



EFFECT OF DRYING METHODS ON THE YIELD, PHYTOCHEMICAL COMPOSITION AND ANTIOXIDANT ACTIVITIES OF POTATO (*SOLANUM TUBEROSUM*) AND TWO SWEET POTATO (*IPOMOEA BATATAS*) VARIETIES

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ABSTRACT

In various parts of the world, drying technologies have been developed to convert tubers into flour which can be used as ingredients in numerous food products. Potato and sweet potato are known to contain certain bioactive constituents that are capable of scavenging free radicals and reducing the risk of degenerative diseases. The effects of two drying methods (sun and solar) on flour yield, antioxidant activity and phytochemical composition of Irish potato (IP) and two sweet potato varieties (orange and white-fleshed) were evaluated. The flour yield (15.20–19.0%) varied significantly ($p < 0.05$) among the samples. The DPPH (1, 1-diphenyl-2-picrylhydrazyl) free radical scavenging activities of the flour samples varied with drying methods and the extracts' concentrations. The total antioxidant activities expressed in terms of the % inhibition (53.58–90.62%) and EC_{50} values (0.584–45.214 mg/ml) were observed to be significantly affected ($p < 0.05$) by the drying methods. Drying processes generally increased the total phenolics (18.72–21.60 mg GAE/g) and total flavonoids (0.50–1.15 mg QE/g) contents of the tubers. The effect of sun-drying was observed to be less favorable on the white-fleshed sweet potato (WFSP) samples compared to solar-drying method. Although solar-dried orange-fleshed sweet potato (OFSP) flour had the highest total antioxidant activity, sun-drying method produced IP and OFSP flours with the highest total phenolics and total flavonoids contents respectively. Sun and solar dried OFSP had the highest beta-carotene content (BCC) and only the BCC of Irish potato significantly varied ($p < 0.05$) with drying methods. This study also revealed that the effects of drying methods on the yield, phytochemical and antioxidant activities of the samples were mostly tuber (potato and sweet potato) dependent.

1. Introduction

Recently, foods that possess certain beneficial health effects have attracted the interest of both the researchers and the general populace. Antioxidant activity of

plant materials has been attributed to varieties of phytochemicals such as alpha-tocopherol, ascorbic acid, beta-carotene phenolics, carotenoids and flavonoids (Cao *et al.*, 1996; Kaur and Kapoor, 2002; Kalt, 2005). Most of these phytochemicals have

been shown to possess antimicrobial, antimutagenic and free radical scavenging activities (Friedman, 1997). Chronic illnesses and pathological disorders such as cardiovascular diseases, cancer, cataracts, neurological dysfunctions, deficiencies in immune response, age-related problems and inflammation have been attributed to free radicals including superoxide, peroxides, oxide and hydroxide ion induced oxidative stress (Diaz *et al.*, 1997; Gomes *et al.*, 2003). Foods that are rich in natural antioxidants are capable of neutralizing a free radical-mediated oxidative reaction through synergistic effects of health promoting compounds and offer beneficial activities in protecting human body from various diseases (Havsteen, 2002).

Potato (*Solanum tuberosum* L.) also known as Irish potato is a starchy, tuberous crop from the perennial nightshade, Solanaceae. Potato is the fourth most important food crop consumed worldwide after maize, wheat and rice. Potato is a rich source of dietary starch, proteins, fibre, minerals, vitamins and important antioxidants such as phenolic acids, carotenoids and flavonoids (Kolasa, 1993; Andre *et al.*, 2007). Hesam *et al.* (2012) have shown that the methanolic extracts of potato could inhibit oxidation process due to the antiradical activity of phenolic compounds.

Sweet potato (*Ipomoea batatas* L.) of the Convolvulaceae family is an important staple crop that grows in many regions of the world. Sweet potato cultivars are known to be rich in dietary fibre, minerals, vitamins and antioxidants, including anthocyanins, phenolic acids, beta-carotene and tocopherol (Van Jaarsveld *et al.*, 2006; Yildirim *et al.*, 2011). Consumption of sweet potato can prevent the growth of human colon, leukemia, stomach cancer cells and ameliorate diabetes in humans (Kurata *et al.*, 2007; Ludvik *et al.*, 2008). Sweet potato can

be grouped into different cultivars depending on their flesh and root skin colours (Woolfe, 1992). Whole white and purple skinned sweet potato are of high nutraceutical value due to high phytochemical content, radical scavenging activities, phenolic composition, essential minerals and amylose-amylopectin ratio in their peels (Salawu *et al.*, 2015). Orange-fleshed sweet potato (OFSP), a bio-fortified sweet potato cultivar, has recently been of interest due to its potential as vitamin A and energy source (Hotz *et al.*, 2012). OFSP has high polyphenolics, carotenoids and antioxidant contents which are mainly responsible for its health promoting function after consumption (Koala *et al.*, 2013; Ruttarattanamongkol *et al.*, 2015).

