

EFFECT OF DRYING METHODS ON THE CHEMICAL AND FUNCTIONAL PROPERTIES OF POTATO (*Solanum tuberosum*) AND SWEET POTATO (*Ipomoea batatas*) VARIETIES

Kolawole^{1*}, F. L., Balogun¹, M. A., Usman¹, F. D. and Akeem², S. A.

ABSTRACT

¹Department of Home Economics and Food Science, University of Ilorin, Ilorin, Nigeria. ²Department of Food Technology, University of Ibadan, Ibadan, Nigeria. *E-mail: flolakolex@yahoo.com / kolawole.fl@unilorin.edu.ng; +2348033764414

In order to minimize postharvest loss of Irish potato and sweetpotato due to their high perishability and to minimize quality deterioration of their dried products, Irish potato and two sweet potato varieties (orange-fleshed and white-fleshed) were dried using two drying methods (sun and solar drying) and their chemical and functional properties were evaluated. Drying methods had a significant effect ($P < 0.05$) on all the chemical properties of the flours except protein, carbohydrate and energy values of Irish potato and orange fleshed-sweet potato flours. Significant difference ($P < 0.05$) existed between the functional properties of sun and solar dried flours except for gelatinization temperature of Irish potato and bulk densities of orange-fleshed sweet potato and Irish potato. The moisture (3.18–8.09%), fat (1.21–2.21%) and protein (1.66–1.77%) contents of the tubers were low while ash (2.74–3.43%), fibre (1.19–4.86%), carbohydrate (83.20–88.91%) and energy value (353.79–374.27 Kcal per 100g) were high. The values for gelatinization temperature (72–78°C) for the flours were low, values for bulk density (0.558–0.836 g ml⁻¹), swelling index (1.03–1.60%), water absorption capacity (2.60–3.80 gg⁻¹) and oil absorption capacity (0.917–2.02 g g⁻¹) were high. The flours were observed to have good functional properties and high calorific value. The chemical value and functional properties of orange-fleshed sweet potato flour were the highest and sun drying was observed to be the best drying method.

Keywords: Sweet potato varieties, potato, drying methods, flour, quality attributes.

INTRODUCTION

Sweet potatoes are of different varieties which are sometimes distinguished by their flesh and root skin colours (Woolfe, 1992). Besides carbohydrates, sweet potatoes are also rich in dietary fibre, ascorbic acid, lysine, minerals and have high water content. They also provide as much as 359 KJ of energy and have low total lipid content (USDA, 2009; Bradbury *et al.*, 1985). They contain certain beneficial and health promoting plant chemicals such as carotenoids, flavonoids, anthocyanins and phenolics (Ezekiel *et al.*, 2013). Sweet potato has played important roles in improving household and national food security, health and general livelihoods of poor families in the developing countries and these may be attributed to its high adaptability to a wide range of farming conditions, shorter growing period, high yield per hectare, low input requirement and low risk of pest infestation (CIP, 2013; Oke and Workney, 2013). Orange fleshed sweet potato (OFSP) is a bio-fortified variety with great potential for use in food-based intervention programmes to address vitamin A deficiency and under nutrition as it can supply significant amounts of pro- vitamin A and energy simultaneously than most vegetables (Low *et al.*, 2009; Jaarsveld *et al.*, 2006). Furthermore, its major carotenoid is all trans- β -carotene, which exhibits highest pro-vitamin A activity among the carotenoids and its β -carotene content is substantially better absorbed than those of most leaves and vegetables (Jalal *et al.*, 1998; Haskell *et al.*, 2004).

