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Physico-chemical properties of selected Irish potato varieties grown in Kenya

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Potatoes have attracted great interest as a feasible solution to food insecurity and climate change in Kenya. Many varieties have been developed but their nutritional value and suitability for domestic and industrial use are not sufficiently studied. A comparative study of physical attributes (tuber weight, size, shape, eye depth and number, specific gravity, colour) and nutrient composition (proximate, minerals, vitamins, and simple sugars) of three varieties (Unica, Shangi and Dutch robjin) were evaluated using standard methods. Shangi and Unica had lengths above 50 mm recommended for French fry processing, but had deep eyes (1.54-2.98 mm). Unica had a red skin colour while Shangi was yellow. Both varieties had yellow coloured flesh. The specific gravity of the varieties ranged from 1.08-1.12. Shangi and Unica were suitable for processing based on their physical attributes except for eye-depths. Dutch robjin had the highest content of protein (1.76%), carbohydrates (20.43%), total ash (1.10%), crude fibre (1.11%), iron (0.87 mg/100 g), thiamine (0.036 mg/100 g), niacin (0.93 mg/100 g), pyridoxine (1.92 mg/100 g) and folic acid (34.62 μg/100 g). Unica had the highest zinc (0.41 mg/100 g) and calcium (8.51 mg/100 g) contents. Reducing sugar content across the three varieties was within recommended range for processing (97.75-107.53 mg/100 g). There was a significant ($p < 0.05$) varietal difference in most of the nutrient components. Dutch Robjin showed the best nutritional quality.

Key words: Potato quality, *Solanum tuberosum* L., physical characteristics, nutrient content, food composition.

INTRODUCTION

The contribution of potatoes (*Solanum tuberosum* L.) to the supply of food in developing countries has been increasing steadily (Okello et al., 2016). Kenya is the fifth largest producer of potatoes in Sub-Saharan Africa, with production and consumption rising faster than any other root crops and cereals (Taiy et al., 2016). Potato is the second most valuable food and cash crop after maize in Kenya (Ogolla et al., 2015). However, due to climate changes affecting the production and yield of maize, potato, which matures faster is expected to overtake

Figure 1. Tuber grades of ShangiUnica and Dutch robjin.

maize in terms of production and consumption (Mumia et al., 2018). Potatoes are also affordable and can be stored for relatively long periods after harvest without heavy loss of quality, traits that enhanced their relevance for food security (Muthoni et al., 2017; Navarre et al., 2019). Additionally, following rapid shrinkage of arable land due to increasing population and urbanization, crops like potatoes which can produce more food, nutrients, and cash per unit area and time are on high demand (Devaux et al., 2020). The high productivity and affordability of potato make it an ideal complement to maize which is over-relied upon as the predominant staple for food security in Kenya.

Not only are potatoes important food security crops, they are also great candidates for commercial utilization. Potato tubers are either consumed as fresh or processed into products such as French fries, crisps, and canned potatoes (Hussain, 2016). Processing adds value to the potatoes, increases their shelf-life and convenience, reduces post-harvest losses, wastage, and produces a wide range of products for different applications (Ministry of Agriculture, Livestock and Fisheries, 2016). In Kenya, the growing population and recent devolution has led to rapid expansion of towns and cities. This has been accompanied by an explosive demand for processed potato products and a tremendous development of fast-food outlets and snack bars in Kenya. There are also numerous media to large scale potato processors such as Tropical heat and NORDA companies. Consequently, there is a high demand for potatoes in terms of quantity and quality to ensure they are suitable for different preparations of fast foods (Maingi et al., 2015). The most common processed potato products in Kenya included crisps, French fries and to a small extent frozen fry (Musita et al., 2019). There is still a huge prospect for expanding the potato market to meet the demand for processed products especially the ready-cut frozen chips and French fries.

In Kenya, however, while new varieties are continually being introduced, their nutritional value and suitability for domestic and industrial use are often overlooked. There is also inadequate information on the processing characteristics of various Kenyan potato varieties, leading to losses during processing, low-quality products, and running out of supplies as processors rely on one

processing variety (Ministry of Agriculture, Livestock and Fisheries, 2016). Additionally, mechanization during production and processing remains a challenge. Processors in Kenya attribute some of their losses to lack of tubers grading and mixing of different potato varieties (Ministry of Agriculture, Livestock and Fisheries, 2016). Some processes such as sorting and grading of tonnes of potato are still done manually especially by small scale producers and processors, thereby increasing labor costs and reducing production rates (Abong and Kabira, 2015). Physical characteristics are vital parameters for the design of grading, sorting, conveying, peeling, slicing/cutting and packaging systems (Abedi et al., 2019).

Information on the nutritional value of various potato varieties commonly grown in Kenya is insufficient. Various factors influenced the nutritional composition and physical properties of potatoes with potato variety being considered among the most significant (Abbasi et al., 2019; Leonel et al., 2017; Yang et al., 2015). This study aimed at characterizing the physical attributes that influence processing, and nutritional composition of three Irish potato varieties grown in Kenya.

MATERIALS AND METHODS

The study entailed a comparative evaluation of three Irish potato varieties (Shangi, Unica, and Dutch robjin) grown in Kenya. The varieties were cultivated under the same cultural practices and agronomic conditions in Nyandarua County in July-October 2019.

Potato tubers' classification

After harvest, tubers for each variety were categorized into three classes using the maximum dimension (length), so that the potato tubers with length ranging between 100 and 150 mm were classified as grade one, tubers with length ranging from 55 to 99 mm were labeled as grade two and tubers with length less than 55 mm as grade three. Two grades of Shangi and Unica were obtained (Figure 1) and only one grade of Dutch robjin was obtained.