Seasonality of many foods coupled with malnutrition, including health and social problems impede economic progress in Nigeria and many other developing countries. Drying is commercially and economically accepted to preserve many raw and intermediate food products by reducing its bulk weight (Zhang *et al.*, 2006). Although dehydration is probably the oldest method of food preservation practiced by human (Antonio *et al.*, 2008), efficient drying techniques and methods that could minimize nutrient loss and retain the health potentials of food products are of utmost important. Therefore, this study aimed at determining the effect of two drying methods (sun and solar drying) on the flour yield, phytochemical composition and antioxidant activities of Irish potato and sweet potato varieties (orange and white-fleshed).

2. Materials and methods

2.1. Sample Collection

About 50 kg each of the fresh tuber samples were obtained within Ilorin metropolis, Kwara state, Nigeria. Orange-fleshed sweet potato (OFSP) was procured

from a farm in Agbamu town while Irish potato (IP) and white-fleshed sweet potato (WFSP) were purchased from Ipata and Ganmo markets respectively. The fresh tuber samples were brought to the Department of Home Economics and Food Science at University of Ilorin, Kwara State, Nigeria for processing.

2.2. Sample Preparation

The tuber samples were washed with clean tap water to remove adhering sand and dirt, peeled using a local potato peeler fabricated by Nigeria Centre for Agricultural Mechanized (NCAM), Ilorin, Kwara state and sliced to about 3.5 mm thickness using a sharp stainless steel knife. The slices were submerged under water for proper rinsing and to slow down the rate of enzymatic reactions. Each of the sliced tuber samples were divided into three portions.

2.2.1. Raw (control)

The first portions (100 g each) were ground using laboratory mortar and pestle and then subjected to phytochemical analysis.

2.2.2. Drying Processes

The second and the third portions (24 kg each) were weighed and subjected to sun and solar drying respectively as described by Kolawole *et al.* (2016). The dried samples were milled, sieved and packaged in cellophane bags (Kolawole *et al.* 2016).

2.3. Determination of OFSP, WFSP and IP Yields

The flour yields of dried OFSP, WFSP and IP were obtained by gravimetric method. The percentage yields of the samples were calculated based on dry weight as:

$$\text{Yield (\%)} = \frac{W_2}{W_1} \times 100$$

Where, W_1 = Weight of fresh sample; W_2 = Weight of the dried sample.

2.4. Extraction of Samples for Antioxidant and Phytochemical Analyses

The flour samples were extracted according to the method described by Salawu *et al.* (2015) with little modifications. Each flour sample (3 g) was extracted with 30 ml acidified methanol (1% conc. HCl in methanol) using a three steps approach as follows: A 10 ml solvent was added to each flour sample in a conical flask and completely covered with aluminum foil. The samples were stirred for 2 hrs using magnetic stirrer, centrifuged in a 50 ml plastic centrifuged tube at 1900 rpm for 10 minutes at room temperature and decanted. The supernatant and the residue was re-extracted in 10 ml of the solvent for 15 minutes, centrifuged and decanted. The supernatant was kept again and the process was repeated the third time for 20 minutes. The supernatant was combined and stored in a glass bottle covered with aluminum foil and kept at 4 °C in refrigerator until further analysis.

2.5. Antioxidant Activity (DPPH Assay)

The method described by Turkmen *et al.* (2005) with some modifications was employed to determine the DPPH (1, 1-diphenyl-2-picrylhydrazyl) free radical scavenging activity of the flour samples. Sample solutions with concentrations 10, 20, 30, 40 and 50 mg/mL were prepared from the stock solution. A 1 ml of varying concentrations of the methanolic extract solution of each flour sample was mixed and vigorously shaken with 4 ml of freshly prepared 0.1 mol/L methanolic solution of DPPH. A blank probe (control) was obtained by mixing 4 ml of 0.1 mol/L methanolic solution of DPPH and 200 µml of deionized distilled water (ddH₂O). After 30 minutes of incubation in the dark at room temperature, the absorbance was read at 517 nm against the prepared blank. The

percentage inhibition of free radicals by DPPH was calculated using the formula:

$[1 - (\text{absorbance of sample} / \text{absorbance of control})] \times 100$.