Potatoes are also referred to as Irish potatoes or white potato mainly to distinguish them from sweet potatoes. It is ranked after maize, wheat and rice as the fourth largest crop (FAO, 2009). Friedman (1997) had reported the content of glycoalkaloids, the toxic compounds in potatoes, in the tuber flesh to be the least thus making it safe for consumption. Potato is best known for its carbohydrate content which is often in the form of starch. It is also rich in vitamins, minerals, fibre as well as phytochemicals such as carotenoids and phenols (USDA, 2016). Like sweet potatoes, potatoes are perishable crops which need to be converted to stable products such as flour through reduction of moisture content in order to minimize postharvest losses and enhance their utilization. Drying is usually aimed at extending the shelf life of foods by slowing down the rate of enzymatic and microbial activities through reduction in water activity. Dried food products can be easily milled into flour to reduce bulkiness and facilitate longer storage. However, there is often a decrease in the quality attributes of dried products because most conventional techniques use high temperature during the drying process (Musa *et al.*, 2005). The extent to which the properties are influenced depends on the time and temperatures of drying (Falade and Solademi, 2010). Thus, this work was designed to examine the effect of solar dryer and sun drying methods on the chemical and functional properties of potato and two sweet potato varieties.

MATERIALS AND METHODS

This study was conducted between the months of January and June, 2015 in department of Home Economics and Food Science of University of Ilorin, Ilorin, Nigeria.

Collection of samples

Fresh samples of Irish potato and white fleshed sweet potato were procured from a local market (ipata market) in Ilorin metropolis while the Orange-fleshed sweet potato (*mothers delight*) was obtained from a farm in Agbamu area of Kwara State, Nigeria. The samples were brought to the food processing laboratory of the Department of Home Economics and Food Science, University of Ilorin, Nigeria.

Preparation of samples

The samples were washed with running water from tap to remove dirt, peeled using a local potato peeler fabricated by Nigeria Centre for Agricultural Mechanized (NCAM), Ilorin, Kwara state and sliced using a sharp stainless steel kitchen knife (3.5 mm thickness as measured by a micrometer screw gauge). The sliced tubers were then divided into two portions (25 kg each) for drying. One portion was dried in the sun for 3 days (approximately 60 hours) with temperature range of 27°C to 33°C depending on the time of the day until the tubers were dried to constant weights and the other portion was dried using solar dryer for a period of 5 days with temperature range of 35°C to 38°C depending on the time of the day until the tuber was dried to a constant weight. After drying, the tubers were pulverised separately using laboratory hammer mill (Siemens-Schurkt, Germany) and sieved through a 200 µm mesh screen to obtain flour with uniform particle sizes. The flour samples were separately packaged in cellophane bags (regenerated cellulose type and 1kg each) and subjected to analysis.

The samples were subjected to proximate analysis using the standard method of AOAC (2000) for moisture, fat, fibre, ash and protein contents. Carbohydrate content was determined by difference (AOAC, 2000). The energy value of the samples were estimated from the Atwater Formula in which the total carbohydrate content was multiplied by 4, percentage crude fat by 9 and percentage crude protein by 4 (Eleazu and Ironua, 2013).

Gelatinization Temperature (GT) was determined by Onwuka (2005) method while the oil absorption capacity of the flour samples were determined using method described by Oyeyinka *et al.* (2014) with slight modification. One gram of each flour sample was mixed with 10 ml of refined oil for 60 seconds. The mixture was allowed to stand at ambient temperature for 30 min, centrifuged at 4000 x g for 30 min. The oil that separated was carefully decanted. The tubes were allowed to drain at an angle of 45° for 10 minutes and then weighed. Oil absorption capacity was expressed as gram of oil bound per gram flour.

Water Absorption Capacity was determined using Onwuka (2005) method while the bulk density was determined using Okezie and Bello (1988) method. Swelling Index was determined using Iwuoha (2004) method. The swelling index of each flour sample was expressed as the ratio of the final volume to the initial volume of the sample in the cylinder (ml per ml).

Statistical analysis

A simple completely randomized design was used and experiments were conducted in triplicates. All data were subjected to one way analysis of variance (ANOVA) using the Statistical Package for Social Sciences (SPSS) version 20.0. Statistically significant difference ($p < 0.05$) between the means were recorded using the Duncan multiple range test.