Sample preparation and analysis

Prior to evaluation, the tubers were cleaned using distilled water and dried using a paper towel to get rid of soil and any other inert matter on the tubers. Under physical attributes, five main parameters; tuber weight, size, shape, eye number and depth, specific gravity and skin and flesh colours were measured. Four main parameters were characterized under nutrient composition; proximate content, minerals, vitamin B complex and simple sugars. Thirty tubers were sampled for physical attributes evaluation. Nutrition analyses were conducted in triplicate.

Physical tuber characteristics determination

For physical properties evaluation, only two varieties (Shangi and Unica) were considered because Dutch robjin yielded only one grade. Thirty representative tubers of similar size were selected from each variety.

Tuber weight

Each individual tuber, from the thirty-representative selected, was weighed using an electronic scale according to the method described by Zheng et al. (2016). The averages for each variety and grade were calculated to obtain mean weight.

Tuber size

Tuber size was measured as described by Abedi et al. (2019). Three linear dimensions were determined by measuring the length (largest diameter of the maximum projected area), width (minimum diameter of the maximum projected area), and thickness (diameter of the minimum projected area) using a Vernier caliper (Mitutoyo-Japan). A length of ≥50 mm is considered suitable for French fries while a width of 40-60 mm is recommended for crisp processing.

Tuber shape

Tuber shape was determined by calculating the shape index (I) of the measured tubers following the formula described by Gamea et al. (2009).

$$I = \frac{L}{\sqrt{DT}}$$

Where, I= shape index, D = tuber width, L =Tuber length, T = tuber thickness. Data obtained were used to classify the tubers as spherical when I was ≤1.5 and I ≥1.5 for oval shape.

Eye-depth and number

Eye depth was determined using a Vernier caliper and recorded as shallow (0-0.2 mm), medium (0.3-0.5 mm), or deep (>0.6 mm). The number of eyes was determined by counting the total number of eyes on each of the 30 tubers per variety.

Specific gravity

Determination of specific gravity was conducted using the method described by Abedi et al. (2019) where the mass of tuber in air and mass of water displaced by the tuber were measured:

$$Specific\ gravity = \frac{Mass\ of\ tuber}{Mass\ of\ water\ displaced}$$

Tuber skin and flesh colour

Colour determination was done as described by Yang et al. (2015) using a hand-held Minolta colour meter (Model CR-200, Osaka, Japan). Skin and flesh colours were measured at three different regions per tuber. The L*, a* and b* values were determined directly from the colour meter. L* represents the darkness or lightness of the sample, a* denotes the redness and b* the yellowness. Calculations were done for hue angle and Chroma value following the method by Yang et al. (2015) using the *a** and *b** values.

Nutrient content

For nutrient composition, all three varieties (Shangi, Unica, and Dutch robjin) were considered. Five representative tubers from each variety were randomly selected for proximate composition analysis. They were hand-peeled and chopped into small pieces for analysis. Tubers for determination of vitamins and reducing sugars were blended into a homogenous puree then analyzed.

Proximate composition

Moisture content, crude protein, crude fibre crude fat, and total ash were determined using AOAC (1995) methods. Total carbohydrates were determined by difference: % carbohydrates = 100- (moisture content + total ash + crude fat + crude fibre + crude protein).

Minerals determination

Iron, zinc, and calcium were determined using AOAC (1995) while phosphorous was determined according to AOAC (1996).

Vitamin B content determination

Vitamins B_1 (Thiamine), B_2 (Riboflavin), B_3 (Niacin), B_6 (Pyridoxine), and B_9 (Folic acid) were determined according to the method by Ekinci and Kadakal (2005). To 5 grams of sample, 20 ml of deionized water was added and the mixture homogenized at medium speed for 1 min. Samples were then eluted through a solid-phase extraction (SPE) with Sep-Pak C18 (500 mg) cartridges. The stationary phase was activated by flushing it with 10ml methanol and 10 ml water adjusted to pH 4.2. Filtration was done for samples through 0.45 µm pore size filters then injected into an Ultra-Flow Liquid Chromatography (UFLC) (Shimadzu Nexera) machine equipped with a UV-Visible diode -array detector (model SPD-M20A), liquid chromatography pump (LC-20AD) and column oven (CTO-10ASvp). The column (Ultisil XB-C18 5-Micron, 4.6 x 250 mm internal diameter) was operated at 40°C with a flow rate of 1ml/min to obtain chromatographic peaks. Vitamins were separated through a gradient elution of 20 min constituting mobile phase A (100 mM KH_2PO_4) and mobile phase B MeOH (0 min-0.5%; 1 min-10%; 5 min-15%; 7.5 min-25%; 11 min-32%; 12.8 min-0%; 20 min-0%). Concentrations of the B-vitamins were calculated using peak areas of the samples and the standard curves of the corresponding standards.

Simple sugars

Simple sugars determination was conducted following the method by Matsuura-Endo et al. (2006). Ten grams of fresh homogenized samples were weighed into pear-shaped flasks and 20 ml ethanol was added and swirled to mix. The mixture was refluxed at 100°C for 60 min and then filtered. The solvent was evaporated to dryness with a rotary evaporator and the dried sample reconstituted with 2ml of distilled water and acetonitrile in the ratio of 1:1. The samples were microfiltered before injecting 20µl into a Shimadzu Nexera Ultra-Flow Liquid Chromatography (UFLC) fitted with a SIL-20A HT prominence autosampler, refractive index detector-20A, and an LC-20AD pump. Separation of sugars was achieved through isocratic elution of water and acetonitrile (25:75) pumped through a normal phase Ultisil NH_2 column with a 6 x 250 mm internal diameter at a flow rate of 1.8 ml/min. The column oven (CTO-10ASvp) was operated at the temperature of 40°C. Sugars were quantified by comparing against standard solutions of fructose, glucose, sucrose, and expressed as mg/100g fresh weight.