The efficiency concentration of each sample at 50% inhibition (EC_{50}) was determined by interpolation.

2.6. Determination of Total Phenolics

The total phenolics content of methanol extract of the flour samples was determined according to the Folin-Ciocalteu method described by Singleton *et al.* (1999).

2.7. Determination of Total Flavonoids

Total flavonoids content was determined using the aluminum chloride method reported by Kale *et al.* (2010).

2.8. Beta-carotene Estimation

The method described by Kumara *et al.* (2011) was used for the β -carotene determination.

2.9. Statistical Analysis

The experiments were conducted in triplicates. All data were analyzed by one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS, version 20.0). The means were separated using Duncan's multiple range test in which $p < 0.05$ was considered to be statistically significant.

3. Results and discussion

3.1. Flour Yields of Potato, White-fleshed and Orange-fleshed Sweet potato Samples

The flour yields of potato, white and orange-fleshed sweet potato samples on dry weight basis are shown in Table 1. The drying yield which is majorly a function of the initial moisture content varied significantly ($p < 0.05$) among the samples. This implied that the drying methods employed as well as the varietal (WFSP and OFSP) and tuber differences (Irish potato

and sweet potato) had significant effect ($p < 0.05$) on the yields of the samples. The flour yields generally ranged from 15.20% in the sun-dried potato sample to 19.00% in the sun-dried white-fleshed sweet potato sample. The flour yields obtained in this study were observed to be lower than the value of 19.60% reported by Kaur and Aggarwal (2015) for water and steam cooked potato tubers. This variation may be attributed to differences in the processing methods employed. Surprisingly, the yield of the solar dried Irish potato sample was observed to be significantly higher ($p < 0.05$) than its corresponding sun dried sample while the reverse was noticed in OFSP and WFSP samples.

3.2. Total Antioxidant Activities of WFSP, OFSP AND IP Flour

The stable free radical DPPH has been widely employed to determine the free radical-scavenging ability of various dietary antioxidants by using the decrease in its absorbance at 517 nm to estimate the reduction capability of DPPH (Brand-Williams *et al.*, 1995). The DPPH free radical scavenging activity of the flours increased with increasing concentration of the extracts (Figure 1). Similar trend had been reported by Hesam *et al.* (2012) for the DPPH free radical scavenging activity of three potato extracts. Variation in the radical scavenging activity of the flour extracts as a result of drying methods was observed.

The total antioxidant activities of WFSP, OFSP and IP flour extracts expressed in terms of percentage inhibition and EC_{50} are presented in Table 2. EC_{50} is a measure of efficiency concentration at which radical scavenging activity is 50% and a lower EC_{50} is an indication of higher antioxidant activity of the sample (Hesam *et al.*, 2012; Irondi *et al.*, 2013). It was observed that drying methods had significant effect ($p < 0.05$) on the antioxidant activities (inhibitory action

and EC₅₀) of the flours. Irondi *et al.* (2013) had also reported significant effects of drying methods on the antioxidant activities of *C. papaya* seeds. The inhibitory activities and the EC₅₀ values of the flour samples ranged from 53.58–90.62% and 0.584–45.214 mg/ml dry sample respectively. Many researchers had reported comparable results for the antioxidant activities of potato cultivars (91.36–94.10%), sweet potato variety (85.28%), heat treated sweet potatoes (57.89–97.92%), white and yellow-fleshed potato cultivars (65.20–89.20) (Al-Saikhan *et al.* 1995; Hesam *et al.* 2012; Tokusoglu and Yildirim, 2012; Eleazu and Ironua, 2013). However, the relatively lower inhibitory activity of the sun-dried WFSP may be attributed to inability of the sun energy to effectively breakdown the cell structures of the sweet potato flesh to facilitate easy extraction of the antioxidants compounds. The combination of the inhibitory actions and the EC₅₀ values can be used for the comparison of the total antioxidant activities of the flour samples. Hence, the order of the total antioxidant activities was solar-dried OFSP > sun-dried IP > solar-dried WFSP > solar dried IP > sun-dried OFSP > sun dried WFSP. Interestingly, the effect of drying methods on the total antioxidant activities of the flour extracts was observed to be tuber dependent. This was because the total antioxidant activities of solar-dried sweet potato varieties (WFSP and OFSP) flours were higher while that of solar-dried IP flour was lower than its corresponding sun-dried sample. Hesam *et al.* (2012) had also reported significant difference among the EC₅₀ values recorded for three potato extracts.

