.
23. Low JW, Arimond M, Osman N, Cunguara B, Zano F, Tschirley D. A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique. J Nutr. 2007; 137:1320-7.
24. Low J, Van Jaarsveld P. The potential contribution of bread buns fortified with b-carotene-rich sweet potato in Central Mozambique. Food Nutr Bull. 2008; 29:98-107.
25. Low JW, Arimond M, Osman N, Cunguara B, Zano F, Tschirley D. A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique1–3. The Journal of Nutrition. 2007;

137:1320–1327.
26. Low J, Kapinga R, Cole D, Loechl C, Lynam J, Andrade M. Challenge theme paper 3: Nutritional impact with orange fleshed sweet potato (OFSP). Unleashing the potential of sweet potato in Sub-Saharan Africa. CIP – Social Sciences Working Paper, 2009, 1.
27. Ludvik B, Hanefeld M, Pacini G. Improved metabolic control by Ipomoea batatas (Caiapo) is associated with increased adiponectin and decreased fibrinogen levels in type 2 diabetic subjects. Diabetes Obes Metab. 2008; 10:586-92.
28. Mei X, Mu TH, Han JJ. Composition and physicochemical properties of dietary fiber extracted from residues of 10 varieties of sweet potato by a sieving method. J Agric Food Chem. 2010; 23(58):7305-10.
29. Mills JP, Tumuhimbise GA, Jamil KM, Thakkar SK, Farlla ML, Tanumihardjo SA. Sweet potato b-carotene bioefficacy is enhanced by dietary fat and not reduced by soluble fiber intake in Mongolian gerbils1, 2. Journal of Nutrition. 2009; 139:44-50.
30. Mitra S. Nutritional status of orange-fleshed sweet potatoes in alleviating vitamin A malnutrition through food based approach. Journal of Nutrition and Food Science 2012; 2:160. http://dx.doi.org/10.4172/2155-9600.1000160.
31. National Micronutrients Status Survey 2011–12. icddr, b, UNICEF, Bangladesh, GAIN, Institute of Public Health and Nutrition, January, 2013.
32. Noda N, Horiuchi Y. The resin glycosides from the sweet potato (Ipomoea batatas L. LAM.). Chem Pharm Bull (Tokyo). 2008; 56:1607-10.
33. Ozaki S, Oki N, Suzuki S *et al.* Structural Characterization and Hypoglycemic Effects of Arabinogalactan-Protein from the Tuberous Cortex of the White-Skinned Sweet Potato (Ipomoea batatas L.). J Agric Food Chem. 2010, Oct 29. [Epub ahead of print].
34. Padmaja G, Premkumar T. Tuber Crops Recipes, Technical Bulletin Series 36, CTCRI, Kerala, India, 2002, 26.
35. Padmaja G, Sheriff JT, Sanjeev MS. Food uses and nutritional benefits of sweet potato, fruits, vegetables and cereals science and biotechnology. 2012; 6:115-123
36. Panda S, Ray RC. Lactic acid fermentation of beta-carotene rich sweet potato (Ipomoea batatas L.) into lacto-juice. Plant Foods for Human Nutr. 2007; 62:65-7
37. Philpott M, Ferguson LR, Gould KS *et al*. Anthocyanidin-containing compounds occur in the periderm cell walls of the storage roots of sweet potato (Ipomoea batatas). J Plant Physiol. Jul. 2009; 166:1112-7.
38. Ray RC, Naskar SK, Sivakumar PS. Sweet Potato Curd, CTCRI Technical Bull. 2005, Series No. 39, 24.
39. Reungmaneepaitoon S, Poolperm N, Jariyavattanavijit C, Teangpook C. Production of sweet potato frozen French-fry- type products from sweet potato grown in Thailand. In: 2nd International Symposium on Sweet Potato and Cassava, Kuala Lumpur, Malaysia, 14-17 June, 2005, 185-186
40. Ruel MT, Alderman H. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition?. Lancet, 2013, (published online June 6.) http://dx.doi.org/10.1016/S0140-6736(13)60843-0
41. Salma O, Zaidah I. Sweetpotato for the production of nutritious food products. In: 2nd International Symposium on Sweet Potato and Cassava, Kuala Lumpur, Malaysia, 14-17 June, 2005, 181-182
42. Samsiah MS, Latifah MS, Ong CY. Sweet potato candy. In: 2nd Inter- national Symposium on Sweet Potato and Cassava, Kuala Lumpur, Malaysia, 14- 17 June, 2005, 223-224
43. Seralathan MA, Thirumaran AS. Utilization of sweet potato (Ipomoea batatas) flour in South Indian dishes. In: Howeler RH (Ed) Tropical Root and Tuber Crops: Changing Role in a Modern World, Proceedings Eighth Symposium of the International Society for Tropical Root Crops. October 30- November 5, Bangkok, Thailand, 1990, 600.
44. Sindi K, Kirimi L, Low J. Can biofortified orange fleshed sweet potato make commercially viable products and help in combatting vitamin A deficiency, 4th ICAAAE, 22-25th September, 2013.
45. Singh S, Riar CS, Saxena DC. Effect of incorporating sweet potato flour to wheat flour on the quality characteristics of cookies. African journal of food science. 2008; 2:065-072.