RESULTS AND DISCUSSION**Proximate composition**

The proximate composition of the sun dried and solar dried Irish Potato (IP), White Fleshed Sweet Potato (WFSP) and Orange Fleshed Sweet Potato (OFSP) flour are presented in Table 1. The moisture content of the flour ranged from 3.18–5.82% for the sun-dried flour. The OFSP flour had the lowest moisture content while the IP flour had the highest moisture content. The moisture content of the solar-dried flour ranged from 3.85–8.09% with OFSP flour having the least moisture content and WFSP flour having the highest. There was significant difference ($P < 0.05$) in the moisture content of sun-dried and solar-dried flour with sun-dried flour having significantly lower moisture content. The moisture content obtained in this study was similar to the range of value (4–8%) reported by Haile *et al.* (2015) for treated and dried OFSP flours. Fetuga *et al.* (2014) observed comparable values of 4.83–10.41% in three sweet potato varieties while slightly higher values of 7.90–9.74% for five new sweet potato varieties and 8.06–12.86% for ten varieties of sweet potato were recorded by Amajor *et al.* (2011) and Olatunde *et al.* (2016), respectively. This may be due to the variation in slice sizes, varietal difference, pretreatment methods, drying methods, and drying time (Falade and Solademi, 2010; Fetuga *et al.*, 2014). The low moisture content (<10%) of the flour samples is a desirable attribute for long term storage (Polycarp *et al.*, 2012) and efficient industrial applications.

The ash content of the sun-dried flour ranged from 2.74–3.43%, with the WFSP flour having the lowest ash content while the IP flour had the highest ash content. The ash content of the solar dried flours ranged from 3.01–3.34% for the solar dried sample with the WFSP having the highest value and OFSP having the least value. Significant difference ($P < 0.05$) among the ash content of the flours was observed due to drying methods. Similar range of values, 2.60–4.0%, 1.68–3.21% and 2.0–3.30% had been reported by Jangchud *et al.* (2003), Ji *et al.* (2015) and Nicanuru *et al.* (2015), respectively. Ash content is an estimation of the inorganic material remaining after oxidation of organic matter at high temperature and it is an index of the total minerals in foods (Wilson, 1987).

The fat content of sun-dried flour values ranged from 1.21–1.45%. The highest fat content was observed in the orange-fleshed sweet potato (OFSP) flour while the Irish potato (IP) flour had the lowest fat content. The solar-dried flour samples had values of 1.63–2.21% recorded for WFSP and IP, respectively. The fat content of sun and solar-dried flour varied significantly ($P < 0.05$). The values obtained were within the range of values, 0.56–1.93g per 100g and 0.90–2.50%, reported by Nicanuru *et al.* (2015) for sweet potato varieties and Haile *et al.* (2015) for treated OFSP, respectively. Kaur and Aggarwal (2015) had reported a lower range of value (0.98–1.02), for potato flours. Fat can influence the shelf life of food products such as baked foods (Ihekoronye and Ngoddy, 1985). Fat also contribute substantially to the energy value of foods and low fat may be beneficial to those that suffer from atherosclerosis and related health issues (Eleazu and Ironua, 2013).

The fibre content of sun-dried flour ranged from 1.19–3.55% for IP and OFSP flours, respectively while the range of value, 2.34–4.85%, was recorded for the solar-dried flour. There was significant difference ($P < 0.05$) between the sun and solar-dried flour samples. The significantly higher fibre values of solar-dried flour compared to the sun-dried flour observed in this study agreed with the report of Nicanuru *et al.* (2015). Fibres are non-starch polysaccharides which are made up of pectin, cellulose, hemicellulose together with little lignin and are resistant to digestion in the intestinal tracts (Robinson and Lawler, 1980; IFIS, 2005). Higher fibre content as recorded in OFSP flour is important in diet as it increases the faecal output, reduces the faecal pH, incidence of colon cancer, diabetes, heart diseases, obesity and certain degenerative diseases (Cummings *et al.*, 1996; Ingabire and Vasanthakalam, 2011).

Protein content ranged from 1.57–1.62% and 1.55–1.65% for sun-dried and solar-dried flour samples, respectively. Drying methods had no significant difference on the protein content of IP but the value obtained was lower than 5.22–5.28% reported by Kaur and Aggarwal (2015) for water and steam cooked potato flour. However, the protein content recorded was comparable to 1.6% reported for sweet potato (FAO, 2001). Protein is essential for hormone production and proper body maintenance including growth, repair and maintenance of the body. Sweet potato protein had been observed to be of good biological value (ILSI, 2008; Van Hal, 2000).

