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Physicochemical properties and flour pasting profiles of popular sweet potato varieties from Kenya and Uganda

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Abstract

Sweet potato varies in physicochemical properties as a result of inherent varietal make up and agroecological zones where grown. Although pasting profiles of sweet potato flour can be used to determine their end use in food processing, information on systematic evaluation of popular varieties in Kenya and Uganda are limited. Four orange fleshed sweet potato varieties from Kenya and four common varieties from Uganda were evaluated for their physicochemical properties and for the pasting profiles of their flours. Results indicated significant variations ($p< 0.01$) in the attributes of the eight varieties. Orange fleshed varieties (OFV) had comparatively higher moisture, beta carotene, fat and mineral contents but lower pasting profiles than the non-orange fleshed varieties (NOFV). Sodium/Potassium ratio of the eight varieties ranged from 0.16 to 0.5 and within <1 that is recommended. Calcium/magnesium ratios ranged from 1.11 to 2.09 and were above the required value of 1. OFV had calcium/phosphorous values above 2.00 while NOFV had values below 0.1 against the required >0.5. OFV had lower Peak viscosities (124-590cP) and cold paste viscosities (89.5-319cP) compared to 677-1060Cp (peak viscosities) and 438-800cP (cold paste viscosities) for NOFV. Positive correlations were recorded between flour pasting profiles and carbohydrates ($r = 0.71 – 0.88$), starch ($r = 0.26 -0.52$), phosphorous ($r = 0.05 – 0.37$), protein ($r = 0.07 – 0.30$) and fiber ($r = 0.54 – 0.79$). Sweet potato consumption can combat hidden hunger since it is rich in various minerals. Shelf life of sweet potato can be prolonged through processing into flour including blended flours for production of high-quality food products.

Keywords: S*weet potato; physicochemical; pasting properties; flour; correlations*

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Introduction

Sweet potato ranks fifth in Kenya among the major staple crops after maize, wheat, rice and Irish potato (Mageto & Gathiaka, 2018). It is grown in a wide range of Agro Ecological Zones (AEZ) and grows better in areas with well-distributed annual rainfall of 600-1600 mm (Kivuva *et al.,* 2014). The sweet potato as an important food security crop has the ability to grow under marginal conditions and survive when other staple crops like maize fail due to low rainfall. Both improved varieties and local landraces of sweet potato are grown in Kenya (Joshua Ombaka Owade *et al.*, 2018). Farmers' preferences for particular varieties are based on many factors including yield, maturity period; consumer preference and organoleptic properties, availability of inputs, awareness, availability of markets and environmental conditions and agronomic traits (Jenkins *et al.*, 2018; Zawedde *et al.*, 2014). Production and consumption of sweet potato in Kenya has been on the rise in the recent years particularly due to the promotion of the biofortified orange fleshed cultivars by CIP (International Potato Centre) and other partners as a food-based approach in combating vitamin A deficiency (VAD) that is prevalent in sub-Saharan Africa (SSA) (Low & Thiele, 2020; Mbusa *et al.*, 2018).

Sweet potato nutritional composition includes carbohydrates, proteins, vitamins and minerals (Joshua Ombaka Owade *et al.*, 2018). The physicochemical properties of sweet potato roots have wide variations depending on factors such as location, cultivar, climate, soil and cultivation practices (Abong' *et al.*, 2020; Curayag *et al.*, 2019; Darko *et al.*, 2020). Dry matter (DM) contents in the roots range between 25.09 and 38.56 (Joshua Ombaka Owade *et al.*, 2018). Higher DM levels are reported in pale yellow and white fleshed varieties meaning that they stay firmer when cooked and their textures are drier and mealier than those with pink, red and orange flesh (Loebenstein & Thottappilly, 2009). Low DM content in most orange fleshed SP varieties limits their adoption and production by farmers(Jenkins *et al.*, 2018).

Carbohydrate contents in sweet potato roots usually range between 10 and 30% which constitute 80 – 90% of the dry weight; with starch being the most abundant constituent (50-80%) of the roots dry matter content (Tumwegamire *et al.*, 2011). Starch is a useful ingredient in both food and non-food applications is the major carbohydrate in sweet potatoes constituting between 53.76 and 71.69 % of the dry matter (Wang *et al.*, 2020). There is therefore need to exploit the starch potential in popular sweet potato varieties.

Protein content is usually minimal thus roots of some sweet potato varieties have yielded protein contents low contents with orange-fleshed sweet potato being among the varieties with the least content (Joshua Ombaka Owade *et al.*, 2018). Dietary fiber is said to be important in reducing the incidences of colon cancer, diabetes, cardiovascular diseases and certain digestive diseases. Sweet potato roots usually contain about 3% fresh weight crude fiber, with peeling during preparation reducing the fiber content (Neela & Fanta, 2019). Fat is essential in the diet for enhanced bioaccessibilty of beta carotene; thus, lack of fat has been linked to deficiency of vitamin A in the body (Failla *et al.*, 2009). Minimal fat (0- 1%) content is however found in sweet potato roots[12]. A study on three OFSP varieties Zapallo, Nyathiodiewo and SPK004/6 in Kenya showed fat contents ranging from 2.10% to 3.21% (Oloo *et al.*, 2014). Ash (mineral) content of roots of some varieties have ranged from 0.4% to 0.44% (Ingabire & Hilda, 2011). Deep OFSP were found richer in potassium, calcium, iron and Zinc (Kivuva *et al.*, 2014). Regular study of the protein, fibre, fat and ash content among other physicochemical properties is essential in determining the nutritional value of the different popular sweet potato varieties as determined by location of cultivation and genetic properties.
Carotenoids have several health-promoting effects: enhancing immunity and reducing the risk of developing degenerative diseases like cataract, cancer, mascular degeneration and cardiovascular diseases (Neela & Fanta, 2019).The orange-fleshed cultivars of sweet potato are particularly high in beta-carotene, the vitamin A precursor (Owade *et al.*, 2019). Some studies on raw roots of Kenyan OFSP varieties have yielded beta carotene content of 1240-10800µg/100g fresh weight with a retention of over 80% when the roots are boiled (Low *et al.*, 2017). Beta carotene content has been known to vary depending on cultivar and the prevailing environmental conditions where sweet potato are grown (Baafi *et al.*, 2016), thus the need to assess different varieties.

Sweet potato roots can be processed into flour to increase their postharvest shelf life for extended use in processing various food products (Olatunde *et al.*, 2016). A study of the pasting profiles of these flours from different varieties is an important guide in determining end use in food applications (Li *et al.,* 2014). Pasting properties (peak viscosity (PV), hot paste viscosity (HPV), cold paste viscosity (CPV), final viscosity (FV) breakdown viscosity (BD) and setback viscosity (SBV) of flour indicate the extent of molecular degradation and degree of paste viscosity and stability of starch (Olatunde *et al.,* 2016). Starch from sweet potato has been found to have high free swelling ability (Dereje *et al.,* 2020). High starch viscosity indicates good quality starch while low viscosity could imply some degree of degradation of starch during processing (Liao *et al.,* 2019).Although pasting profiles of sweet potato flour can be used to determine their end use in food processing, information on systematic evaluation of popular varieties in Kenya and Uganda is limited. The current study was carried out to evaluate the physicochemical properties and flour pasting profiles of eight selected sweet potato varieties to determine their suitability for extended use in food processing.