3.3. Total Phenolic Content (TPC) of Fresh Tubers and Flour Samples

Phenolic compounds are secondary plant metabolites present in fruits and vegetables

which can contribute directly to antioxidant properties as a result of their redox properties (Zheng and Wang, 2001; Brown, 2005). Drying processes caused a dramatic increase in the TPC of the flour samples and the values obtained ranged from 4.51–9.82 mg GAE/g for fresh samples and 18.72–21.60 mg GAE/g for flour samples (Figure 2). Ruttarattanamongkol *et al.* (2015), Bellail *et al.* (2012) and Tokusoglu and Yildirim (2012) had reported similar observations in their studies. The increment in the TPC of the samples might have been caused by the degradation of cellular constituents during heat treatment and resulted into the breakdown and release of some free phenolics. However, the TPC of the flour samples varied significantly according to drying methods and the effect was observed to be tuber dependent. Different total phenolic contents according to drying methods had also been reported for sweet potato flour (Ahmed *et al.*, 2010). The TPC of flours obtained in this study was comparable to the values of 15–34 mg GAE/g for hot air dried sweet potato flours, 32.2 mg GAE/g DW for a red fleshed sweet potato and 9.60–54.30 mg/g DW reported by Ruttarattanamongkol *et al.* (2015), Cevallos-Casals and Cisneros-Zevallos (2003) and Ji *et al.* (2015) respectively. On the other hand, many other researchers had recorded relatively lower values for the TPC of potato and sweet potato flours (Al-Saikhan *et al.*, 1995; Ahmed *et al.*, 2010; Hesam *et al.*, 2011; Koala *et al.*, 2013). This could be due to the variation in genetic composition, sample treatment, processing method, extraction condition and environmental factors such as abiotic stress, nutrients, weather, water supply, temperature and other growing conditions (Vinson *et al.*, 1998; Kaur and Kapoor, 2002; Reyes and Cisneros-Zevallos, 2003; Huang *et al.*, 2005; Mohagheghi Samarin *et al.*, 2008; Hamouz *et al.*, 2007).

3.4. Beta-carotene Content (BCC) of the Flour Samples

Beta carotene is an important precursor of vitamin A found in plants and it ranged from 1.88 µg/g in the sun-dried WFSP and solar-dried IP flours to 3.81 µg/g in the sun-dried and solar-dried OFSP flours (Table 3). OFSP is known to be a rich source of β-carotene (Amajor *et al.*, 2011). Ezekiel *et al.* (2013) had also stated that potato cultivars with yellow or orange flesh contained more carotenoids compared to cultivars with white flesh. However, the beta-carotene content (3.81 µg/g) recorded for sun and solar dried OFSP flour samples indicated that the two drying methods had similar effect on the beta-carotene of OFSP. It was observed that the beta-carotene content of IP varied significantly ($p < 0.05$) with the drying methods. Beta-carotene content of 0.42–2.19 DW µg/g in sixteen native Andean potato varieties, 0.181–0.254 mg/100g in two sweet potato varieties and 0.18–226 µg/g FW in sweet potato cultivars had been reported by Andre *et al.* (2007), Tumuhimbise *et al.* (2013) and Teow *et al.* (2007) respectively. Amajor *et al.* (2011) reported a lower beta carotene content of 0.02×10^3 – 3.99×10^3 µg/100g carotenoids in five varieties of sweet potato. High beta carotene values as compared to those recorded in this study had been reported by many other researchers (Haile *et al.*, 2015; Nicanuru *et al.*, 2015; Ruttarattanamongkol *et al.*, 2015; Nkom and Ojimelukwe, 2016). Variation in beta-carotene content may be due to differences in varieties, cultivars, growing conditions, stages of maturity, harvesting and post-harvest handling, processing and storage, air and soil temperature, radiation, location, fertilization, soil moisture and other

environmental factors (K'Osambo *et al.*, 1998; Rodriguez-Amaya, 2000; Mbwaga *et al.*, 2007; Ukom *et al.*, 2009). Beta carotene may be one of the major phytochemicals contributing to the total antioxidant activities of the flour samples studied.