Statistical analyses

Taking the varieties as the source of variation, the results were

Table 1. Physical properties of two grades of two potato varieties cultivated in Kenya.

Parameter/variety	Grade 1			Grade 2		
	Shangi	Unica	P-value	Shangi	Unica	P-value
Weight (g)	313.30±22.31[a]	299.70±27.29[a]	0.0974	142.42±14.19[a]	141.78±4.53[a]	0.9034
Length (mm)	123.68±11.75[a]	133.15±8.44[a]	0.0535	89.46±6.33[a]	89.41±7.96[a]	0.9888
Width (mm)	70.65±4.80[a]	69.67±4.04[a]	0.6250	55.87±3.91[a]	53.76±3.98[a]	0.2483
Thickness(mm)	52.89±5.27[a]	50.91±4.21[a]	0.3653	45.26±2.63[a]	43.72±3.08[a]	0.2468
Shape index	2.03±0.21[a]	2.27± 0.19[b]	0.0182	1.79±0.21[a]	1.85±0.15[a]	0.4150
No. of Eyes	15.33±2.68[b]	10.72±1.41[a]	<0.0001	11.87±2.51[b]	9.42±2.77[a]	0.0006
Eye-depth	2.98±0.65[b]	2.04±0.80[a]	0.0043	2.09±0.54[a]	1.69±0.35[a]	0.0969
Specific gravity	1.12±0.02[b]	1.08±0.01[a]	<0.0001	1.11±0.03[b]	1.08±0.01[a]	0.019

Values are means ± standard deviation (n=30). Means with different superscript letters in the same row are significantly different at p<0.05.

subjected to one-way analysis of variance (ANOVA) using STATA software (version 2011). Tests were conducted at p ≤ 0.05 level of significance and Bonferroni's mean separation test was applied to determine whether the differences between the means were statistically significant.

RESULTS AND DISCUSSION

Physical characteristics

The physical tuber characteristics are presented in Table 1. Depending on their length, the tubers were manually categorized into different classes based on the market segregation. Shangi and Unica yielded grades 1 and 2 while only one category (grade-2) was obtained for Dutch robjin, hence it was not considered for physical attributes evaluation.

Tuber weight

There was no significant variation (p>0.05) in the weight of the two varieties classified under grade one. The average weight for grade-1 Shangi tubers was 313.30 g while that of Unica was 299.70 g. Similarly, Shangi (142.42 g) and Unica (141.78 g) tubers in grade-2 did not display a significant variation. Tuber weight is important as it is one of the major indices for determining the yield of produce and also, potatoes are usually sold on weight basis. Average weights of both varieties and grades were consistent with the mean values for grade-1 (213.17-220.94 g) and -2 (132.00-147.08 g) tubers reported by Abedi et al. (2019).

Tuber geometric properties (length, width, thickness)

There was no significant difference (p>0.05) in length between Shangi and Unica tubers in both grades 1 and 2. For grade-1, Shangi tubers had an average length of 123.68mm while Unica had an average length of 133.15

mm. Grade-2 tubers of Shangi had an average length of 89.46 mm, while Unica was 89.41 mm long. Similarly, there was no significant difference in tuber width between Shangi and Unica for both grades. Grade-1 Shangi tubers had a width of (70.65 mm) while Unica had a width of 69.67 mm. Grade-2 tubers of Shangi and Unica had average widths of 55.87 and 53.76 mm, respectively. A similar observation was made for thickness whereby no significant difference was observed between the two varieties. Shangi displayed thickness values of 50.91 and 45.26 mm for grade-1 and 2, respectively. Unica presented tuber thickness of 50.91 and 43.72 mm for grades-1 and-2, respectively. Length, width, and thickness are important parameters in potato tubers as they determine the suitability of tubers of processing of products such as French fries and crisps. Long tubers are ideal for French fry processing while tubers with large widths are preferred for crisp processing. Tubers with a length 50 mm and above are ideal for French fry processing (Nain et al., 2019), and based on length alone, both varieties and grades in this study are suitable for French fries.

Tubers with widths ranging between 40 to 60 mm are recommended for crisp processing (Lara and Malaver, 2019). Tubers having width greater than 60 mm are unsuitable because they are likely to produce fragile crisps that are prone to breakage during packaging and transportation. In this regard, both Shangi and Unica varieties in grade-1 failed this criterion. For the grade-2 category, both varieties had mean widths of 53.76 and 55.87 mm and were therefore within the recommended range for crisp processing.

Tuber shape

Tuber shape as per the shape index values demonstrated that Shangi and Unica varieties were oval. There was a significant difference in the shape index between grade-1 tubers with Unica recording the higher shape index value of 2.27 while Shangi recorded a value of 2.03. Tubers in

Table 2. Skin and Flesh colour profiles of three Irish potato varieties grown in Kenya.

Variety	(L*) Lightness	(a*) Redness	(b*) Yellowness	(C*) Chroma	(H*) Hue angle
	Skin colour attributes				
Shangi	60.94±1.74[b]	1.23±1.25[a]	25.64±1.54[b]	25.70±1.52[b]	87.17±2.84[b]
Unica	48.87±1.95[a]	14.05±1.91[b]	12.34±1.[14a]	18.79±1.24[a]	41.50±5.61[a]
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Flesh colour					
Shangi	67.28±4.24[a]	-4.81±0.72[a]	21.14±4.03[a]	21.68±4.08[a]	102.89±0.71[b]
Unica	66.08±2.78[a]	-4.74±0.63[a]	23.99±1.69[b]	24.47±1.67[b]	101.22±1.59[a]
P-value	0.4171	0.8080	0.0367	0.0430	0.0010

Values are means ± standard deviation (n=30). Means with different superscript letters in the same row are significantly different at $p<0.05$.

grade-2 had no significant difference in shape index. Unica scored a value of 1.85 while Shangi had 1.79. These values exceeded the 1.5 threshold and tubers of both varieties were thus classified as oval. Both varieties and grades met the prerequisites for French fry processing since long and oval tubers are preferred (Wayumba et al., 2019).