Materials and Methods

Materials acquisition

Fresh sweet potato roots of four varieties, Kenspot 4, Kabode, Vitaa and Sallyboro were obtained from the Kenya Agricultural and Livestock Research Organization (KALRO) farm in Kitale in March 2016, while the roots of Kawogo, Zidamukooti, Kyebadula and Dimbuka varieties were obtained from Uganda in April 2016 after harvesting on maturity (Table 1 and Figure 1). These were wrapped in polyethylene bags and sealed in carton boxes then transported within 24 hours to the University of Nairobi for analyses at the Food Science, Nutrition and Technology laboratories.

Table 1. Physical characteristics of eight sweet potato varieties from Kenya and Uganda

Variety name	Site collected from	Skin color	Flesh color
Kenspot – 4	KALRO Kitale, Kenya	Purple	Light orange
Kabode	KALRO Kitale, Kenya	Purple	Deep orange
Vitaa	KALRO Kitale, Kenya	Purple	Orange
Sallyboro	KALRO Kitale, Kenya	Cream pink	Orange
Kawogo	Kampala, Uganda	Purple	Very light yellow
Zidamukooti	Kampala, Uganda	Light brown	White
Dimbuka	Kampala, Uganda	Light brown	Pale yellow
Kyebadula	Kampala, Uganda	Purple	White

Figure 1: Photos of the Eight sweet potato varieties from Kenya and Uganda

Samples Preparation for analyses
Sweet potato roots from each variety were peeled and finely grated to obtain composite samples of each variety. These were used to analyze moisture content, beta carotene, reducing sugars and starch content accordingly. Grated sweet potato samples were oven dried at 45^{0}C for 16hours then milled into flour. The flour was then kept in air tight polyethylene bags ready for analysis. These were used for proximate analyses and to test pasting profiles.

Reagents
All the reagents used were of analytical grade and were obtained from Sigma-Aldrich chemical company (Nairobi, Kenya).

Analytical methods
Determination of moisture content
Moisture content of raw sweet potato was determined as per the AOAC method number 930.15 (AOAC, 2005). About 2 grams composite sample of each variety was dried in air oven at 105^{0}C for about 5hours, cooling in a desiccator and weighing again until a constant weight was reached. Moisture content was calculated as the weight loss due to evaporated water.

Determination of crude protein content
Crude protein content was determined using the micro-Kjeldahl distillation technique as per the procedure of AOAC method number 978.04 (AOAC, 2005).
Determination of crude fiber content

Crude fiber was determined using standard method number 962.09 of AOAC (2005) using sulphuric acid and potassium hydroxide.

Determination of crude fat content
Crude fat content was determined by Soxhlet extraction, using the standard method no. 930.09 of the AOAC (2005). Approximately 5g composite samples of each variety were used for extraction of crude fat using analytical grade petroleum ether (boiling point 40-60^{0}C) in soxhlet extraction apparatus for 16 hours. The petroleum ether was then evaporated in a rotary vacuum evaporator and the residual oil dried in an air-oven at 105^{0}C for 1hour. The weight of the residue was calculated as percent fat content.
Determination of ash content

Ash content was determined as per the AOAC (2005) official methods number 930.05. About 20g of sweet potato composite root samples were weighed into previously weighed crucibles and placed in the muffle furnace (600^{0}C) for 2h. The crucibles were cooled and reweighed. The remaining weight was taken as the ash content and the percent ash content calculated.

Determination of total carbohydrates content
The total carbohydrate was determined by difference; Total carbohydrate = 100 - (%fat + % protein + % moisture + % ash + % fiber)14.
Determination of starch content

Starch from fresh roots was obtained as per the method described by Ikegwu *et al.*, (2009) and involved washing, manual peeling of sweet potato roots, washing, grating, processing in the laboratory blender, sieving with muslin cloth, sedimentation, decanting and drying. Starch content was then calculated as a percentage of the sample weight.

Determination of beta carotene content
Approximately 2g composite sample of roots of each sweet potato variety were used to estimate the β-carotene content using the UV spectrophotometric method described by Biswas *et al.*, (2011). Acetone was used as the extraction solution and the beta carotene content determined at 450 nm absorbance against standard beta carotene solutions of 32, 16, 8, 4, 2, 1, 0.025, 0.125, 0.062, 0.03 and 0 μg/ml.

Determination of mineral content
In determining Mineral content, Atomic Absorption spectrophotometer (AAS) was used for measurement of Zinc (Zn), Copper (Cu), Iron (Fe) and Calcium (Ca) while Flame photometry was used for analysis of potassium (K), Sodium (Na), Magnesium (Mg) and phosphorous (P)29after acid digestion of the samples as per AOAC official methods30.

Reducing Sugars determination
Reducing sugars content were established from 10g of sample by the Luff-schoorl method No. 4 (International Starch Institute, 2002). Figure 2 shows some steps in the determination of the composition of sweet potato samples.

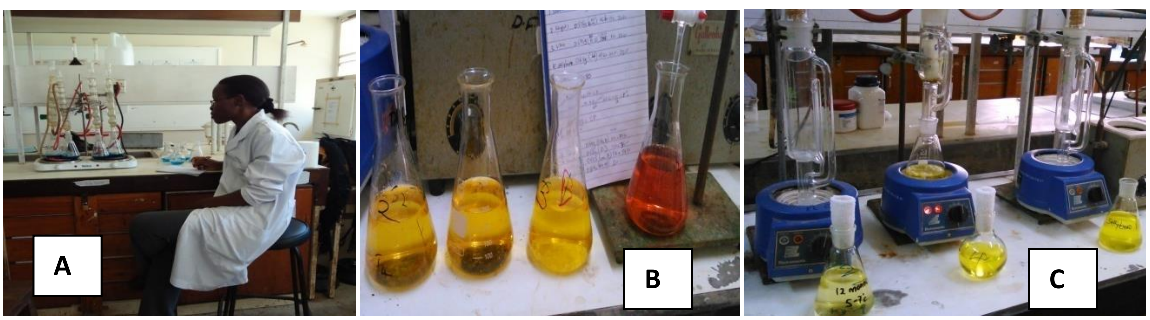

Figure 2: Photos of some laboratory processes in the proximate analyses: A-Reflux condensing stage in reducing sugars content determination; B- Titration stage from pink to golden yellow in crude protein content determination; C-Soxhlet extraction apparatus in crude fat content determination.

Sweet potato flour pasting profiles determination
Pasting profiles were determined using the Brabender® (Duisburg Nr. 175508, type 800101, West Germany). About 50g flour suspension in 450 ml of distilled water in aluminums can were subjected to heating from 30 to 95oC in 3.5minutes and held at 95oC for 2.5minuteswith constant stirring at 160rpm speed, cooled back to 50oC in 4minutes and held at 50oC for 2minutes. Gelatinization time(minutes), gelatinization temperature (^{0}C), peak viscosity (PV), peak viscosity temperature, peak viscosity time, hot paste viscosity (HPV), breakdown viscosity (BDV) and cold paste viscosity (CPV) were recorded. Viscosity was recorded as centipoises (cP).