3.5. Total Flavonoids Content (TFC) of the Fresh and Flour Samples

Drying generally increased the TFC of Irish potato, white-fleshed and orange-fleshed sweet potato flour samples (Figure 3). The TFC ranged from 0.22 mg QE/g in IP to 0.36 mg QE/g in OFSP for the fresh samples and 0.50 mg QE/g in solar-dried OFSP to 1.15 mg QE/g in sun-dried OFSP for the flour samples. Comparable value of 50.77 mg QE/100g on fresh weight basis in sweet potato variety and significantly high range of value (96.91–579.63 mg QE/g) in sweet potato varieties had been reported by Eleazu and Ironua (2013) and Salawu *et al.* (2015) respectively. Drying methods had significant effect ($p < 0.05$) on the TFC of the sweet potato varieties (OFSP and WFSP) flour samples with the highest values recorded for the sun-dried samples. The low value of TPC recorded for the solar-dried OFSP flour may be an indication that flavonoid is not one of the major bioactive compounds responsible for the total antioxidant activities of potato and sweet potato flours investigated. Flavonoids are polyphenolic compounds which had been attributed to free radical scavenging activity in foods and inhibition of proliferation of a wide variety of cancer cell lines through scavenging or chelating process (Cook and Samman, 1996; Huang *et al.*, 1999; Kessler *et al.*, 2003; Pourmorad *et al.*, 2006).

Table 1. Flour yields of OFSP, WFSP and IP samples from different drying methods

Samples	Drying Time (Days)	Fresh weight (kg)	Flour yield (%)
OFSP _{Sun-dried}	3	5.00	18.00 ^b
OFSP _{Solar-dried}	5	5.00	17.20 ^c
WFSP _{Sun-dried}	3	5.00	19.00 ^a
WFSP _{Solar-dried}	5	5.00	15.60 ^e
IP _{Sun-dried}	3	5.00	15.20 ^f
IP _{Solar-dried}	5	5.00	16.00 ^d

Values with different superscript differ significantly ($p < 0.05$) from each other. **OFSP**= Orange fleshed sweet potato, **WFSP**= white fleshed sweet potato, **IP**= Irish potato.

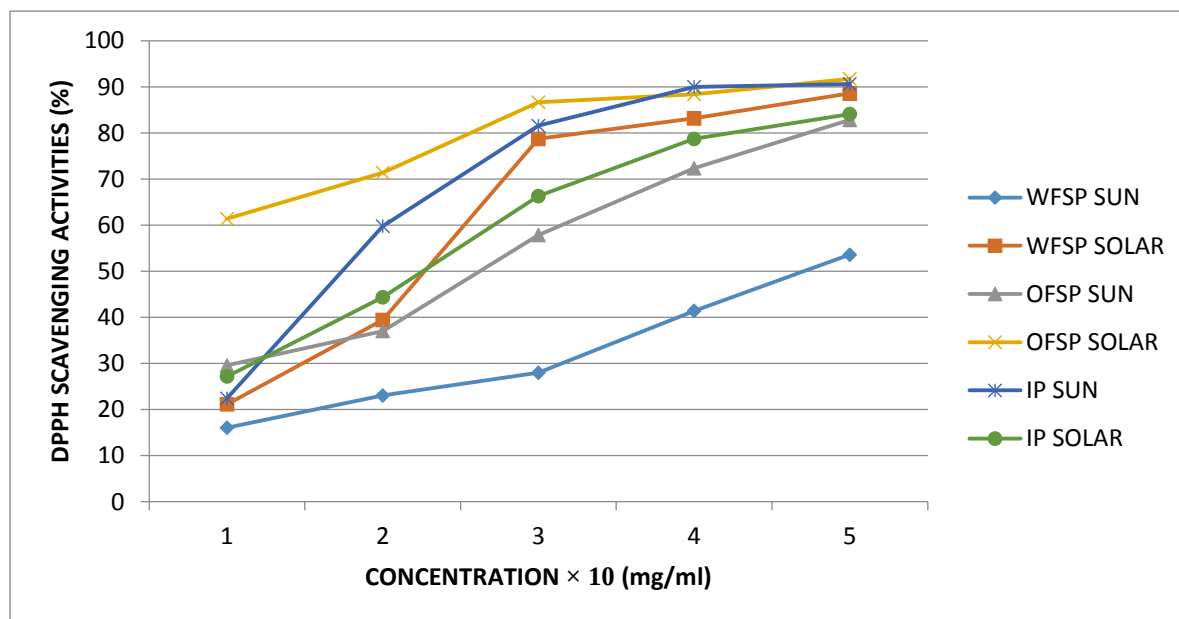
**Figure 1.** DPPH radical scavenging activities of OFSP, WFSP and IP flour samples as affected by drying methods