Eye number and depth

Eye number and depth are largely a varietal characteristic (Nain et al., 2019). A significant difference (p<0.05) in the number of eyes was observed between the varieties. Shangi had the highest average number of eyes across both grades-1 and -2 (15.33 and 10.72, respectively). Unica had a mean eye number of 11.87 for grade-1 and 9.42 for grade-2. These values were higher compared to those reported by Rahman et al. (2017). Shangi variety also had deeper eyes than Unica for both grades. Varieties with shallow eyes are the most ideal for processing as deep eyes result in high losses during peeling and trimming, thus reducing product yield. Eye depth is classified as shallow, medium, and deep (Rahman et al., 2017). Based on this classification, both varieties under this study were found to have deep eye depths which might affect peeling and trimming efficiency during processing.

Specific gravity

There was a significant difference in the specific gravities of the varieties, both grades-1 and -2. Shangi had the highest specific gravity for both grades-1 (1.12) and -2 (1.11). For Unica, both grades recorded a specific gravity value of 1.08. These values were in agreement with those observed by other studies. Lara and Malaver, (2019) reported specific gravity in the range of 1.070-1.113 in eighteen potato varieties cultivated in Peru. Similarly, a range of 1.061-1.096 specific gravity was

observed by Mohammed (2016) in three Ethiopian potato varieties. Specific gravity is considered one of the most practical indices for potato quality as it is positively correlated with starch content, total solids, and dry matter (Mohammed, 2016). High specific gravity is desired for processing of dehydrated and fried products as it enhances high product recovery rates, lower oil absorption, less energy consumption during processing, better flavor and texture, and generally high quality of fried products (Soboka et al., 2017; Wayumba et al., 2019). Tubers with low specific gravity on the other hand are suitable for canning because they are less likely to fall apart during processing (Ndungutse et al., 2019). Both varieties and grades had a specific gravity of at least 1.07 recommended for processing of crisps and French fries (Rahman et al., 2017).

Skin and flesh colour

Colour is an important parameter as it is largely the main characteristic that influences consumers' perception (Spence, 2015). The varieties analyzed in this study varied significantly (p<0.05) in terms of skin colour (Table 2). Shangi was yellowish based on the high *b** value of 25.64 relative to Unica's 12.34. Unica had reddish skin as demonstrated by the higher value of *a** of 14.05 compared to 1.23 for Shangi. Shangi variety was further characterized by a higher hue angle (H*) of 87.17 which fell in the yellow region of the colour scale; while Unica had a lower value (41.50) leaning towards red colour. Shangi displayed higher luminosity as displayed by the higher lightness (L*) value (60.94) compared to Unica which had 48.87. In Kenya, white, yellow, and red skin colours are associated with good quality by many consumers.

With regard to flesh colour, there was no significant difference (p>0.05) between the varieties in terms of lightness and redness. The *b** values indicated that both varieties were yellowish. There was however a significant difference in the *b** values with Unica displaying a higher

Table 3. Proximate composition of three Irish potato varieties grown in Kenya (g 100g^{-1} fresh weight).

Parameter	Variety			P value
	Shangi	Unica	Dutch Robjin	
Moisture	78.50±0.56[b]	81.03 ±0.33[c]	75.55±0.94[a]	0.0002
Crude Protein	1.63±0.10[a]	1.67±0.03[a]	1.76± 0.09[a]	0.2098
Carbohydrate	18.15±0.45[b]	15.61±0.16[a]	20.43±1.03[c]	0.0003
Total ash	0.89±0.05[a]	0.88±0.01[a]	1.10±0.03[b]	0.0004
Crude fat	0.08±0.01[a]	0.07±0.01[a]	0.08±0.02[a]	0.0950
Crude fibre	0.78±0.05[ab]	0.77±0.15[a]	1.11±0.15[b]	0.0246

Values are means ± standard deviation (n=30). Means with different superscript letters in the same row are significantly different at p<0.05.

b* value (23.99) than Shangi (21.14). Additionally, Unica scored a hue angle value of 101.22 while that of Shangi was 102.89. These values are situated in the second quadrant of the CIE *L*a*b** colour scale whereby the lowest values fall within the yellow region (90°h) and the highest values on the green side (180°h) (Kortei et al., 2015). There was a significant difference between the chroma values of the two varieties with Unica having a higher C* value of 24.47 than Shangi whose C* value was 21.68. This implies that Unica's flesh colour had a higher intensity than that of Shangi. Similar values of chroma were reported by Yang et al. (2015) in eight processing potato varieties cultivated in Spain. Yellow fleshed potatoes have been reported to have higher antioxidant contents compared to white fleshed potatoes (Beals, 2018).

Nutrient content of the potato varieties

Proximate composition

Unica variety had the highest moisture content (81%) followed by Shangi (78.5%) and Dutch Robjin (75.55%) (Table 3). These values compared well with the range reported by Tsikrika et al. (2019) and Sato et al. (2017) of 72.48-81.54% and 78.55- 82.98%, respectively. Higher values of moisture content (81.10-83.74%) have been reported by Jin et al. (2016). Low moisture content is desired in potato tubers because water content is inversely proportional to the dry matter content. Low moisture content linked to high dry matter content is associated with better crispiness and texture of fried products, less frying time to eliminate moisture from crisps and fries, less oil absorption during frying, lower risk of soggy products and discolouration during cooking, and higher productivity and profitability (Cruz et al., 2018). A moisture content of less than 80% is favourable for processing, and in this study, Dutch robjin and Shangi met this criterion.