Statistical analysis
All statistical analyses were performed using Genstat software 15th Edition. Data were subjected to analysis of variance (ANOVA) to determine means and standard deviation for significant differences at $p<0.05$. Bonferroni test was performed to establish significant differences in means of the physicochemical properties of the eight sweet potato varieties. Correlations

between the physicochemical properties and pasting properties were also established.

Results

Physicochemical properties of sweet potato varieties

Table 2. shows the physico-chemical properties of the eight sweet potato varieties. Moisture contents among the varieties differed significantly ($p<0.001$) and ranged from 60.3±0.42% to 72.50±0.71%. The non-orange fleshed varieties (Kawogo, Dimbuka, Kyebadula and Zidamukooti) in the current study recorded significantly ($p<0.001$) lower moisture content values (60% - 62%) than the orange fleshed varieties (Kenspot 4, Kabode, Vitaa and Sallyboro) which showed moisture content of 65% to 72%. Protein contents of the eight varieties significantly ($p<0.05$) differed from 2.01±0.04to 4.59±0.82% (dwb) irrespective of the flesh colour.

Table 2: Physicochemical properties (dry weight basis) of eight sweet potato varieties from Kenya and Uganda

Variety	Moisture %	Protein %	Fat %	Fiber %	Ash %	Carbohydrates %	Starch (% DM)	β carotene (mg/100g)
Kenspot – 4	65.50±0.71^{c}	2.01±0.04^{a}	4.95±0.21^{b}	4.03±0.04^{b}	3.10±0.14^{c}	59.20±1.05^{cd}	49.57±0.42^{d}	2.12±0.01^{c}
Kabode	72.50±0.71^{e}	3.18±0.11^{b}	3.8±0.14^{b}	4.33±0.25^{bc}	3.90±0.28^{d}	44.70±0.78^{a}	54.55±0.42^{bc}	12.76±0.00^{e}
Vitaa	72.00±0.00^{e}	2.15±0.35^{ab}	3.45±0.21^{b}	3.60±0.14^{a}	3.88±0.32^{d}	53.30±0.39^{ab}	50.85±0.21^{ab}	15.82±0.01^{f}
Sallyboro	68.50±0.71^{d}	2.75±0.21^{ab}	3.50±0.14^{b}	3.55±0.21^{a}	3.60±0.14^{cd}	57.50±0.00^{bc}	41.43±0.21^{a}	6.00±0.01^{d}
Kawogo	67.70±0.42^{d}	3.00±0.21^{ab}	0.73±0.21^{a}	4.18±0.13^{b}	1.25±0.08^{b}	71.70±0.42^{d}	43.34±0.71^{ab}	0.34±0.00^{b}
Zidamukooti	60.30±0.42^{a}	4.59±0.82^{c}	0.65±0.46^{a}	4.70±0.14^{d}	0.60±0.06^{b}	73.50±087^{e}	41.44±0.21^{cd}	0.83±0.01^{a}
Dimbuka	62.05±0.35^{b}	2.16±0.17^{ab}	0.35±0.21^{a}	6.45±0.15^{e}	0.93±0.77^{ab}	73.97±0.95^{e}	38.70±0.04^{b}	0.29±0.01^{b}
Kyebadula	60.60±0.28^{a}	2.74±0.74^{ab}	0.58±0.28^{a}	4.63±0.08^{cd}	0.23±0.06^{a}	79.26±1.44^{e}	51.73±0.18^{e}	0.18±0.01^{a}
% CV	0.8	15	11.2	3.5	14.7	3.8	2.3	0.7
Grand mean	66.14	2.82	2.25	4.43	2.18	22.17	15.62	1.36
S.E	0.51	0.42	0.25	0.16	0.32	0.85	0.36	0.01
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Values are means of duplicates ±SD. Values in the same column followed by different alphabetical letter superscript are significantly different at p≤0.05

Fat content (dwb) among the varieties was significantly ($p<0.001$) different ranging from 0.35±0.21% to 4.95±0.21%. The orange fleshed varieties recorded significantly ($p<0.001$) higher fat contents (3.45 – 4.95%) while the yellow and white fleshed varieties recorded fat contents of less than one percent. Fiber content (dwb) ranged from 3.55±0.21% (Sallyboro) to 6.45±0.15% (Dimbuka). The white and yellow fleshed varieties in the current study recorded significantly ($p<0.01$) higher fiber contents than the orange fleshed varieties. The orange fleshed sweet potatoes are improved varieties with less fiber which is a desirable characteristic by consumers. Ash content (dwb) varied significantly ($p<0.01$) from 0.23±0.06%

(Kyebadula) to 3.90±0.28% (Kabode). White fleshed varieties had the least ash content, followed by yellow fleshed varieties. Orange fleshed varieties had, significantly ($p<0.01$), the highest ash content. There was significant ($p<0.01$) difference in the ash content between Kenyan and Ugandan varieties of sweet potato whereas no significant difference ($p>0.05$) existed among the four Kenyan varieties likewise among the Ugandan varieties.

Carbohydrate contents (dwb) were in the ranges of 44.70±0.78% (Kabode) to 79.26 ±0.87% (Kyebadula) with significant ($p<0.001$) differences among the varieties. On fresh weight basis, these were 12.30% to 31.23%. Carbohydrates contents of Orange fleshed varieties were comparably lower than the yellow and white fleshed varieties. Starch content (dwb) in the varieties in the current study differed significantly ($p<0.001$), ranging from 41.43±0.21% in Sallyboro to 54.55±0.18% in Kabode. Kabode, Kyebadula, Vitaa and Kenspot 4 had high starch contents, in descending order. Dimbuka variety had the least starch content, it requires about 1.4 times the given quantity of Kabode variety to get the same amount of starch from Dimbuka variety. Beta carotene content (dwb) in the study ranged from 0.18±0.01mg/100g (Kyebadula) to15.82±0.01mg/100g (Vitaa) with significant ($p<0.001$) differences among the varieties. The non-orange fleshed varieties had less than 1mg/100g beta carotene. Reducing sugars content (Figure 3) varied significantly ($p<0.01$) from 0.85% (Dimbuka) to 4.45% (Vitaa). Orange fleshed varieties had higher reducing sugar contents of 1.75% and above. The differences in sugar levels could be due to the growth environment and the genetic makeup of the varieties.

