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Study on Post-harvest Proximate Composition and Water Activity of Three Cultivars of Frafra Potatoes (*Solenostemon rotundifolius* [Poir.]) from Upper East Region, Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Author SA designed the study, wrote the protocol and the first draft of the manuscript. Authors EAS and SAA identified the three frafra potato cultivars used for the experiment. Author GAA reviewed the design and all drafts of the manuscript. Author SA managed the laboratory analyses. Authors SA and EAS performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Solenostemon rotundifolius (frafra potato) is an important food security crop in areas where it is cultivated in Ghana. However, the crop suffers research neglect in Ghana. More research on the crop is therefore needed for the crop to experience any form of meaningful improvement and utilisation beyond the area of its cultivation in Ghana. This present experiment therefore aimed to study the post-harvest proximate composition and water activity of three cultivars (black, white and brown cultivars) of frafra potatoes (*Solenostemon rotundifolius*) from the Upper East Region of Ghana. The white cultivar recorded the highest water activity value of 0.72 whiles the black and brown cultivar both recorded a lower water activity value of 0.68. The white cultivar recorded the

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highest moisture content of 7.20% whiles the brown and black cultivars recorded moisture content of 7.00% and 6.60% respectively. The brown cultivar recorded the highest protein content of 5.25 %, followed by 4.81% for the black cultivar and 4.38% for the white cultivar. Considering the ash content, the brown cultivar recorded a higher value of 4.00% followed by 3.80% recorded by the white cultivar and least value of 3.20% recorded by the black cultivar. The white cultivar recorded the highest fat content of 1.00% whiles the brown and black cultivar both recorded the lowest fat content of 0.20%. The black and brown cultivars both recorded the same higher fibre content of 1.00% followed by the lowest fibre content of 0.20% by the white cultivar. The black cultivar recorded the highest Nitrogen free extract (NFE) content (84.19%) followed by that of the white cultivar (83.42%) with the least being that recorded by the brown cultivar (82.55%). In all, mean water activity, moisture, protein, ash, fat, fibre and NFE values for the three cultivars were 0.69±0.02, 6.93±0.31%, 4.81±0.44%, 3.67±0.42%, 0.47±0.46%, 0.73±0.46% and 83.39±0.82% respectively. The mean moisture content and water activity recorded in this study indicate that processing frafra potatoes into flour will extend its post-harvest shelf life. Based on the moisture content and water activity values reported in this present study, the black cultivar of frafra potatoes will have the longest postharvest shelf life followed by the brown and white cultivars when processed into flour.

Keywords: Solenostemon rotundifolius (frafra potato); proximate composition; water activity; cultivar.

1. INTRODUCTION

Solenostemon rotundifolius (frafra potato) belongs to the mint family Labiatae (lamiaceae) [1]. Frafra potatoes are herbaceous perennials normally cultivated as annuals [2]. The area of cultivation of the crop mainly covers the Upper East and Upper West regions of Ghana. These two regions form part of the Guinea and Sudan savannah agro-ecological zones of Ghana. Frafra potato, which plays the important role of food security crop, is mainly boiled and eaten after the peel has been removed. The crop also has some sociocultural and medicinal importance [3,4]. A recent study suggests that Bread and Koose (a traditional Ghanaian pastry) made from partially substituted frafra potato flour is comparable to those made from wholly wheat flour [5].

Due to the rapid increase in human population and consequent shortages of grain crops, collection, improvement and utilisation of underutilized tuber crops such as frafra potato are paramount [6]. However, frafra potato has suffered research neglect in Ghana, especially when compared to other root and tuber crops like yam, cassava and sweet potato. More research on the crop is therefore needed for it to experience any form of meaningful improvement and utilisation beyond the area of its cultivation. This study therefore has the overall objective of determining the post-harvest proximate composition and water activity of three cultivars of frafra potatoes (*Solenostemon rotundifolius*) from the Upper East Region, Ghana.

The proximate analysis provides information on the basic chemical composition of food samples. According to Dublecz [7], Proximate analysis is a system that divides food into six fractions: moisture, ash, crude protein, ether extract (crude fat), crude fibre and nitrogen free extract.