Crude protein content did not vary significantly across the varieties. Dutch robjin had protein content of 1.76

g/100 g followed by Unica with 1.67g/100 g then Shangi with 1.63 g/100 g. These values compared well with those of Ngobese et al. (2017) who cited protein content values between 1.57-2.87 g/100 g in potatoes grown in South Africa. Similarly, protein content ranging between 1.6-1.8 g/100 g in Brazilian varieties was reported by Fernandes et al. (2015). Protein content values observed in this study were higher than the content (0.913 g/100 g) reported in a Polish potato variety by Wszelaczyńska et al. (2020).

For carbohydrates, the results indicated a significant difference (p<0.05) across the three varieties with Dutch Robjin having the highest content (20.43 mg/100 g), followed by Shangi (18.15 mg/100 g) and then Unica (15.61 mg/100 g). This difference could be attributed to genotypic differences among varieties. These values compare favourably with the findings of Tsikrik et al. (2019) and Jin et al. (2016) who reported a range of 16.04-23.06 and 15.14 -16.07 g/100 g, respectively. Carbohydrate is the principal macronutrient in potatoes with starch being predominant (Beals, 2018). Starch content influences the quality of processed potato products. Starch content has been reported to affect crisp texture whereby higher starch levels yield greater crispiness of the potato chip slices (Abbasi et al., 2019). Tubers with high carbohydrate content would thus be suitable for processing of crispy potato chips.

Total ash differed significantly (p<0.05) between Dutch robjin and the other two varieties. Ash content was highest in Dutch robjin with 1.10 g/100 g while Shangi and Unica had ash contents of 0.89 and 0.88g/100g, respectively. This variation was attributed to varietal differences. This range was in agreement with the findings of Jin et al. (2016) who reported total ash content in the range of 0.87-1.04 g/100 g in four Korean potato varieties. Similar ranges of 0.81-1.38 and 0.88-1.03 g/100 g were reported by Leonel et al. (2017) in Brazilian potato varieties and Sato et al. (2017) in Japanese varieties, respectively.

Crude fat content did not differ significantly (p>0.05) across the three varieties. Shangi and Dutch robjin had crude fat content of 0.08 g/100 g while Unica contained

Table 4. Minerals content of three Irish potato varieties grown in Kenya.

Mineral	Level (mg 100^{-1} fresh weight)			P value
	Shangi	Unica	Dutch Robjin	
Iron	0.63±0.02[b]	0.81±0.07[a]	0.87±0.05[a]	0.0028
Zinc	0.37±0.05[a]	0.41±0.03[a]	0.28±0.01[b]	0.0071
Calcium	5.44±1.23[a]	8.51±1.30[a]	7.63±1.69[a]	0.0903
Phosphorous	32.37±1.32[a]	28.18±1.10[b]	21.02±1.03[c]	0.0001

Values are means ± standard deviation (n=30). Means with different superscript letters in the same row are significantly different at p<0.05.

0.07 g/100 g. These values were comparable with crude fat in the range of 0.03-0.13 g/100 g reported by Liang et al. (2019) in Chinese potato varieties. The values in this study were, however, slightly higher than the range of 0.03 and 0.06 g/100 g reported by Sato et al. (2017) in four Japanese potato varieties. Although the low fat content in potatoes might not have any substantial nutritional effect, it is important in enhancing the sensory attributes of cooked tubers and promoting cellular integrity and resistance to bruising in tubers (Kalita and Jayanty, 2017).

There was a significant difference (p<0.05) in the content of crude fibre between Unica and Dutch robjin. Crude fibre was highest in Dutch robjin (1.11 g/100 g), followed by Shangi (0.78 g/100 g) and then Unica (0.77 g/100 g). These values are consistent with those reported by Leonel et al. (2017) of 0.4-0.8 g/100 g and were slightly higher than the ranges reported by Garcia et al. (2015) of 0.61-0.66 mg/100 g. Generally, the level of fibre in potatoes is low compared to other vegetables and root crops. Interestingly, however, processed potatoes such as French fries and potato flakes have been found to have a higher concentration of crude fibre (Raigond et al., 2020).

Mineral content

Iron content differed significantly (p<0.05) between Shangi and the other two varieties as shown in Table 4. Shangi had the lowest iron content (0.63 mg/100 g) while Unica and Dutch robjin had iron content of 0.81 and 0.87 mg/100 g. This range is consistent with the values reported for 13 Andean potato varieties by Wijesinha-Bettoni and Mouillé (2019) of 0.94-3.94 mg/100 g. A higher range of iron content (1.24-2.52 mg/100 g) was reported by Fernandes et al. (2015) in two potato varieties cultivated in Brazil. While the iron content in potatoes is not particularly exceptional, its bioavailability exceeds that of many other iron-rich plants owing to extremely low levels or no antinutrients and chelators which inhibit iron absorption (Beals, 2018). Additionally, potatoes are rich in vitamin C which promotes iron absorption (Beals, 2018).

There was a significant variation in zinc content (p<0.05) with Unica presenting the highest concentration (0.41 mg/100 g) and Dutch robjin the least (0.28 mg/100g). This range is in agreement with the values of 0.23-0.39 mg/100 g reported in raw potatoes by Campos and Ortiz (2020). Similarly, Fernandes et al. (2015) and Liang et al. (2019) reported zinc content ranging between 0.20-0.37 and 0.347-0.438 mg/100 g in Brazilian and Chinese potato varieties, respectively. These concentrations are lower than those of cereals and legumes but just like iron, the bioavailability of zinc in potatoes may be higher due to low amounts of phytic acid which hinders absorption of zinc and iron (Campos and Ortiz, 2020).