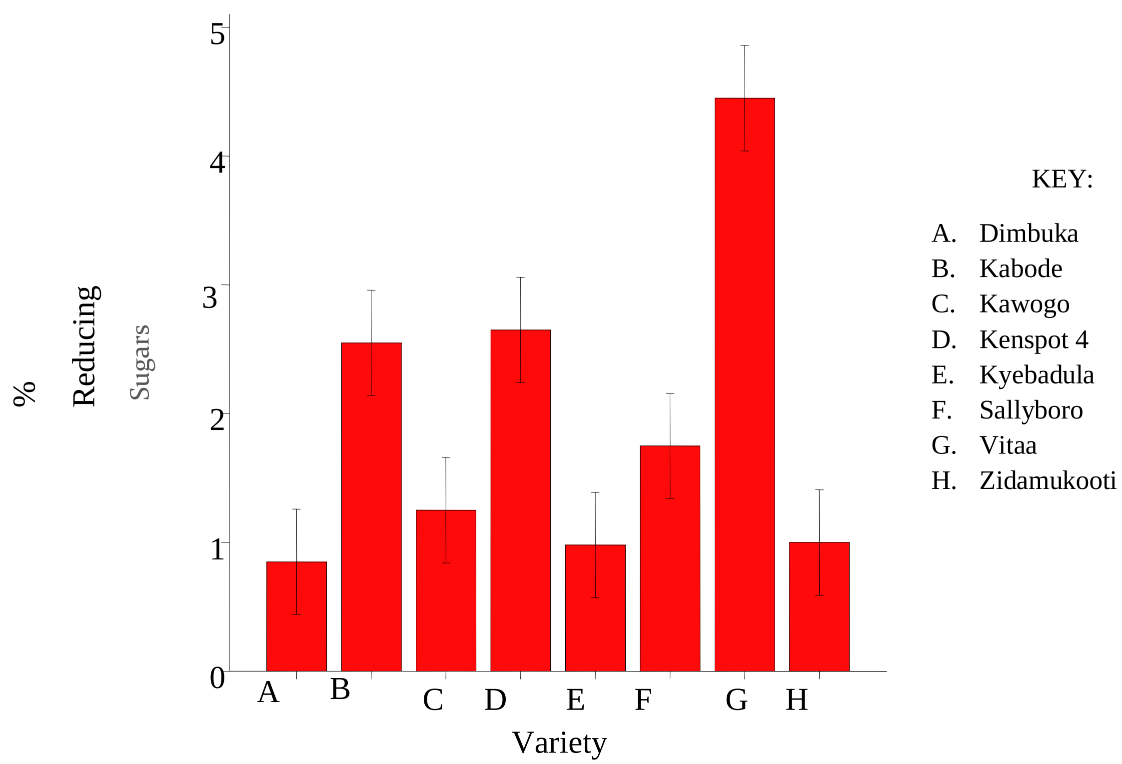

Figure 3. Reducing sugars content (%) of sweet potato varieties

Mineral composition of sweet potato varieties in Kenya and Uganda

Table 3 displays the mineral composition of the eight sweet potato varieties used in the current study. Potassium (K) had the highest level in all the varieties (ranging from 199.5±2.12 mg/100g in Kyebadula to 657.5±10.61mg/100g in Sallyboro) compared to other minerals. Potassium levels in the orange-fleshed varieties in the current study were significantly ($p<0.001$) higher than in the yellow and white-fleshed varieties. Sodium (Na) levels (ranging 61.9±10.82 mg/100g in Zidamukooti to 137.7±0.49mg/100g in Kawogo) were second highest in the mineral composition

Table 3: Mineral content (dwb) of eight sweet potato varieties from Kenya and Uganda

Variety	**Na (mg/100g)**	**Mg (mg/100g)**	**Ca (mg/100g)**	**Fe (mg/100g)**	**P (mg/100g)**	**K (mg/100g)**	**Zn (mg/100g)**	**Cu (mg/100g)**
Kenspot 4	107.2±0.49^{c}	51.50±4.95^{b}	95.15±0.21^{b}	0.61±0.06^{c}	36.17±0.11^{a}	526.5±68.59^{a}	0.12±0.01^{a}	0.03±0.00^{ab}
Kabode	106.5±1.34^{c}	59.02±1.73^{c}	96.75±1.06^{c}	0.68±0.00^{c}	34.90±0.14^{a}	598.0±2.83^{d}	0.12±0.00^{a}	0.29±0.02^{c}
Vitaa	112.1±0.57^{c}	47.10±0.57^{b}	97.75±0.35^{d}	0.58±0.00^{c}	42.75±0.35^{b}	576.0±1.41^{bc}	0.13±0.00^{a}	0.02±0.00^{ab}
Sallyboro	107.2±0.71^{c}	50.20±0.42^{b}	104.9±0.14^{e}	0.40±0.03^{b}	45.10±0.14^{b}	657.5±10.61^{e}	0.61±0.71^{a}	0.03±0.00^{ab}
Kawogo	137.7±0.49^{d}	0.21±0.04^{a}	0.30±0.14^{a}	0.17±0.06^{a}	85.25±1.10^{c}	277.1±3.75^{b}	0.14±0.06^{a}	0.03±0.03^{ab}
Zidamukooti	61.9±10.82^{a}	0.37±0.03^{a}	0.41±0.04^{a}	0.24±0.04^{a}	44.75±1.48^{b}	221.4±3.89^{ab}	0.11±0.04^{a}	0.06±0.02^{b}
Dimbuka	69.05±1.06^{ab}	0.27±0.18^{a}	0.40±0.18^{a}	0.22±0.11^{a}	45.05±1.48^{b}	195.6±0.64^{a}	0.13±0.10^{a}	0.00±0.00^{a}
Kyebadula	81.4±3.11^{b}	0.04±0.01^{a}	0.08±0.01^{a}	0.20±0.08^{a}	34.75±1.48^{a}	199.5±2.12^{a}	0.03±0.01^{a}	0.00±0.00^{a}
% CV	4.1	7.2	0.8	15.2	2.2	6.1	149.1	24
Grand mean	97.9	26.09	49.47	0.385	46.09	406.5	0.17	0.06
S.E	4.05	1.87	0.41	0.06	1.0	24.65	0.25	0.01
Fpr	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
RDA for adult (mg/day)	500	350	800	15	800	2000	15	
Contribution to RDA for children (%)	15.5 – 34.3	0.02 – 34.7	0.01 -13.1	1.7 – 6.8	4.34 – 10.66	12.2 – 41.1	0.3 – 6.1	
Contribution to RDA for adult (%)	12.4 – 27.4	0.01 – 16.9	0.01 – 13.1	1.13 – 4.53	4.34 – 10.66	9.8 – 32.9	0.2 – 4.1	

Values are means of duplicates ±SD. Values in the same column followed by different alphabetical letter superscript are significantly different at $p≤0.05$

The differences were significant ($p<0.001$) among the varieties with orange fleshed varieties posting higher values. Magnesium (mg) levels were significantly ($p<0.001$) lower in the non-orange fleshed varieties (0.04 – 0.21mg/100g) than in the orange fleshed varieties (47.1 – 59.02mg/100g). Iron (Fe) contents in orange fleshed varieties (0.4-0.68mg/100g) were significantly ($p<0.001$) lower than in the white and yellow fleshed varieties (0.17-0.24mg/100g).

There were no significant differences ($p>0.05$) among the varieties in values of Zinc (0.03 – 0.61mg/100g). The varieties in this study can supply about 0.2 – 6.1% of RDA Zinc.

Calcium (Ca) level in non-orange fleshed varieties ranged from 0.08 to 0.41mg/100g while in the orange fleshed varieties it ranged from 95.15 to 104.9mg/100g. The differences among the non-orange fleshed varieties were insignificant ($p>0.05$) while the differences among the orange-fleshed varieties were significant ($p<0.001$).

Copper was below detectable levels in Dimbuka and Kyebadula varieties. It was significantly high, 0.02 – 0.29mg/100g, ($p<0.001$) in the other six varieties with Kabode variety recording the highest level. There were significant ($p\leq0.05$) differences in phosphorous content, ranging from 34.75mg/100g (Kyebadula) to 85.25mg/100g (Kawogo). These levels are relatively low considering their ability to contribute about 4.3-11% of the recommended dietary allowance of 800mg/day phosphorous.