The carbohydrate content of the samples ranged from 85.87–88.91% for the sun-dried flour and 83.20–85.80% for the solar-dried flour. While drying methods had no significant effect on the carbohydrate content of OFSP flour samples, the carbohydrate content of sun-dried WFSP and IP flour were observed to be significantly higher than their corresponding solar dried flour samples. Values obtained in this study were within 74.55–90.92%, value range reported by Olatunde *et al.* (2016) for sweet potatoes. The high carbohydrate content of the flour indicated that they are good sources of carbohydrate, a major source of energy.

Energy values

The energy values which are functions of fat, carbohydrate and protein, obtained for the flours ranged from 362.89–374.27 Kcal per 100g, for the sun-dried flour and 353–365.64 Kcal per 100g for the solar-dried flour (Table 2). Among the samples, only the WFSP flour was significantly affected by the drying methods employed. Haile *et al.* (2015) reported comparable range values of 352.90–365.60 Kcal per 100g for different pre-treated and dried OFSP flour. This showed that all the flour samples can be used in the production of high energy food products due to their high calorific values. The fact that energy value of about 2500–3000 Kcal had been suggested as the daily calorie requirement for adults (Onyeike and Oguike, 2003), implied that about 755g of potato and sweet potato (2665.15–2825.4 Kcal) is required to meet this daily demand.

Functional properties

The functional properties of food materials which depend on the characteristics of their macromolecules such as protein, fibre, carbohydrate, fat, starch and sugars, influence the general quality of food as well as their acceptability and industrial applications (Prinyawiwatukul *et al.*, 1997; Adeleke and Odedeji, 2010; Fetuga *et al.*, 2014). Table 3 shows the investigated functional properties of IP, WFSP and OFSP flour samples.

Significant differences existed between the gelatinization temperatures of the sun and solar-dried white-fleshed sweet potato flour and OFSP flour. The gelatinization temperature ranged between 72 and 78°C for the sun-dried flour and 74 and 76°C for the solar-dried flour. These results were observed to be lower than 87.50°C and 89.0°C reported by Amajor *et al.* (2014) for fermented sun-dried OFSP flour and 90.75°C reported by Eleazu and Ironua (2013) for cream-fleshed sweet potato. Gelatinization occurs over a temperature range and it involves the disruption of molecular order within starch granules as a result of heating in water. It is characterized by leaching of amylose, loss of birefringence, irreversible swelling and reduced crystallinity (IFIS, 2005). The low gelatinization temperature may be desirable and makes the flour useful in applications that require the formation of gels at low temperature (Amajor *et al.*, 2014), especially to minimize loss of heat labile nutrients in such foods. The oil absorption capacity ranged from 1.28–2.20 g g⁻¹ for the sun-dried flour while 0.917–2.02 g g⁻¹ was recorded for the solar-dried flour. Eleazu and Ironua (2013) reported a comparable value of 1.75 g g⁻¹ while Haile *et al.* (2015) reported a relatively lower value range of 0.55–1.03 ml g⁻¹. Drying methods significantly affect the water absorption capacity of the flour with sun-dried OFSP flour having a significantly lower value and sun-dried white-fleshed sweet potato flour and Irish potato flour recording significantly higher values than their corresponding solar-dried flour samples. High oil absorption capacity is desirable since oil acts as flavour retainer, increases the mouth feel of foods, improves palatability and extends the shelf life of food products particularly in bakery, soup mixes or meat products where fat absorptions are desired (Seena and Sridhar, 2005).