Calcium levels did not differ significantly (p>0.05) across the varieties. Unica had calcium content of 8.51 mg/100 g, followed by Dutch robjin with 7.63 mg/100 g and Shangi with 5.44 mg/100 g. This range compares well with the values of 5-11 mg/100 g reported by Fernandes et al. (2015) in Brazilian potato varieties. Jin et al. (2016) and Ngobese et al. (2017) also reported a similar range of calcium content (5.25-9.31) and (5.2-10.2) mg/100 g in four Korean and European varieties respectively. Potatoes are generally not valuable sources of calcium but due to lower phytic acid concentration, bioavailability of calcium from potatoes is relatively high (Raigond et al., 2020).

Phosphorous content (mg/100 g) across the three varieties was significantly different (p<0.05). Shangi recorded the highest value (32.37) followed by Unica (28.18) and then Dutch robjin (21.02). These varietal differences could be attributed to varietal-genotype differences influencing the rate of phosphorous uptake from the soil. Phosphorous uptake influencing phosphorous content in potatoes is important as it has been found to be positively related to tuber dry matter content and low content of total sugars (Leonel et al., 2017). Phosphorous values observed in this study were lower than the ranges of 33.00-63.27 and 43.5-47.7 mg/100 g reported by Jin et al. (2016) and Ngobese et al. (2017), respectively. This variation may be due to differences in growing conditions including geographical factors and cultural practices. Phosphorous is among the main mineral present in tubers and is a healthy key player for healthy teeth, bones, and cells (Navarre et al., 2019).

Table 5. Vitamin B content of three Irish potato varieties grown in Kenya.

Parameter	Level (fresh weight)			P value
	Shangi	Unica	Dutch Robjin	
Thiamine (B_1) mg/100 g	0.026 ± 0.01^a	0.025 ± 0.02^a	0.036 ± 0.01^b	<0.0001
Riboflavin (B_2) mg/100 g	0.023 ± 0.01^a	0.023 ± 0.02^a	0.023 ± 0.02^a	0.8987
Niacin (B_3) mg/100 g	0.83 ± 0.14^{ab}	0.67 ± 0.05^a	0.93 ± 0.09^b	0.0439
Pyridoxine (B_6) mg/100 g	0.55 ± 0.06^a	0.36 ± 0.05^a	1.92 ± 0.02^b	< 0.0001
Folic Acid (µg/100 g)	12.92 ± 1.13^a	11.21 ± 0.66^a	34.62 ± 1.06^b	< 0.0001

Data are mean ±standard deviation (n=3). Means on the same row with different letters are statistically significant (P<0.05) n=3.

Vitamin B content

Thiamine content (mg/100 g) differed significantly (p<0.05) between Shangi and the other two varieties. Dutch robjin had the highest content (0.036) followed by Unica (0.026) and then Shangi with 0.025 as shown in Table 4. These values compared well with the findings of Jin et al. (2016) who observed a range of 0.023-0.034 in four potato varieties. Thiamine content in this study was also fairly comparable with the range reported by Liang et al. (2019) of 0.03-0.05 mg/100 g in fourteen Chinese potato varieties.

There was no significant variation in riboflavin content across the three varieties. All the varieties recorded an equal concentration of 0.023 mg/100 g, which was in alignment with values of 0.021- 0.059 mg/100 g, reported by Liang et al. (2019) in Chinese potato varieties.

A significant difference in Vitamin B_3 (Nicotinamide) concentration was observed among the varieties (Table 5). Dutch Robjin had the highest concentration (0.93 mg/100 g) while Unica variety had the least content (0.67 mg/100 g) of Vitamin B_3. Shangi had vitamin B_3 content of 0.83 mg/100 g. In a study conducted by Jin et al. (2016) on potato varieties cultivated in Korea, lower Vitamin B_3 concentration ranging between 0.015 and 0.280 mg/100 g was reported. Vitamin B_3 is very important in potatoes as it has been demonstrated to be a potent inhibitor of acrylamide synthesis during potato processing (Ashkezari and Salehifar, 2019) (Table 5).

Vitamin B_6 (Pyridoxine) varied significantly across the varieties with Dutch Robjin recording the highest concentration (1.92 mg/100 g) and Unica the lowest (0.36 mg/100 g). Potatoes are a good source of vitamin B_6 which is involved in more bodily functions than any other single nutrient. It is a strong antioxidant and a versatile co-factor of numerous metabolic processes (Navarre et al., 2019). The concentrations of vitamin B_6 obtained in this study were higher than the values reported by Bagri et al. (2018) of 0.052-0.102 mg/100 g. A 150 g medium-size raw tuber of Dutch robjin would possibly contribute up to 169% of the Recommended Dietary Allowance (RDA) for pyridoxine (1.3-1.7 mg/day) for both male and female adults (Ministry of Health, 2011).

Folate content varied significantly (p<0.05) with Dutch robjin recording the highest value (34.62 µg/100 g) followed by Shangi (12.92 µg/100 g) then Unica (11.21 µg/100 g). These values are consistent with folate content values of 12-41 µg/100g reported by Navarre et al. (2019). Higher folate concentrations (33-385 µg/100 g) were reported by De Lepeleire et al. (2018) in yellow-fleshed potato cultivars. A similar observation was made in this study whereby cultivar Dutch robjin which had the highest yellowness index exhibited the highest folate concentration.