Table 4 shows ratios of selected minerals. The mineral ratio Na/K, Ca/Mg and Ca/P of foods has been used to determine their potential health benefits when consumed. The Na/K ratio ranged from 0.16 to 0.50.

Table 4. Mineral ratios of the eight sweet potato varieties

Variety	Ca/P ratio	Na/K ratio	Ca/Mg ratio
Kenspot 4 (orange fleshed)	2.63	0.20	1.85
Kabode (orange fleshed)	2.77	0.18	1.64
Vitaa (orange fleshed)	2.28	0.19	2.08
Sallyboro (orange fleshed)	2.33	0.16	2.09
Kawogo (pale yellow fleshed)	0.00	0.50	1.43
Zidamukooti (white fleshed)	0.01	0.28	1.11
Dimbuka (pale yellow fleshed)	0.01	0.35	1.48
Kyebadula (white fleshed)	0.00	0.41	2.00
Recommended values	>0.5	< 1	1

Pasting profiles of flour from eight sweet potato varieties

Pasting profiles of flour from the eight sweet potato varieties are shown in Tables 5 and 6. Gelatinization (pasting) temperature of the sweet potato flour varied from 55.50±3.54^{0}C to 75.50±12.02 ^{0}C with significant variations ($p\leq0.05$) among the varieties (Table 5). Orange fleshed varieties in the current study had significantly lower ($p\leq0.05$) pasting temperatures than the other varieties.

Flour from the eight varieties differed significantly ($p<0.05$) on gelatinization time, peak time and peak viscosity temperature. Gelatinization time ranged from 8.20±0.28 to 15.50±2.12 minutes. Kenspot 4, Kabode, Vitaa and Sallyboro (orange fleshed) varieties had significantly ($p<0.01$) lower gelatinization time than the white and yellow fleshed varieties

In the current study, orange fleshed (OFSP) varieties required lesser time (10.40 – 12.60 minutes) than that (13.50 – 20.50minutes) required by the non-orange fleshed varieties to reach peak viscosity.

Table 5. Pasting profiles of flour of eight sweet potato varieties

Variety	G_{temp} (°C)	G_{time} (min)	P_{temp}(°C)	P_{time}(min)
Vitaa (OF)	55.50±3.54^{a}	8.50±0.71^{a}	69.50±0.71^{a}	10.42±0.04^{a}
Kabode(OF)	59.50±2.12^{ab}	8.20±0.28^{a}	70.50±0.71^{a}	10.40±0.14^{a}
Sallyboro (OF)	63.95±1.48^{abc}	9.60±0.57^{ab}	74.00±1.41^{ab}	10.75±0.35^{a}
Kenspot 4 (OF)	64.50±2.12^{abc}	10.65±0.49^{ab}	75.00±1.41^{ab}	12.60±0.57^{ab}
Kawogo(PYF)	65.00±4.24^{abc}	11.00±0.00^{ab}	76.00±2.83^{ab}	13.50±0.71^{ab}
Kyebadula (WF)	66.00±5.66^{a}	13.00±2.83^{bc}	79.00±7.07^{b}	15.50±3.54^{b}
Zidamukooti(WF)	72.00±5.65^{bc}	15.00±1.41^{c}	78.00±2.83^{ab}	15.00±1.41^{b}
Dimbuka (PYF)	75.50±12.02^{c}	15.50±2.12^{c}	86.50±0.71^{c}	20.50±2.12^{c}
Mean	65.2	11.43	76.06	13.83
CV%	8.6	12.2	3.9	11.4
Fpr	0.105	0.004	0.009	0.002
SE	5.59	1.398	2.99	1.58

G_{temp}=Gelatinization temperature, G_{time}=Gelatinization time, P_{temp} –Peak temperature, P_{time}-Peak time, OF –Orange fleshed, WF –White fleshed, PYF –Pale yellow fleshed
Means±SD in the same column bearing same superscripts are not significantly different (P>0.05)

There were significant variations ($p \leq 0.05$) in the flour peak viscosities (PV), hot paste viscosities (HPV), breakdown viscosities (BDV) and cold paste viscosities (CPV) among varieties with orange fleshed varieties exhibiting significantly ($p<0.05$) lower values compared to non-orange fleshed varieties (Table 6). The lowest peaks found for orange-fleshed sweet potato varieties ranged from 124 to 590cP. Highest peak viscosity was attained by Dimbuka variety (1060±74cP). Hotpaste Viscosity (HPV) is the lowest viscosity that is achieved when the flour paste is held at 95°C and can be used to indicate the paste's ability to withstand breakdown during cooling[13]. Dimbuka had the highest value (759cP) while Kabode, Vitaa and Sallyboro (OFSP) had lowest values (69, 67 and 73cP respectively) of HPV.

Table 6: Pasting profiles of eight sweet potato varieties continued

Variety	PV (cP)	HPV (cP)	BDV (cP)	CPV (cP)	SBV (cP)
Vitaa (OF)	124±2.83^{a}	67±11.3^{a}	57±84.9^{a}	89.5±2.12^{a}	34.5±0.71^{a}
Kabode (OF)	127±1.41^{a}	69±14.1^{a}	58±12.73^{a}	89.5±3.54^{a}	37.5±2.12^{a}
Sallyboro (OF)	141.8±7.42^{a}	73±15.6^{a}	69±8.13^{a}	97±1.41^{a}	44.8±8.84^{a}
Kenspot 4 (OF)	590±2.83^{b}	296±76.4^{b}	294±73.5^{b}	319±17^{b}	271±19.8^{b}
Kawogo(PYF)	677.2±126^{bc}	332±19.8^{b}	345±106.4^{bc}	438±12.7^{c}	239±113.5^{ab}
Kyebadula (WF)	809±104^{c}	312±33.9^{b}	497±70^{c}	481±28.3^{cd}	327±75.7^{b}
Zidamukooti(WF)	747±111^{bc}	419±17^{c}	328±128.7^{bc}	527±25.5^{d}	220±137.2^{ab}
Dimbuka (PYF)	1060.5±74^{d}	759±41^{d}	302±33.2^{b}	800±72.1^{e}	261±146.4^{b}
Mean	534	290.9	244	355.1	179
CV%	14	12.1	28.9	8.4	48
Fpr	<0.001	<0.001	0.002	<0.001	0.038
SE	74.8	35.21	70.4	29.83	86.1

PV-Peak Viscosity, HPV-Hot Paste Viscosity, CPV-Cold Paste Viscosity, SBV –Setback Viscosity, BDV –Breakdown Viscosity, OF –Orange fleshed, WF –White fleshed, PYF –Pale yellow fleshed
Means±SD in the same column bearing same superscripts are not significantly different (P>0.05)

Breakdown viscosity (BDV) is the difference between PV and HPV. Flours from OFSP varieties (Kabode, Vitaa, Kenspot 4 and Sallyboro) exhibited low BDV values (57-294cP). Setback viscosities of the eight varieties did not differ significantly.

Correlations between physico-chemical properties and pasting properties

Correlations between the physico-chemical properties of the sweet potato tubers and the pasting properties of their flours are displayed in Table 7. Significant (p<0.001), strong positive correlations (r= 0.706 to 0.882) were noted between carbohydrates content and pasting properties of the flours. Significant (p< 0.01) strong positive correlations (r = 0.543 to 0.789) were also evident between fiber content and pasting properties. Low but significant (p<0.05) positive correlations were observed with starch (r = 0.267 to 0.522) and phosphorous (r = 0.052 to 0.372).