Table 1: Proximate composition of sun-dried and solar-dried potato and sweet potatoes flour

Sample	Moisture (%)	Ash (%)	Fat (%)	Fibre (%)	Protein (%)	Carbohydrate (%)
WFSP _{sun}	4.02±0.02d	2.74±0.01e	1.35±0.01d	1.37±0.02e	1.62±0.01b	88.91±0.06a
WFSP _{solar}	8.09±0.01a	3.34±0.01b	1.63±0.01c	2.34±0.01d	1.58±0.01c	83.20±0.01e
OFSP _{sun}	3.18±0.02f	3.16±0.01c	1.45±0.02d	3.65±0.01b	1.59±0.01c	85.87±0.97cd
OFSP _{solar}	3.85±0.02e	3.01±0.01d	1.76±0.02b	4.86±0.01a	1.65±0.01a	85.80±1.15bcd
IP _{sun}	5.82±0.02c	3.43±0.01a	1.21±0.01e	1.19±0.01f	1.57±0.01cd	86.80±0.05bc
IP _{solar}	6.12±0.20b	3.02±0.01d	2.21±0.01a	2.70±0.01c	1.55±0.01d	84.56±0.09de

Each value is a mean of three determinations ± standard deviation; Means within column having different superscripts differ significantly ($p < 0.05$) from each other. WFSP= white-fleshed sweet potato, OFSP= orange-fleshed sweet potato, IP= Irish potato

Table 2: Estimated energy values of sun-dried and solar-dried potato and sweet potatoes flour

Samples	Energy value (Kcal per 100g)
WFSP _{sun-dried}	374.27±0.37a
WFSP _{solar-dried}	353.79±4.10c
OFSP _{sun-dried}	362.89±0.33b
OFSP _{solar-dried}	365.64±0.17b
IP _{sun-dried}	364.37±4.82b
IP _{solar-dried}	364.33±0.49b

Each value is a mean of three determinations ± standard deviation; Means within column having different superscripts differ significantly ($p < 0.05$) from each other. WFSP= white-fleshed sweet potato, OFSP= orange-fleshed sweet potato, IP= Irish potato

Table 3: Functional properties of sun-dried and solar-dried potato and sweet potatoes flour

Samples	Gelatinization Temperature (°C)	Oil Absorption Capacity (g g ⁻¹)	Water Absorption Capacity (gg ⁻¹)	Bulk Density (gml ⁻¹)	Swelling Index (ml ml ⁻¹)
WFSP _{sun-dried}	72 ^d	1.47 ^c	2.60 ^f	0.669 ^c	1.33 ^c
WFSP _{solar-dried}	74 ^c	2.02 ^b	3.00 ^d	0.836 ^a	1.14 ^d
OFSP _{sun-dried}	78 ^a	2.20 ^a	3.80 ^a	0.558 ^d	1.15 ^d
OFSP _{solar-dried}	76 ^b	2.02 ^b	3.60 ^b	0.558 ^d	1.03 ^e
IP _{sun-dried}	74 ^c	1.28 ^d	2.80 ^e	0.772 ^b	1.60 ^a
IP _{solar-dried}	74 ^c	0.917 ^e	3.20 ^c	0.775 ^b	1.57 ^b

Each value is a mean of three determinations ± standard deviation; Means within column having different superscripts differ significantly ($p < 0.05$) from each other. WFSP= white-fleshed sweet potato, OFSP= orange-fleshed sweet potato, IP= Irish potato

Water absorption capacity was observed to range from 2.60 g g⁻¹ in white-fleshed sweet potato flour to 3.80 g g⁻¹ in OFSP flour for sun-dried samples and 3.00–3.60 g g⁻¹ for solar-dried flour samples. Significant difference was observed between sun dried flours and their corresponding solar dried flours. These values were within the range of values, 167.50–702.50 g per 100g and 2.81–3.90 ml g⁻¹ reported by Fetuga *et al.* (2014) and Haile *et al.* (2015) but higher than 125 g per 100g and 140–280% reported by Eleazu and Ironua (2013) and Olatunde *et al.* (2016), respectively. The variation in the values may be due to varietal difference, pre-treatment and processing techniques employed. Water absorption capacity can also be influenced by the hydrophilic food constituents such as protein and carbohydrate (Guy, 2012).