Simple sugars

There was a significant difference (p<0.05) in the content of simple sugars across the three varieties (Table 6). Unica contained the highest fructose content (59.14 mg/100 g) followed by Dutch robjin (52.08 mg/100 g) and then Shangi (37.97 mg/100 g). Glucose was highest in Shangi (59.78 mg/100g), followed by Dutch robjin (55.06 mg/100 g) and then Unica (48.39 mg/100 g). Sucrose concentration ranged between 62 and 115 mg/100 g with Dutch robjin recording the highest content and Unica the least. Total reducing sugars ranged between 97.75-107.53 mg/100 g which compared positively with the range of 80-250 mg/100 g observed by Mareček et al. (2016).

Simple sugar content is a critical quality parameter when selecting tubers for processing. During high temperature cooking such as frying, and baking, reducing sugars in potatoes interact with free amino acids such as asparagine in a non-enzymatic reaction is called Maillard reaction (Campos and Ortiz, 2020). This reaction leads to the formation of a compound called acrylamide (a potential carcinogen) that has caused global food safety concerns over products such as French fries and crisps (Campos and Ortiz, 2020). In addition to acrylamide formation, high reducing sugar content leads to production of dark-coloured, bitter fries and crisps which are undesirable (Clasen et al., 2016). A limit of 200 mg/100 g is recommended for tubers intended for processing (Mareček et al., 2016). All three varieties

Table 6. Simple sugars content of three Irish potato varieties grown in Kenya (Fresh weight basis).

Parameter	Simple sugars (mg 100^{-1}) / Potato variety			P value
	Shangi	Unica	Dutch Robjin	
Fructose	37.97±3.37[b]	59.14±3.16[a]	52.08±2.14[a]	0.0003
Glucose	59.78±2.64[a]	48.39±2.13[b]	55.06±0.29[a]	0.0012
Sucrose	93.14±2.81[b]	62.39±2.05[c]	115.30±1.84[a]	< 0.0001
Total reducing sugars	97.75±1.79[b]	107.53±2.74[a]	107.14±1.87[a]	0.0024

Values are means ± standard deviation (n=3). Different superscript letters in the same row indicate significant differences at $p<0.05$.

under this study met this requirement.

Conclusion

With regard to physical characteristics, there were no significant variations in the weight and geometric properties of the varieties. The eye number and depth, shape index and specific gravity on the other hand exhibited significant differences between the varieties. Both Shangi and Unica in grades-1 and -2 were suitable for French fry processing based on their shape and length. Both grades-1 and -2 tubers were also acceptable for crisp processing based on their width. However, grade-1 tubers would yield large fragile crisps prone to breaking during packaging and transport, thus grade-2 tubers are recommended. With respect to specific gravity, both varieties in grades-1 and -2 had values recommended for processing in order to yield high quality products. However, both Shangi and Unica across both grades had deep eyes which might affect peeling and trimming efficiency during processing. Information on the tuber physical characteristics obtained in this study is valuable in predicting suitability for use. This information can also be used for designing grading, peeling and packaging equipment to improve mechanization and boost performance in the potato industry.

There were significant differences in the nutrient content of the varieties evaluated in this study. Dutch Robjin showed superior nutritional attributes as it was ranked highest in proximate and Vitamin B contents. Unica is a relatively new variety, believed to be rich in zinc and iron. In this study, Unica recorded the highest zinc and calcium contents. The results of this study emphasize that potatoes can contribute significantly to human nutrition.

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CONFLICT OF INTEREST

The authors have not declared any conflict of interests.

REFERENCES

Abbasi KS, Qayyum A, Mehmood A, Mahmood T, Khan SU, Liaquat M, Sohail A, Ahmad A (2019). Analysis of selective potato varieties and their functional assessment. Food Science and Technology, 39(2):308-314.

Abedi G, Abdollahpour S, Bakhtiari MR (2019). The physical and mechanical properties of potato (*Solanum tuberosum* L.) tubers as related to the automatic separation from clods and stones. Research in Agricultural Engineering 65(3):77-84.

Abong GO, Kabira J N (2015). Potential food safety concerns in fried potato products in Kenya. Open Access Library Journal 02(05):1-11.

AOAC (1995). AOAC Official Methods of Analysis. In Association of Official Agricultural Chemists. Washington, D.C. (16th ed., Vol. 1).

AOAC. (1996). Official methods of analysis of AOAC International (P. Cunniff (ed.); 16th ed., 4). AOAC International.

Ashkezari MH, Salehifar M (2019). Inhibitory effects of pomegranate flower extract and vitamin B3 on the formation of acrylamide during the donut making process. Journal of Food Measurement and Characterization 13(1):735-744.

Bagri DS, Upadhyaya DC, Kumar A, Upadhyaya CP (2018). Overexpression of PDX-II gene in potato (*Solanum tuberosum* L.) leads to the enhanced accumulation of vitamin B6 in tuber tissues and tolerance to abiotic stresses. Plant Science 272: 267-275.

Beals KA (2018). Potatoes, nutrition and health. American Journal of Potato Research 96(315):102-110.

Campos H, Ortiz O (2020). The potato crop. its agricultural, nutritional and social contribution to humankind. In: P. M. Harris (Ed.), The Potato Crop (pp. 37-74). Springer International Publishing. Available at: https://doi.org/10.1007/978-3-030-28683-5

Clasen BM, Stoddard TJ, Luo S, Demorest ZL, Li J, Cedrone F, Tibebu R, Davison S, Ray EE, Daulhac A, Coffman A, Yabandith A, Retterath A, Haun W, Baltes NJ, Mathis L, Voytas DF, Zhang F (2016). Improving cold storage and processing traits in potato through targeted gene knockout. Plant Biotechnology Journal 14(1):169-176.

Cruz G, Cruz-Tirado J, Delgado K, Guzman Y, Castro F, Rojas ML, Linares G (2018). Impact of pre-drying and frying time on physical properties and sensorial acceptability of fried potato chips. Journal of Food Science and Technology 55(1):138-144.