46. Sommer A. Vitamin A deficiency disordered: origins of the problem and approaches to its control. AgBio World, 2011. http://www.agbioworld.org/biotech-info/topics/goldenrice/vit_a.html.
47. Suri S, Kumar D. Short article: Determination of subclinical vitamin A deficiency among children 1–5 years in a rural community of Jammu. Indian Journal of Community Health. 2015; 27:263-269.
48. Sweet potato: http://www.whfoods.comgenpage.phptname=nutrientprofile&dbid= 128. (2014), September 8, 2014.
49. Tan JD, Forio EE, Estoy LS. Production and market potential of sweet potato flakes. In: 2nd International Symposium on Sweet Potato and Cassava, Malaysia, 14-17 June, 2005, 215-216.
50. Teferra TF, Nigusse G, Kurabachew H. Nutritional, Microbial and Sensory Properties of Flat- bread Prepared from Blends of Maize (Zea mays L.) and Orange-fleshed Sweet Potato (Ipomoea batatas L.) Flours. International Journal of Food Science and Nutrition Engineering 2015; 5(1):33-39.
51. Thakkar SK, Kim JY, Failla ML. Bioaccessibility of b-carotene in orange fleshed sweet potato. FASEB Journal, 2009, 896 (Meeting Abstract Supplement).
52. Trancoso- Reyas N, Ochoa-martinez LA, Bello – Perez LA, Morales- Castro J, Estevez – Santiago R, Olmedilla - Alonso B. Effect of pre-treatment on physiochemical and structural properties and bioaccessibility of β- carotene in sweet potato flour, food chemistry. 2016; 200:199-205.
53. Truong VD. New developments in processing sweet potato for food. In: International Sweet Potato Symposium, 20-26 May, Visca, Philippines, 1987.
54. Tumuhimbise GA, Namutebi A, Muyonga JH. Microstructre and in vitro beta carotene bioaccessibilty of heat processed organe fleshed sweet potato. Plant Food Human Nutrition. 2009; 64:312-318.
55. USAID. Orange-Fleshed Sweet Potatoes: Improving Lives in Uganda. Nutritious crop addresses critical vitamin A deficiency. USAID, 2015: https:// www.usaid.gov/results-data/success-stories/orange-fleshed-sweet-potatoes- improving-lives-uganda.
56. Utomo JS, Che Man YB, Rahman RA, Saad MS. Physical and chemical characteristics of restructured sweet potato sticks made from three sweet potato cultivars. In: 2nd International Symposium on Sweet Potato and Cassava,

Kuala Lumpur, Malaysia, 14-17 June, 2005, 221-222
57. Van Jaarsveld PJ, Marais De Wet, Harmse E, Nestel P, Rodriguez-Amaya DB. Original article: Retention of b-carotene in boiled, mashed orangefleshed sweet potato. Journal of Food Composition and Analysis. 2006; 19:321-329.
58. Vimla B, Nambisan B, Hariprakash B. Retention of carotenoids in orange fleshed sweet potato during processing, Journal of food science and technology. 2011; 48(4):520-524
59. Wang YJ, Zheng YL, Lu J *et al*. Purple sweet potato color suppresses lipopolysaccharide-induced acute inflammatory response in mouse brain. Neurochem Int. 2010; 56:424-30.
60. WHO. Guideline: Vitamin A supplementation in infants and children 6–59 months of age. World Health Organization, 2011
61. WHO. WHO technical consultation on vitamin A in newborn health: mechanistic studies. Geneva: World Health Organization, 2012.
62. WHO, Global prevalence of Vitamin A deficiency in populations at risk 1995-2005: WHO database on vitamin deficiency. Geneva: World Health Organization, 2009.
63. WHO, Xeropthalmia and night blindness for the assessment of clinical vitamin A deficiency in individuals and populations. World Health Organization, 2014**.**
64. Wiersema SG, Hesen J, Song BF. Report on a sweet potato post-harvest advisory visit to the People's Republic of China, 12-27 January, International Potato Centre, Lima, Peru, 1989.
65. Wilson CD, Pace RD, Bromfield E, Jones G, Lu JY. Sweet potato in a vegetarian menu plan for NASA's Advanced Life Support Program. Life Support Biosph Sci 1998; 5:347-51.
66. Woolfe JA. Sweet Potato: An Untapped Food Resource, Cambridge University Press, 1992, 643.
67. Wu KL, Sung WC, Yang CY. Characteristics of dough and bread as affected by the incorporation of sweet potato paste in the formulation. Journal of marine science and technology, 2009; 17:13-22.
68. Xie J, Han YT, Wang CB *et al*. Purple sweet potato pigments protect murine thymocytes from (60)Co gamma-ray-induced mitochondria-mediated apoptosis. Int J Radiat Biol. Aug 10. [Epub ahead of print]. 2010
69. Yin YQ, Huang XF, Kong LY *et al*. Three new pentasaccharide resin glycosides from the roots of sweet potato (Ipomoea batatas). Chem Pharm Bull (Tokyo), 2008; 56:1670-4.
70. Zhang ZF, Fan SH, Zheng YL *et al*. Purple sweet potato color attenuates oxidative stress and inflammatory response induced by d-galactose in mouse liver. Food Chem Toxicol. 2009; 47:496-501.