Table 2. Effect of drying methods on the total antioxidant activities of WFSP, OFSP and IP flour samples

Samples	(%) Inhibition at 50 mg/ml	EC ₅₀ value (mg/ml)
WFSP _{Sun dried}	53.58±1.33 ^c	45.214 ^a
WFSP _{Solar dried}	90.62±3.26 ^a	22.853 ^c
OFSP _{Sun dried}	84.10±2.45 ^b	26.429 ^b
OFSP _{Solar dried}	90.62±1.97 ^a	0.584 ^e
IP _{Sun dried}	90.62±2.98 ^a	17.143 ^d
IP _{Solar dried}	84.10±2.21 ^b	22.857 ^c

Each value is a mean of three determinations ± standard deviation. Means within column not followed by the same superscripts are significantly different ($p < 0.05$) from each other. **OFSP**= Orange-fleshed sweet potato, **WFSP**= white-fleshed sweet potato, **IP**= Irish potato.

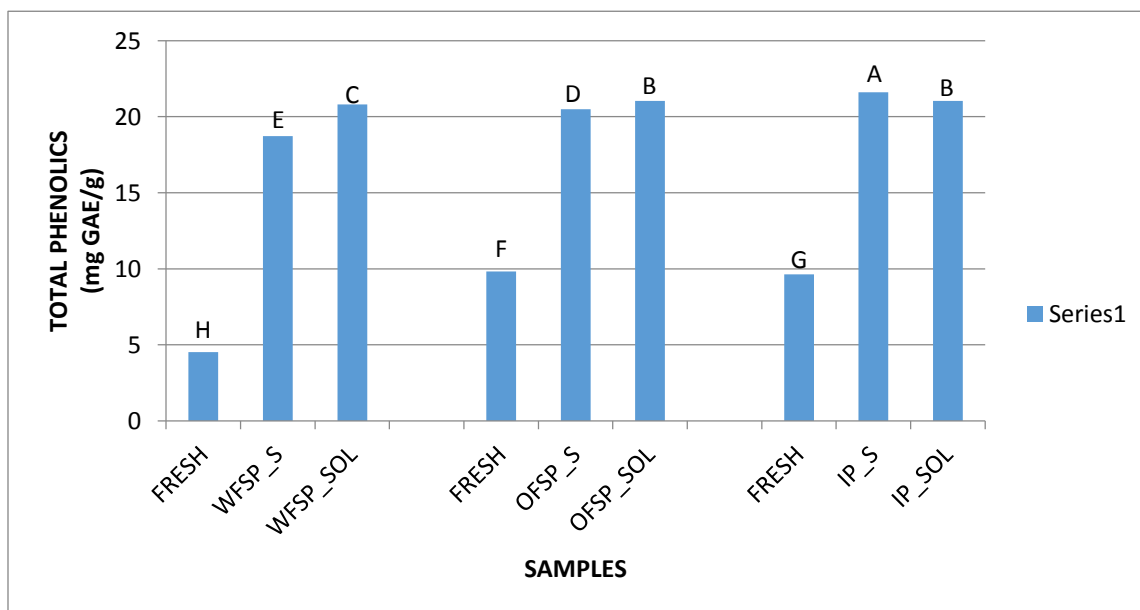


Figure 2: Total Phenolics Content (TPC) of fresh and flour samples. Bar charts not followed by the same alphabets are significantly different ($p < 0.05$) from each other. S= Sun-dried, SOL= Solar-dried.