The bulk density ranged from 0.558–0.772 g ml⁻¹ for sun-dried flour and 0.558–0.836 g ml⁻¹, for solar-dried flour. These values were comparable to the range of value, 0.71–0.74 g ml⁻¹ reported by Haile *et al.* (2015) but lower than the value of 0.92 g ml⁻¹ reported by Eleazu and Ironua (2013). Only the bulk density of the white-fleshed sweet potato was observed to be significantly affected by the drying methods. Bulk density of a food material is a function of the individual particle mass, size, property, density and geometry. Bulk density can influence the design, choice and effectiveness of packages (Oyeyinka *et al.*, 2014). High bulk density is a desirable property in flour, for example, sweet potato flour with bulk density of about 0.7453 g ml⁻¹ can be used as a thickener or base in foods such as yoghurt (USDA, 2009). The swelling index, which is associated with binding within the starch granules of the micelle network, ranged from 1.15–1.60 ml per ml for the sun-dried flour and 1.03–1.57 ml per ml for the solar-dried flour. These values were within the range of value of 0.52–3.71 reported by Fetuga *et al.* (2014) but lower than 1.75 and 1.66–5.00 reported by Amajor *et al.* (2014) and Olatunde *et al.* (2016), respectively. The low swelling index obtained in this study may be attributed to the high amylose content of the flour as high amylose reduces the swelling index (Adebawale *et al.*, 2005). The swelling index of the sun and solar-dried flour varied significantly ($p < 0.05$). Priyawiatkul *et al.* (1997) stated that the differences in swelling index can be attributed to starch content, pre-treatment, processing history and presence of other components such as lipids and proteins.

CONCLUSION

Drying methods had varying effect on the potato and the sweetpotato as evident in the chemical and functional properties of the flour samples. Sun drying gave the lowest moisture contents for all the samples. All the flour samples were high energy, low protein foods which may need to be supplemented with protein rich foods such as legumes to compensate for the low protein content. The low moisture content of the flour coupled with appropriate packaging and good storage condition could extend the shelf life of the flour samples thereby minimizing loss and ensuring their all year round availability. The variation in the functional properties will determine their application in foods generally. Further studies are however required on the bioavailability of nutrients and acceptability of various added products produced from these flour.