Water activity is defined as the ratio of water vapour pressure of food substrate to the vapour pressure of pure water at the same temperature [8]. Water activity of food describes the degree to which water is bound in the food, its availability to participate in chemical/biochemical reactions and its ability to make possible the growth of microorganisms [9]. Safefood [10] also states that water activity is more important for qualitative considerations such as product stability, shelf life (e.g. microbiological and enzymatic stability, aroma retention), handling characteristics, physical properties and chemical stability. According to Nielsen [11], Water activity is a better indicator of food perishability than is water content. There is a critical water activity level below which no microorganisms can grow. Pathogenic bacteria cannot grow below a water activity of 0.85, whereas yeast and molds are more tolerant to reduced water activity, but usually, no growth occurs below a water activity of about 0.60 [12]. Most fresh foods have water activity values that are close to the optimum growth level of most microorganisms, 0.97 to 0.99 [9]. A number of methods can be used to measure water activity including a restrictive electrolytic, a capacitance or a dew point hygrometer [10].

2. MATERIALS AND METHODS

2.1 Geographical Location of the Experimental Site

The experiment was carried out between November 2012 to December 2012 at the laboratory of the Department of Horticulture-Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. Proximate analysis was done at the Faculty of Renewable Natural Resources laboratory, KNUST, Kumasi, Ghana. Water activity determination was done at the Food Research Institute, Accra, Ghana. The experiment lasted two months.

2.2 Procurement of Frafra Potato (*Solenostemon rotundifolius*) Tubers and Preparation

Fifty tubers each of the black, white and brown cultivars of frafra potatoes used for this research were all obtained randomly from a single farm in Bongo-soe, in the Bongo district of the Upper East region of Ghana. In all, one hundred and fifty (150) tubers of frafra potatoes were used. The farm was monitored from planting to harvest. Fresh tubers were subsequently obtained on the day of harvest and transported to the location of experiment on the same day. The samples were visually inspected for any sign of rot and defective samples discarded.

2.3 Proximate Analysis

The components measured, with reference from [37], were moisture, ash, protein, fat, fibre, and nitrogen free extract.

2.3.1 Determination of moisture content

A 5.00 g sample of ground frafra potato tubers was transferred to a previously dried and weighed dish. The dish was then placed in an oven, thermostatically controlled at 105 ^{o} C, for 24 hours. The dish was removed and placed in a desiccator to cool to room temperature and weighed. The sample was dried again for 30 minutes, cooled down and weighed. The process was repeated until a constant weight was reached. Percentage moisture was calculated using the formula below:

Percentage moisture (%) = (Weight of wet sample - Weight of dry sample) / Weight of wet sample x 100 (1)

2.3.2 Determination of crude fat (ether extract)

A previously dried 250 ml round bottom flask was weighed and 2.00 g of dried sample (ground frafra potato tubers) was transferred into a 22 × 80 mm paper thimble. The next step involves placing a small ball of cotton wool into the thimble to prevent loss of the sample. 150 ml of petroleum spirit (B.P 60-80°C) was added to the round bottom flask and the apparatus assembled. The quickfit condenser to the soxhlet extractor was then connected and refluxed for 4 hours on high heat (16 hours on normal heat) on the heating mantle. After extraction, the thimble was removed and the solvent recovered by distillation. The flask with the fat was heated next for 30 minutes in an oven at a temperature of 103°C. The flask and its contents were then cooled to room temperature in a desiccator. The final step involved accurately weighing the flask and determining the weight of the fat collected. The fat content, expressed as a percentage by weight, was calculated as:

Percentage fat (%) = Weight (g) of the extracted matter / Weight of the tested sample x 100 (2)

2.3.3 Determination of crude fibre

The sample from the crude fat determination was transferred into a 750 ml Erlenmeyer flask and approximately ½ g of asbestos added. The next step involved adding 200 ml of boiling 1.25% H_2SO_4 and immediately setting the flask on a hot plate and connecting the condenser. The contents started boiling within one minute. Care was taken to keep material from remaining on the sides of the flask. At the end of 30 minutes, the flask was removed and immediately filtered through a linen cloth in a funnel and washed with a large volume of boiling water until the residue washing was no longer acidic. The filtrate containing the sample from the acidic hydrolysis and asbestos was washed back into the flask with 200 ml boiling 1.25% NaOH solution. The flask condenser was connected and boiled for exactly 30 minutes. The contents in the flask were filtered again through a linen cloth and washed thoroughly with boiling water until residue washing was no longer basic. The next step involved washing the filtered residue with approximately 15ml alcohol and transferred to a porcelain crucible quantitatively with water. The crucible and its contents were next dried for one hour at 105°C. The sample was then cooled in the desiccator and reweighed. The crucible was ignited again in a furnace for 30 minutes, cooled and reweighed. Loss of weight observed was reported as the crude fibre content. Percentage fibre was calculated by:

Percentage crude fibre (%) = Weight of crude fibre / Weight of sample x 100 (3)

2.3.4 Determination of crude ash content

A 2.00 g sample (ground frafra potato tubers) was transferred into a crucible, which was previously ignited in a muffle furnace (pre-heated to 600°C) for two hours. The crucible was removed, permitted to cool in a desiccator and weighed. Percentage ash was calculated as:

Percentage ash (%) = Weight of ash / Weight of sample x 100 (4)

2.3.5 Determination of crude protein content

The Kjeldahl method was used in determining the protein content. In this method, a sample was heated in the presence of a catalyst (0.7 g mercury oxide and 15 g potassium sulphate) and digested till the carbon and hydrogen were oxidized, as the protein nitrogen was reduced and transformed into ammonium sulphate. The concentrated sodium hydroxide was added, and the digest heated to drive off the liberated ammonium sulphate into a volume of standard acid solution. The unreacted acid was determined and by calculation, the percentage nitrogen in the sample determined. In the calculation, the assumption was that N is derived from protein containing 16% N, and multiplying the N value by 100/16 or 6.25, an approximate protein value was obtained.

2.3.6 Determinations of nitrogen free extract (NFE) content

The determination of Nitrogen Free Extract (NFE) was made after completing the analysis for ash, crude fibre, ether extract and crude protein. The calculation was made by adding the percentage values on dry matter basis of these analysed contents and subtracting them from 100%. That is,

Percentage NFE= 100 % - (% crude protein + % ether extract + % crude fibre + % ash) (5)

2.4 Water Activity of Frafra Potato Flour

The Rotronic HygroLab 2 water activity meter (#29348002) was used to determine the water activity of samples at room temperature.

2.5 Statistical Analysis

Mean, standard deviation (SD) and coefficient of variation (CV) were computed for all parameters using Microsoft office Excel 2010.

3. RESULTS

3.1 Water Activity (aW)

From Table 1, the white cultivar recorded the highest water activity value of 0.72 whiles the black and brown cultivar both recorded a lower water activity value of 0.68. The mean water activity value is 0.69±0.02.

3.2 Moisture Content

From Table 1, the white cultivar recorded the highest moisture content of 7.20%. The brown and black cultivars recorded moisture content of 7.00% and 6.60% respectively. The mean moisture content is 6.93±0.31%.

3.3 Crude Protein Content

The brown cultivar recorded the highest protein content of 5.25 %, followed by 4.81% for the black cultivar and 4.38% for the white cultivar with the mean crude protein content being 4.81±0.44% as represented in Table 1.

3.4 Crude Ash Content

Considering Ash content of the flour produced from the tubers, the brown cultivar recorded a higher value of 4.00%. This is followed by 3.80% recorded by the white cultivar and least value of 3.20% recorded by the black cultivar. The mean crude ash content is 3.67 ±0.42%. This is shown in the Table 1.

3.5 Crude Fat Content

From Table 2, the white cultivar recorded the highest fat content of 1.00%. The brown and black cultivar both recorded the lowest fat content of 0.20%. The mean crude fat content is 0.47±0.46%.

3.6 Crude Fibre Content

The black and brown cultivars both recorded the highest fibre content of 1.00% followed by the lowest fibre content of 0.20% by the white cultivar. The mean crude fibre content is 0.73±0.46%.This is shown in Table 2.