Protein content were also positively correlated though low (r = 0.069 to 0.304) and insignificant (p > 0.05). Reducing sugars (Rs) were negatively and significantly (p<0.01) correlated with the pasting properties (r = -0.536 to -0.877).

Correlation coefficients between the various pasting properties of the flours

There were significant (p<0.05, p<0.01) strong positive correlations (r = 0.58 to 0.972) among the various pasting properties of the flours (Table 8). Increase in gelatinization time resulted in increase in peak temperature, peak time, PV, SBV and TV of the flour.

Table 7. Pearson correlations (r) between physico-chemical and pasting properties

Chemical properties	BDV	FV	G_{temp}	G_{time}	PV	SBV	TV	P_{temp}	P_{time}
Moisture content	-0.794***	-0.856***	-0.763***	-0.888***	0.820***	-0.760***	-0.781***	-0.761***	-0.821***
Protein	0.069	0.160	0.304	0.23	0.130	0.146	0.121	0.173	0.166
Fat	-0.484*	-0.759***	-0.47*	-0.643**	-0.632**	-0.353*	-0.598**	-0.561**	-0.685**
Ash	-0.824***	-0.851***	-0.627**	-0.834***	-0.830***	-0.700**	-0.713**	-0.702**	-0.806***
Fiber	0.543**	0.789***	0.636**	0.759***	0.769***	0.606**	0.766***	0.724***	0.777***
Carbohydrates	0.864***	0.882***	0.706**	0.879***	0.859***	0.765***	0.750***	0.764**	0.851***
Reducing sugars	-0.635	-0.877	-0.667	-0.731	-0.760	-0.536	-0.698	-0.723	-0.811
Starch	0.522	0.391*	-0.268	0.42*	0.445*	0.494*	0.362*	0.267	0.374*
Sodium (Na)	-0.289	-0.673**	-0.602**	-0.626**	-0.595**	-0.339*	-0.596**	-0.538***	-0.637***
Phosphorous (P)	0.052	0.356*	0.338*	0.313	0.249	0.097	0.372*	0.298	0.329*
Calcium (Ca)	-0.832***	-0.751***	-0.594**	-0.751***	-0.741***	-0.80***	-0.675**	-0.627**	-0.758***
Copper (Cu)	-0.522**	-0.421*	-0.314	-0.38*	-0.412*	-0.412*	-0.291	-0.471*	-0.426*
Potassium (K)	-0.729***	-0.879***	-0.648**	-0.864***	-0.871***	-0.727***	-0.838***	-0.757***	-0.884***
Magnesium (Mg)	-0.73***	-0.697***	-0.498*	-0.724***	-0.692**	-0.659**	-0.584**	-0.523**	-0.706**
Zinc (Zn)	-0.598**	-0.234*	-0.394*	-0.379*	-0.333*	-0.692**	-0.241	-0.388*	-0.298

*significant at P <0.05; **significant at P < 0.01, ***significant at P < 0.001

BDV – Breakdown Viscosity; FV – Final Viscosity; Gtemp – Gelatinization temperature; Gtime – Gelatinization time; PV – Peak Viscosity; SBV – Setback Viscosity; TV – Trough Viscosity; P temp – Peak temperature; Ptime - Peak time

Table 8. Pearson correlation coefficients between the various pasting properties of the flours

Parameters	BDV	FV	G_{temp}	G_{time}	PV	SBV	TV	Peak temp
FV	0.711**							
Gtemp	0.699**	0.83***						
Gtime	0.759***	0.933***	0.893***					
PV	0.734***	0.931***	0.775***	0.94***				
SBV	0.887***	0.709**	0.799***	0.832***	0.797***			
TV	0.580*	0.92***	0.799***	0.905***	0.882***	0.730***		
Peak temp	0.727***	0.888***	0.911***	0.881***	0.867***	0.792***	0.850***	
Peak time	0.727***	0.972***	0.874***	0.961***	0.945***	0.795***	0.942***	0.903***

*significant at P <0.05; **significant at P < 0.01; ***significant at P < 0.001

Discussion

Physicochemical properties of sweet potato varieties

These differences in moisture contents of the sweet potato roots can be attributed to the agronomic practices, environmental factors and inherent variety differences .These values are within ranges reported in another study by Wheatley & Loechl (2008). Low dry matter (<25%) of the orange fleshed varieties can negatively influence their adoption and production by farmers (Rukundo *et al.,* 2013). Higher dry matter content in the white fleshed and pale-yellow varieties is responsible for the roots staying firmer with drier and mealier textures if cooked than the roots with orange flesh (Loebenstein & Thottappilly, 2009).The acceptable levels of root DM by consumers is lower in Southern Africa than in East Africa; about 27% versus 30%, respectively (Wheatley & Loechl, 2008).

The differences in protein contents can be attributed to variety of sweet potato (Kivuva *et al.,* 2014). The results reveal that these eight varieties are poor sources of dietary protein thus, need for other sources to supplement sweet potato in the diet. Though low, the protein in sweet potato is considered of high biological value due to its high lysine content (Sgroppo *et al.,* 2010).These values are within those reported in other studies, 3.5-9.5% (Kivuva *et al.,* 2014).

The differences in fat contents can thus be linked to variety. This shows that the varieties used in the present study are also poor sources of dietary fat. Dietary fat is essential for enhancing the bio-efficacy of beta carotene in the body (Oloo *et al.,* 2014). This calls for the roots to be prepared through methods that require additional fat in cooking such as frying. Fat content of the orange-fleshed varieties in the current study are higher than values recorded in another study of three varieties but the values for the white and yellow fleshed are within ranges recorded for Tanzanian six varieties (Lyimo *et al.,* 2010). The orange fleshed sweet potatoes are improved varieties with less fiber which is a desirable characteristic by consumers. This implies that the eight varieties are good sources of dietary fiber especially the white and yellow fleshed ones and can provide sufficient daily requirements. Fiber is essential in the body for the well-functioning of the digestive system. Adequate intake of dietary fiber has been associated with low risk of developing digestive disorders, colon cancer, diabetes and coronary heart conditions among others (Oladebeye *et al.,* 2009). The fiber contents in this study were however, higher than those of four china varieties and three Kenyan varieties reported in previous studies (Ji *et al.,* 2015; Oloo *et al.,* 2014). White fleshed varieties had the least ash content, followed by yellow fleshed varieties. Orange fleshed varieties had, significantly (p<0.01), the highest ash content. The difference was significant (p<0.01) between Kenyan varieties and Ugandan varieties. There was no significant difference (p>0.05) among the four Kenyan varieties likewise among the Ugandan varieties. The differences reported are probably due to different geographical locations where the roots were grown and differences of variety. The ash content values were within findings reported on three Kenyan varieties (Oloo *et al.,* 2014), six varieties in Tanzania (Lyimo *et al.,* 2010), and four varieties in China (Ji *et al.,* 2015). The ash content is usually an indication of the presence of mineral elements deposited in the roots (Antia *et al.,* 2006). This possibly explains why the orange fleshed varieties are a better source of minerals than the white and yellow varieties. Minerals are very essential for the proper functioning of the nerves and heart, for building strong bones and maintenance of the composition of the body fluid (Sanoussi *et al.,* 2016). A deficiency of micronutrients (hidden hunger) namely vitamins and minerals is a global problem affecting about three billion people (Kihara *et al.,* 2020), and this can be well combated through dietary means.