REFERENCES

- Adebowale, A. A., Sanni, L. O. and Awonorin, S. O. 2005. Effect of texture modifiers on the Physio-chemical and sensory properties of dried fufu. *Food Science Technology International*, 11(5):373-382.
- Adeleke, R. O. and Odedeji, J. O. 2010. Functional properties of wheat and sweet potato flour blends. *Pak. J. Nutri.*, 9:535-538.
- Amajor, J. U., Eleazu, C. O., Oti, E., Ikpeama, A. I. and Udoh, E. F. 2011. Effect of variety on the physico-chemical, carotenoid and microbial loads of flours of five new varieties of sweet potato. *Biotech.*, 10: 286-291.
- Amajor, J. U., Oti, E., Ekeledo, N., Omodamiro R., Amajor, E. E., Aniedu, C. 2014. Studies on the Characteristic Properties of Fermented, Sun-Dried Orange- Fleshed Sweet Potato Flour. *Nigerian Food Journal*, 32 (1): 45-53.
- AOAC. 2000. Official Methods of Analysis 14th edition. Association of official Analytical Chemists, Arlington, Virginia.
- Bradbury, J. H., Hammer, B., Nguyen, T. Anders, M. and Millar, J. S. 1985. Protein quantity and quality and trypsin inhibitor content of sweet potato cultivars from the highlands of Papua New Guinea. *J. Agric. Food Chem.*, 33: 281-285.
- Centro Internacional De La Papa (CIP). 2013. Sweet potato facts: production, utilization, consumption, feed use.
- Cummings, J. H., Beatty, E. R., Kingman, S. M., Bingham, S. A., and Englyst, H. N. (1996). Digestion and physiological properties of resistant starch in the human bowel. *Brit. J. Nutr.* 75:733.
- Eleazu, C. O. and Ironua, C. 2013. Physicochemical composition and antioxidant properties of a sweet potato variety (*Ipomoea batatas* L.) commercially sold in South Eastern Nigeria. *African Journal of Biotechnology*, 12(7): 720-72.
- Ezekiel, R., Narpinder, S., Shagun, S. and Amritpal, K. 2013. Beneficial phytochemicals in potato - A review. *Food Res. Int.*, 50: 487-496.
- Falade, K. O. and Solademi, J. O. 2010. Modelling of air drying of fresh and blanched sweet potato slices. *Int. J. Food Sci. Technol.*, 45: 278-288.
- FAO (United Nations Food and Agricultural Organisation). 2009. "International Year of the Potato 2008 – The potato". Retrieved 26 October 2011.
- FAO 2001. Improving nutrition through home gardening: Nutrition Programmes Service Food and Nutrition Division. Rome, Italy.
- Fetuga, G., Tomlins, K., Henshaw, F. and Idowu, M. 2014. Effect of variety and processing method on functional properties of traditional sweet potato flour ('elubo') and sensory acceptability of cooked paste ('amala'). *Food Sci. Nutr.*, 2: 682-691.
- Friedman, M. 1997. Chemistry, biochemistry, and dietary role of potato polyphenols. A review. *J. Agric. Food Chem.*, 45: 1523-1540.
- Guy, E. 2012. Nutrient composition and functional properties of bean flours of three soya bean varieties from Ghana. *Afr. J. Food Sci. Technol.*, 3(8): 176-181.
- Haile, F., Admassu, S. and Fisseha, A. 2015. Effects of Pre-treatments and Drying Methods on Chemical Composition, Microbial and Sensory Quality of Orange-Fleshed Sweet Potato Flour and Porridge. *American Journal of Food Science and Technology*, 3(3): 82-88.
- Haskell, M. J., Jamil, K. M., Hassan, F., Peerson, J. M., Hossain, M. I., Fuchs, G. J. and Brown, K. H. 2004. Daily Consumption of Indian Spinach (*Basella alba*) or Sweet Potatoes Has a Positive Effect on Total-Body Vitamin A Stores in Bangladeshi Men. *American Journal of Clinical Nutrition*, 80: 705-714.
- Ihekonye, A. I and Ngoddy, P. O. 1985. Integrated Food Science and technology for the tropics. Macmillan publishers, pp.313-346.
- Ingabire, M. R. and Vasanthakalam, H. 2011. Comparison of the Nutrient composition of four sweet potato varieties cultivated in Rwanda. *Am. J. of Food and Nutr.*, 1(1): 34-38.
- International Food Information Service (IFIS). 2005. *Dictionary of food science and technology*. Blackwell publishing, USA.