Table 1. Water activity (aW), moisture, protein and ash content of frafra potatoes

Cultivar	Water activity (aW)	Moisture (%)	Protein (%)	Ash content (%)
Black	0.68	6.60	4.81	3.20
White	0.72	7.20	4.38	3.80
Brown	0.68	7.00	5.25	4.00
Mean	0.69	6.93	4.81	3.67
SD	±0.02	±0.31	±0.44	±0.42
CV	3.35	4.41	9.04	11.34

3.7 Nitrogen Free Extract (NFE) Content

The highest NFE content was recorded by the black cultivar (84.19%) followed by that of the white cultivar (83.42%) with the least being that recorded by the brown cultivar (82.55%). This is indicated in the Table 2. The mean NFE content is 83.39±0.82%.

Table 2. Crude fat, crude fibre and Nitrogen Free Extract (NFE) content of frafra potatoes

Cultivar	Fat (%)	Fibre (%)	NFE (%)
Black	0.20	1.00	84.19
White	1.00	0.20	83.42
Brown	0.20	1.00	82.55
Mean	0.47	0.73	83.39
SD	±0.46	±0.46	±0.82
CV	98.27	63.27	0.98

4. DISCUSSION

Flour generally has a water activity value in the range of 0.67 to 0.87 [9]. The water activity values of the *Solenostemon rotundifolius* (frafra potato) flour in this research work ranged from 0.68 to 0.72 (with the mean being 0.69±0.02). The finding of this study is therefore in line with the findings of [9]. Pathogenic bacteria cannot grow below a water activity of 0.85 [12]. Rahman [12] further indicates that yeast and molds are more tolerant to reduced water activity levels. Water activity levels ranging between 0.68 to 0.72 for *Solenostemon rotundifolius* flour in this study, therefore, implies that the flour will be less susceptible to pathogenic bacteria in storage and more susceptible to yeast and molds in storage. Water activity range of 0.68 for the brown and black cultivars of *Solenostemon rotundifolius* flour means that the flours will be especially susceptible to Maillard Browning. Maillard Browning is maximum at a water activity range of 0.60 to 0.70 [10]. Water activity level of 0.72 for the white cultivar suggests that it may be less susceptible to Maillard Browning than the black and brown cultivars. The three cultivars varying in terms of water activity values could be due to cultivar differences that enabled a varying degree of osmotic interactions. Babajide [13] indicates that characteristics between species vary considerably and according to Andrew [14], some products increase in water activity with an increase in temperature whereas some other products decrease in water activity with an increase in temperature caused by varying degree of osmotic interaction. The low water activity levels of the flour of the black and brown cultivar (0.68) compared to that of the white cultivar (0.72) indicates that the flour of the black and brown cultivars would have a reduced enzymatic activity than that of the white cultivar in storage. A reduced enzymatic activity contributes significantly to a longer shelf life since enzymatic activities lead to changes in nutritional values, colour and flavour of produce. According to Safefood [10], lower water activity levels lead to lower chemical and biochemical reactions.

Moisture is a predominant constituent in many food products. As a medium, it supports chemical reactions, and it is a direct reactant in hydrolytic processes [15]. According to Nasir [16], moisture content has a significant effect on crude protein, crude fat, mould growth and insect infestation of stored wheat flour. Nasir [16] further states that a moisture content ranging between 9% and 10% is suitable for storage stability and longer shelf life of wheat flour. From a microbiological standpoint, low water levels limit the development of microorganisms, with the exception of molds [17]. Ogiehor and Ikenebomer [18] also states that lower moisture content in flour is a good indicator of stability and may also contribute to reducing the tendency of staling in baked food products. A mean moisture content of 6.93±0.31%; 7.20 % (white cultivar), 7.00 (brown cultivar) and 6.60% (black cultivar) in this present study, therefore, suggest that the three cultivars will likely have higher storage stability and longer shelf life. It also implies that the black cultivar, in particular, will likely have higher storage stability, lesser staling in baked food products and longer shelf life than the white and brown cultivar. The mean moisture content of the three cultivars recorded in this present study is above the 4.13% recorded by Razali et al. [19] and below the 68.8% and 76.7% recorded by Opaleye et al. [20]. The difference in moisture content could be attributed to difference in varieties, types of storage conditions [21].