On fresh weight basis, carbohydrates contents were 12.30% to 31.23% which is in agreement with a general observation (Owade *et al.,* 2018). Carbohydrates contents of Orange fleshed varieties were comparably lower than the yellow and white fleshed varieties. Carbohydrates are the main constituents of the dry matter in sweet potato and these particular carbohydrates in sweet potato are found to be of low glycemic index (Fetuga *et al.,* 2014). Carbohydrates are a rich source of energy hence the white and yellow flesh varieties in this study can be preferred over the orange fleshed in cases where high carbohydrates are required.

Starch values in the current study are however lower than those reported by another study by Nabubuya et al. (2012). Starch is important in industrial use for both food and non-food applications (Tsakama *et al.,* 2011). Nearly 9% of the world's starch production is derived from sweet potato, and this comes third after cereals and cassava (Chang & Mais, 2014). It is therefore important that high starch yielding sweet potato varieties are selected since twice as much sweet potato is required to produce same amount of starch as cassava.

The differences in beta carotene contents are inherent in the varieties. The ranges are within the beta carotene levels (0.43mg/100g to 18.37mg/100g on dry weight basis) found in nine varieties in Uganda (Niringiye *et al.,* 2014). The current results imply that orange fleshed varieties (Kabode, Vitaa, Kenspot 4 and Sallyboro) are a more reliable source than white and yellow fleshed for dietary supply of beta carotene thus their consumption should be greatly encouraged. Beta carotene is an important pro-Vitamin A carotenoid (pVAC) found richly in orange fleshed sweet potato varieties (Burri, 2011), and converts to Vitamin A in the body once absorbed (Kidmose *et al.,* 2007). Vitamin A is an essential micronutrient required in the body for prevention of poor night vision, growth, development, genes expression and some immune functions (De Moura *et al.,* 2015). Unfortunately, this vitamin's deficiency is very prevalent in the sub-Saharan Africa (Owade *et al.,* 2018). It has been reported that over 80% of Vitamin A intake in developing countries is from plant sources (Burri, 2011; Kidmose *et al.,* 2007). The consumption of orange fleshed varieties with higher beta carotene levels like Vita, Kabode and Sallyboro should therefore be promoted since they are a cheaper and easily accessible source of pro-Vitamin A carotenoids unlike meat and fish (Kidmose *et al.,* 2007).

The differences in sugar levels among the varieties could be due to the growth environment and the genetic makeup of the varieties. Reducing sugars influence the color, texture and other functional properties of sweet potato flour and starches (Nabubuya *et al.,* 2012). High Reducing sugars and low starch contents in roots favour oxidation reactions during frying or drying yielding darker brown products with some bitter tastes (Rukundo *et al.,* 2013).

Higher levels of reducing sugars increase the intensity of brown color of fried and baked sweet potato products due to the Maillard's reaction with the amino acids in the sweet potato13. Kyebadula and Kenspot 4 can offer better quality fried or baked products since they possess a combination of both high starch and low reducing sugars content.

Mineral composition of sweet potato varieties in Kenya and Uganda

The levels of potassium in the current study were lower than those reported in one study , though the values in the white and yellow fleshed are within results reported in other studies (Kivuva *et al.*, 2014). Potassium (K) levels were also reported to be the highest (308.67–328.67mg/100g) in another study among the minerals in ten elite sweet potato landraces of Benin (Sanoussi *et al.*, 2016). Potassium consumption is important in neurotransmission and heartbeat regulation and in higher amounts, increases iron utilization in the body (Alinnor & Oze, 2011; Archana *et al.*, 2013; Sanoussi *et al.*, 2016). Consumption of 100g of the varieties in this study can supply about 13% to 42% of daily requirement.

The differences in sodium levels were significant ($p<0.001$) among the varieties with orange fleshed varieties posting higher values. Differences in sodium levels could be due to variety and soils where they were grown. These values were higher than levels reported in ten varieties (29.0 – 34.0mg/100g) in Benin (Sanoussi *et al.*, 2016). High consumption of sodium has been associated with high urinary calcium levels and can therefore accelerate osteoporosis for individuals on low-calcium diet. Zidamukooti, Dimbuka and Kyebadula varieties could be better choice for individuals on low sodium diet.

The huge differences in magnesium levels can be attributed to variety. The orange fleshed varieties are therefore a better source of magnesium than the white and yellow fleshed varieties. Magnesium levels range of 12.20 – 30.40mg/100g has also been reported in other studies elsewhere (Ukom *et al.*, 2009). The differences in Fe content could be attributed to variety of sweet potato and Fe content in soils where they were planted (Burgos *et al.*, 2021). Iron content levels in the white and yellow-fleshed varieties were lower than those reported elsewhere though the orange fleshed values were within the reported range (Sanoussi *et al.*, 2016). Contribution of OFSP varieties is about 7.1% (0.71mg /100 g) and white fleshed sweet potato varieties about 3% (0.3mg/100g) iron to the diet of children aged four to eight years (Leighton *et al.*, 2010). Iron is one of the micronutrients whose dietary deficiency is a global health concern (Burgos *et al.*, 2021). Orange fleshed varieties in this study have the ability to supply higher dietary iron content than the non-orange fleshed varieties. The varieties in this study can supply about 0.2 – 6.1% of RDA Zinc. The findings imply that the sweet potato varieties are generally very low sources of dietary zinc.

Differences in calcium content are probably due to variety of sweet potato. This finding is in agreement with Leighton's observation that orange fleshed varieties were higher in calcium content than white fleshed varieties (Leighton *et al.*, 2010). Ca content differences may also be due to the level of other nutrients in the soil. For instance, lower level of Ca in sweet potato has been attributed to high levels of K and Fe in the soil which lower the uptake of Ca by the roots (Fernandes *et al.*, 2020). Calcium is needed for teeth and bone formation in addition to its role in muscle contraction among other functions in the body (Senga *et al.*, 2013). The orange fleshed varieties in the current study are therefore better sources of dietary calcium than the non-orange fleshed varieties.

Copper was below detectable levels in Dimbuka and Kyebadula varieties. The findings of copper levels are within ranges reported in other studies (Neela & Fanta, 2019). Copper (Cu) is nutritionally required in conjunction with iron (Fe) for the red blood cell formation and healthy functioning of the nerves and the immune system. These varieties are generally poor sources of copper.

Phosphorous levels were relatively low considering their ability to contribute about 4.3-11% of the recommended dietary allowance of 800mg/day phosphorous. Low or high phosphorous content in the sweet potatoes could be a result of low or high phosphorous in the soil where they were grown due to low or high soil pH (Laurie *et al.*, 2012; Sanoussi *et al.*, 2016). Phosphorous is an essential mineral in the body as it works together with calcium in strengthening of teeth and bones particularly for children and lactating women (Andzouana & Mombouli, 2012).The values in the current study are within those reported in four South African varieties (Leighton *et al.*, 2010).