- International Life Sciences Institute, (ILSI). 2008. Nutritionally improved sweet potato, in Assessment of foods and feeds. *Compr. Rev. Food Sci. Food Saf.*, 7: 81–91.
- Iwuoha, C. I. 2004. Comparative evaluation of physicochemical qualities of flours from steam-processed yam tubers. *J. Food Chem*, 85: 541-551.
- Jaarsveld, J., Marias, D., Harmse, E., Nestel, P. and Rodriguez-Amaya. 2006. Retention of b-carotene in boiled, mashed orange-fleshed sweet potato. *Journal of Food Composition and Analysis*, 19(4): 321-329.
- Jalal, F., Nesheim, M. C., Agus, Z., Sanjur, D. and Habich, J. P., 1998. Serum retinol concentrations in children are affected by food sources of beta-carotene, fat intake, and anthelmintic drug treatment. *American Journal of Clinical Nutrition*, 68: 623-629.
- Jangchud, K., Phimolsiripol, Y. and Haruthaithanasan, V. 2003. Physicochemical properties of sweet potato flour and starch as affected by blanching and processing. *Starch/Starke*, 55: 258–264.
- Ji, H., Zhang, H., Li, H. and Li, Y. 2015. Analysis on the Nutrition Composition and Antioxidant Activity of Different Types of Sweet Potato Cultivars. *Food and Nutrition Sciences*, 6: 161-167.
- Kaur, S. and Aggarwal, P. 2015. Antioxidant and nutritional activities of potato flour as affected by different cooking methods. *Res. Environ. Life Sci.*, 8(4): 645-650.
- Low, J., Lynam, J., Lemaga, B., Crissman, C., Bakr, I. and Thiele, G. 2009. Sweetpotato in Sub-Saharan Africa. In G. Loebenstein and G. Thottappilly, eds. *The sweetpotato*. Springer Science +Business Media, Berlin, Germany.pp. 359–390.
- Musa, O., Derya, A. and Ahmet, U. 2005. Effects of drying methods on the mineral content of basil. *Journal of Food Engineering*, 69: 375-379.
- Nicanuru, C., Laswai, H. S. and Sila, D. N. 2015. Effect of sun- drying on nutrient content of orange fleshed sweet potato tubers in Tanzania. *Sky Journal of Food Science*, 4(7): 91-101.
- Oke, M. O. and Workneh, T. S. 2013. A review on sweet potato postharvest processing and preservation technology. *Afr. J. Agric Res.*, 8 (40): 4990-5003.
- Okezie, B. O. and Bello, A. B. 1998. Physio-chemical and functional properties of Winged bean flour and isolate compared with soy isolate. *Journal of Food Science*, 53: 450- 454
- Olatunde, G. O., Henshaw, F. O., Idowu, M. A. and Tomlins, K. 2016. Quality attributes of sweet potato flour as influenced by variety, pretreatment and drying method. *Food Science and Nutrition*, 4(4): 623–635.
- Onwuka, G. I. 2005. *Food Analysis and Instrumentation. Theory and Practice*. Naphtali Prints, Lagos, Nigeria. Pp. 133-137.
- Onyeike, E. N. And Oguike, J. U. 2003. Influence of heat processing methods on the nutrient composition and lipid characterization of groundnut (*Arachis hypogaea*) seed pastes. *Nig. Soc. Exp. Biol. Biokemistri*, 15(1): 34-43.
- Oyeyinka, S. A., Oyeyinka, A. T., Opaleke, D. O, Karim, O. R., Kolawole, F. L., Ogunlakin, G. O. and Olayiwola, O. H. 2014. Cake production from wheat (*Triticum aestivum*) and cowpea (*Vigna unguiculata*) flours using date fruit as a sweetener. *Annals. Food Science and Technology*, 15(1): 20-28.
- Polycarp, D., Afoakwa, E. O., Budu, A. S. and Otoo, E. 2012. Characterization of chemical composition and anti-nutritional factors in seven species within the Ghanaian yam (*Dioscorea*) germplasm. *Int. Food Res. J.*, 19: 985–992.
- Prinyawiwatkul, W., McWatters, R. H., Beuchat, L. R. and Phillips, R. D. 1997. Functional characteristics of cowpea (*Vigna unguiculata*) flour and starch as affected by soaking, boiling and fungal fermentation before boiling. *Food Chem.*, 58: 361–372.
- Robinson CH, Lawler M (1980). *Normal and Therapeutic Nutrition*. Macmillan Co Ltd., New York. Rodriguez-Amaya DB (2001). *A Guide to Carotenoid Analysis in Foods*. Washington D.C, ILSI Press
- Seena, S. and Sridhar, K. R. 2005. Physicochemical, functional and cooking properties of under explored legumes, Canavalia of the southwest coast of India. *Food Res. Int.*, 38 : 803–814.
- USDA (U.S. Department of Agriculture), Agricultural Research Service. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Nutrient Data Laboratory Home Page,
- United States Department of Agriculture, (USDA). 2016. Agricultural Research Service, Nutrient data laboratory, USDA National Nutrient Database for Standard Reference, Release 28.
- Van Hal, M. 2000. Quality of sweet potato flour during processing and storage. *Food Rev. Int.*, 16: 1–37.
- Wilson, G. F. 1987. Status of banana and plantain breeding strategies. In: Persley G J, De Langhe E, editors. *Proceeding of an International workshop held at Cairns, Australia*, 13-17th October.
- Woolfe, J. 1992. *Sweet Potato: An Untapped Food Resource*. Cambridge UK: Cambridge University Press and the International Potato Center (CIP). Pp: 643. [ISBN 9780521402958](#).