The mean protein content of 4.81±0.44% falls within the range reported by Allemann and Coertze [22] and below that of [2]. The protein content in this present study of 4.81% for the black cultivar and 4.38% for the white cultivar falls within the range reported by Allemann and Coertze [22]. According to Allemann and Coertze [22], protein content of *Solenostemon rotundifolius* is in the range of 4.70% to 5.20 %. However, the 5.25% recorded by the brown cultivar is in the higher range of 5.00-13.00 % reported by [2]. All cultivars in this present study recorded protein content higher than the lower range of 1.60 % and 4.06% reported by [20]. A similar variation in protein content in yam has been attributed to factors including cultural practices, climate and edaphic factors under cultivation, maturity at harvest, and storage period [23]. For instance, soils with low nitrogen levels have been reported to influence protein levels [24].

The ash content of 4.00% (brown cultivar), 3.80% (white cultivar), 3.20% (black cultivar) and mean of 3.67 ±0.42% reported in this study vastly contradicts the lower ash content of 1% reported by [25,26] and the higher ash content of 4.27% reported by [19]. The difference in ash content as reported by other authors may be a result of differences in soil mineral content, climatic conditions, harvest maturity and genetic variations [21,27]. The ash content of food materials reflects the mineral content in such foods [21,27]. This present study, therefore, suggests that the brown cultivar has the highest mineral content followed by the white and black cultivars.

The fat content ranged from 1.00% (white cultivar) to 0.20 % (brown and black cultivars) with the mean being 0.47±0.46%. Blench [25] reported the fat content of *Solenostemon rotundifolius* to be 0.50 %, [19] reported 0.20% whiles [22] also reported 3.5 %. The differences in fat content may be due to location and varietal differences since characteristics between species vary considerably [13]. Diets with high fat content contribute significantly to the energy requirements of humans [21]. High fat flours are also good for flavour enhancers and useful in improving palatability of foods in which it is incorporated [28]. The results in this present study, therefore, implies that the white cultivar will be a better source of energy and will also be a good flavour enhancer than the brown and black cultivar. The low fat content of the black and brown cultivar, however, makes both cultivars a healthier choice of food especially in relation to cardio-vascular diseases [29].

The fibre content in this experiment ranged between 1.00% (brown and black cultivars) and 0.20 % (white cultivar) with the mean being 0.73±0.46%. This contradicts the 0.50 % fibre content reported by [25], the 3.5 % and 1.1% reported by [22] and [30] respectively. Diets with high fibre content have been associated with immense health benefits on intestinal transit, cholesterol and glycaemic levels, fecal bulk, stimulating the proliferation of intestinal flora and also cancer prevention by trapping substances that can be dangerous for humans, such as mutagenic and carcinogenic agents [31,32,33, 34]. The results of this present study, therefore, suggest that the black and brown cultivars possess more of such fibre beneficial effects than the white cultivar. According to Dhingra [35], a fibre rich diet often has a lower fat content. The results of this study proves this assertion since the black and brown cultivars which recorded the same higher fibre content of 1.00% also recorded the same lowest fat content of 0.20%. Dhingra [35] also states that a fibre rich diet has lower energy density and is richer in micronutrients. The results of this present study, therefore, imply that the black and brown cultivars have a lower energy density and are richer in micronutrients than the white cultivar.

A part of carbohydrates is crude fibre, the remaining is nitrogen free extract (NFE). Nitrogen free extract (NFE), normally measured by difference method, consist of readily available carbohydrates such as sugars, starches and sugar-like substances [36]. The nitrogen free extract (NFE) content of 84.19% (black cultivar), 83.42% (white cultivar), 82.55 % (brown cultivar) and mean of 83.39±0.82% recorded in this present study contradicts the 21.4% reported by [26], the 22.84%, 20.57%, 19.67% and 15.58% reported by [20]. The result of this present study, therefore, suggests that frafra potato is a good source of readily available energy rich carbohydrates with the black cultivar being the highest, followed by the white and black cultivar.

5. CONCLUSION

The results of this present study indicate that *Solenostemon rotundifolius* (frafra potato) is rich source of readily available carbohydrates with appreciable amounts of protein, fat, fibre and ash content. The mean moisture content and water activity recorded in this study also indicate that processing frafra potatoes into flour will extend its post-harvest shelf life. Based on the lowest moisture content and lowest water activity values reported in this present study, the black cultivar will have the longest postharvest shelf life followed by the brown and white cultivars when processed into flour.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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