The ratio Na/K of less than 1 is essential in control of high blood pressure (Alinnor & Oze, 2011). All the eight varieties are therefore suitable as they have a Na/K ratio of less than 1. Ca / P ratio ranged from 0.00 to 2.77. Ca/P ratio of greater than 1 is best since it fosters calcium absorption in the small intestines (Adjatin *et al.,* 2013). The orange fleshed varieties in this study are therefore the best for posting Ca/P ratio above 2 while the non-orange fleshed had the ratios less than 1. Ca/Mg ratio ranged 1.11 to 2.09. A value of 1 is usually recommended since magnesium is vital in calcium metabolism in bones (Sanoussi *et al.,* 2016). All the eight varieties had Ca/Mg ratios exceeding 1 thus other dietary source for the two minerals can be utilized to balance the ratio.

Pasting profiles of flour from eight sweet potato varieties

Orange fleshed varieties in the current study had significantly lower ($p \leq 0.05$) pasting temperatures than the non-orange fleshed, a finding in agreement with that in an earlier study of 10sweet potato varieties (Nabubuya *et al.,* 2012). Pasting temperature is the minimum temperature required to gelatinize or cook the flour and where viscosity increase at its first detectable level is measured (Julianti *et al.,* 2015). Lower gelatinization temperature has been associated with greater water availability (Coral *et al.,* 2009). This is observed in the current study where the orange fleshed varieties had higher moisture contents and subsequently lower gelatinization temperatures. Pasting temperature range of 65 to 72oC has been reported in the literature (Mohd Hanim *et al.,* 2014). Sweet potato flours with lower pasting temperatures are likely to have higher amylose content (Olatunde *et al.,* 2016). Pasting temperature is important during processing as it determines the swelling, gelatinization and gel formation .Higher pasting temperatures could mean that the flour possesses great structural rigidity (Aprianita *et al.,* 2009; Mohd Hanim *et al.,* 2014). From the results of the current study, the non-orange fleshed varieties Kawogo, Kyebadula, Zidamukooti and Dimbuka are likely to possess lower amylose content and smaller starch granules which require higher temperatures in processing.

Gelatinization time ranged from 8.20±0.28 to 15.50±2.12 minutes. Kenspot 4, Kabode, Vitaa and Sallyboro (orange fleshed) varieties had significantly ($p<0.01$) lower gelatinization time than the white and yellow fleshed varieties. Rate of gelatinization is determined by the size of starch granules in the flour since larger granules swell faster and tend to give higher pasting viscosities24.

Peak time is determined by the rate of water absorption by the swelling granules of starch in the flour (Nabubuya *et al.,* 2012). In the current study, orange fleshed (OFSP) varieties required lesser time (10.40 – 12.60minutes) than that (13.50 – 20.50 minutes) required by the non-orange fleshed varieties to reach peak viscosity. OFSP varieties in this study are therefore likely to possess larger starch granules which absorbed water faster.

When gelatinized starch reaches the maximum viscosity during heating in water, this point is referred to as peak viscosity[24]. Lowest peak viscosities (124-590cP) were recorded in the orange fleshed varieties in the present study. Highest peak viscosity was attained by Dimbuka variety (1060±74cP). Higher peak viscosities indicate higher thickening power of the flour in food processing (Eke-Ejiofor, 2015); thus, the flour can be a suitable thickening agent. Dimbuka, Kyebadula and Zidamukooti flours could be suitably utilized as thickening agents in sauces and soups due to their high peak viscosities. Hotpaste Viscosity (HPV) is the lowest viscosity that is achieved when the flour paste is held at 95^{o}C and can be used to indicate the paste's ability to withstand breakdown during cooling (Nabubuya *et al.,* 2012). Dimbuka had the highest value (759cP) while Kabode, Vitaa and Sallyboro (OFSP) had lowest values (69, 67 and 73cP respectively) of HPV.

Breakdown viscosity (BDV) is the difference between PV and HPV. BDV is an indication of the ease with which the swollen granules in the paste can be disintegrated (Julianti *et al.,* 2015). Flours with high BDV like Kyebadula, Kawogo and Zidamukooti are likely to form weaker gels since they possess low ability to withstand the heat and shear stress during cooking (Mohd Hanim *et al.,* 2014; Nabubuya *et al.,* 2012). Such are useful in making pastries. Cold paste viscosity (CPV) is achieved after cooling the paste to 50^{o}C resulting in gel/paste formation due to the re-association of starch granules (Nabubuya *et al.,* 2012). CPV values were significantly ($p<0.001$) different among the varieties and the differences could be associated with amylose content differences. CPV for the flours were higher than respective PV. High CPV levels show great potential for high retrogradation hence gel formation (Tsakama *et al.,* 2011).

SBV is the difference between CPV and HPV. Low SBV values show a low tendency to retrogradation (Olatunde *et al.,* 2016). Setback viscosities of the eight varieties did not differ significantly. Values of the pasting profiles of flour from these eight sweet potato varieties were lower than those reported in other ten varieties (Nabubuya *et al.,* 2012). Flours with high SBV like Kyebadula, Kenspot 4 and Dimbuka are not suitable for products like pie fillings as high retrogradation is likely to cause syneresis. Flours with high paste viscosities could be suitably utilized as thickeners and stabilizing agents in some food products while flours with low paste viscosities like Kabode, Vitaa, Sallyboro could be suitable for food formulations like weaning foods (Olatunde *et al.,* 2016). Flours with high peak viscosities like Dimbuka could be suitable in food applications where high gel strength and elasticity matter and in baked products where volume of product is a very important quality[13].

Correlations between physico-chemical properties and pasting properties

Significant ($p<0.001$), strong positive correlations ($r= 0.706$ to 0.882) between carbohydrates content and pasting properties of the flours and also significant ($p< 0.01$) strong positive correlations ($r = 0.543$ to 0.789) between fiber content and pasting properties imply that higher contents of carbohydrates and fiber resulted in higher paste viscosities of the flours. Flours with larger size of starch granules were likely to have higher paste viscosities since the granules swell and break faster.

Higher levels of Rs in sweet potato results in low pasting viscosities since Rs have a higher affinity than starch for available water in the flour-water paste thereby reducing the starch swelling ability (Nabubuya *et al.,* 2012). Strong correlations between pasting properties and the chemical components (fiber, protein, fat, carbohydrates, reducing sugars, ash) could probably be reflective of the high solubility of these chemical components. These outcomes likely imply that carbohydrates, fiber, starch and reducing sugars contents in sweet potato pose a significant effect on the pasting viscosities of the flours.

Correlation coefficients between the various pasting properties of the flours

Increase in gelatinization time resulted in increase in peak temperature, peak time, PV, SBV and TV of the flour. The various pasting properties had positive interrelationships implying that flours with high peak viscosities had high SBV and TV.

Conclusion and Recommendations

Variations in the physico-chemical properties of sweet potatoes are due to the varietal differences and ecological environment where they are grown. The orange fleshed varieties are richer in mineral content than the non-orange fleshed sweet potato varieties. Pasting viscosities of flours from the orange fleshed varieties are lower than the white and pale-yellow fleshed varieties. Pasting viscosities are negatively correlated with all the minerals except for phosphorous which is positively correlated. There is need to blend sweet potato flours which are rich in nutrients with other flours with higher paste viscosities for better quality end products in food processing. This will ensure diversification of sweet potato utilization and prolonged shelf life when processed into flour. Further studies should be done to establish changes in the pasting profiles of the flours stored over a period of time.

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