Table 3: Beta-carotene of OFSP, WFSP and IP flours as affected by drying methods

Samples	Beta-Carotene Content (TCC) ($\mu\text{g/g}$)
WFSP Sun dried	1.88 ± 0.01^c
WFSP Solar dried	1.90 ± 0.02^{bc}
OFSP Sun dried	3.81 ± 0.01^a
OFSP Solar dried	3.81 ± 0.02^a
IP Sun dried	1.92 ± 0.03^b
IP Solar dried	1.88 ± 0.01^c

Values are means of three determinations $\pm$ standard deviations. Means not followed by the same superscripts are significantly different ($p < 0.05$). **OFSP**= Orange-fleshed sweet potato, **WFSP**= white-fleshed sweet potato, **IP**= Irish potato.

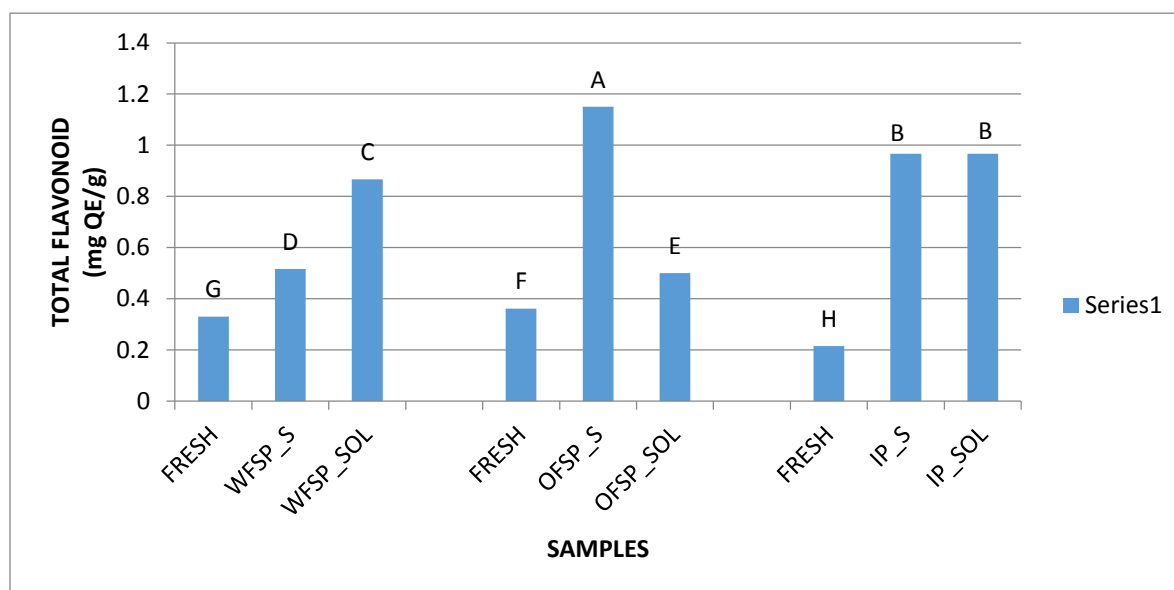


Figure 3: Total Flavonoids Content (TFC) of fresh and flour samples. Bar charts not followed by the same alphabets are significantly different ($p < 0.05$) from each other. S= Sun-dried, SOL= Solar-dried.

4. Conclusions

Flours were produced from IP, OFSP and WFSP using two drying methods (sun and solar). The effect of drying methods on the flour yields was observed to be significant ($p < 0.05$) irrespective of the tuber and varietal differences. The DPPH free radical scavenging activities of the flours

were noticed to be drying methods and extracts' concentrations dependent. It was shown that drying processes increased the TPC and TFC of the flour samples. The variation in the effects of drying methods on the total antioxidant activities, TPC, beta-carotene content and TFC were observed to be tuber (Irish potato and sweet potato) dependent. Sun-drying method had significant less favorable effect on the

WFSP sample compared to solar-drying method. Although solar-dried OFSP flour had the highest total antioxidant activity, sun-drying method produced IP and OFSP flours which had the highest TPC and TFC respectively. Based on this observation, it may be suggested that the total phenolics and the beta-carotene are majorly responsible for the antioxidant activities of the flour samples investigated. This study had shown that IP, WFSP and OFSP flours are good sources of phytochemicals most of which are responsible for their antioxidant activities as well as vitamin A supplementation in the body. Selection of potato and sweet potato varieties with high levels of phytonutrients should go hand in hand with the adoption of technological techniques with high favorable effect on the yield, antioxidant capacity and phytochemical composition of the plants in order to enhance output and maximize health benefits derivation.

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