De Lepeleire J, Strobbe S, Verstraete J, Blancquaert D, Ambach L, Visser RGF, Stove C, Van Der Straeten D (2018). Folate biofortification of potato by tuber-specific expression of four folate biosynthesis genes. Molecular Plant 11(1):175-188.

Devaux A, Goffart JP, Petsakos A, Kromann P, Gatto M, Okello J, Suarez V, Hareau G (2020). Global food security, contributions from sustainable potato agri-food systems. in the potato crop (Issue April, pp. 3-35). Springer International Publishing. Available at: https://doi.org/10.1007/978-3-030-28683-5_1

Ekinci R, Kadakal Ç (2005). Determination of seven water-soluble vitamins intarhana, a traditional Turkish cereal food , by high-perfomance liquid chromatography. Acta Chromatographica 15:289-297.

Fernandes AM, Soratto RP, Moreno L, Evangelista RM (2015). Qualidade de tubérculos frescos de cultivares de batata em função da nutrição fosfatada. Bragantia 74(1):102-109.

Gamea G, Abd El-Maksoud MA, Abd El-Gawad AM (2009). Physical characteristics and chemical properties of potato tubers under different storage systems. Misr. Journal of Agricultural Engineering 26(1):385-408.

Garcia ÉL, do Carmo EL, de Pádua JG, Leonel M (2015). Industrial processing potential of potato cultivars. Ciencia Rural 45(10):1742-1747.

Hussain T (2016). Potatoes : Ensuring food for the future. Advances in Plants and Agriculture Research 3(6):178-182.

Jin YX, Kim SM, Kim SN, Kim HR, Kim SC, Hwang J, Choi Y (2016). Food Composition of Raw and Boiled Potatoes. Korean Journal of Food and Cookery Science 32(4):517-523.

Kalita D, Jayanty SS (2017). Nutrient composition of continuous and kettle cooked potato chips from three potato cultivars. Current Research in Nutrition and Food Science 5(2):75-88.

Kortei NK, Odamtten GT, Obodai M, Appiah V, Akonor PT (2015). Determination of color parameters of gamma irradiated fresh and dried mushrooms during storage. Croatian Journal of Food Technology, Biotechnology and Nutrition 10(1-2):66-71.

Lara RT, Malaver RHT (2019). Quality attributes for processing potato clones of purple-fleshed in Peru. Revista de Ciencias Agroveterinarias 18(4):444-452.

Leonel M, do Carmo EL, Fernandes AM, Soratto RP, Ebúrneo JAM, Garcia ÉL, dos Santos TPR (2017). Chemical composition of potato tubers: the effect of cultivars and growth conditions. Journal of Food Science and Technology 54(8):2372-2378.

Liang Z, Tai-hua MU, Meng-mei MA, Ruo-fang Z, Qing-hua SUN, Yan-wen XU (2019). Nutritional evaluation of different cultivars of potatoes (Solanum tuberosum L.) from China by grey relational analysis (GRA) and its application in potato steamed bread making. Journal of Integrative Agriculture 18(1):231-245.

Maingi E, Kaguongo W, Owour, WB (2015). Potato Market Assessment for East Africa 2015.

Mareček J, Ivanišová E, Frančáková H, Musilová J, Krajčovič T, Mendelová A (2016). Evaluation of primary and secondary metabolites in selected varieties of potatoes. Potravinarstvo 10(1):145-151.

Matsuura-Endo C, Ohara-Takada A, Chuda Y, Ono H, Yada H, Yoshida M, Kobayashi A, Tsuda S, Takigawa S, Noda T, Yamauchi H, Mori M (2006). Effects of storage temperature on the contents of sugars and free amino acids in tubers from different potato cultivars and acrylamide in chips. Bioscience, Biotechnology and Biochemistry 70(5):1173-1175.

Ministry of Agriculture, Livestock and Fisheries (2016). The National Potato Strategy 2016-2020.

Ministry of Health (2011). The Kenya National Micronutrient Survey. Available at: http://www.nutritionhealth.or.ke/wp-content/uploads/Downloads/The Kenya National Micronutrient Survey 2011.pdf

Mohammed W (2016). Specific gravity , dry matter content , and starch content of potato (Solanum tuberosum L .) varieties cultivated in Eastern Ethiopia. East African Journal of Sciences 10(2):87-102.

Mumia BI, Muthomi JW, Narla RD, Nyongesa MW, Olubayo FM (2018). Seed Potato Production practices and quality of farm saved seed potato in kiambu and nyandarua counties in Kenya. World Journal of Agricultural Research 6(1): 20-30.

Musita CN, Okoth MW, Abong GO (2019). Postharvest handling practices and perception of potato safety among potato traders in Nairobi, Kenya. International Journal of Food Science 2019 (2342619):1-7.

Muthoni J, Nyamongo DO, Mbiyu M (2017). Climatic change, its likely impact on potato (Solanum tuberosum L.) production in Kenya and plausible coping measures. International Journal of Horticulture, 7(14): 116-121. Available at: https://doi.org/10.5376/ijh.2017.07.0014

Nain CW, Njoya MA, Yunenui PM, Nde SN, Imele H, Nambangia JO, Lendzemo WV, Tata NP, Woin N (2019). Assessing the processing attributes of some potato (Solanum tuberosum L) varieties grown in the North West Region of Cameroon. Journal of Food Science and Technology 4(9): 946-955.

Navarre DA, Brown CR, Sathuvalli VR (2019). Potato vitamins, minerals and phytonutrients from a plant biology perspective. American Journal of Potato Research 96(2):111-126.

Ndungutse V, Muthoni P, Ngoda N, Vasanthakaalam H, Shakala EK, Faraj AK (2019). Processing quality of selected potato (Solanum tuberosum L.) cultivars grown in Rwanda. Potato Journal 46(1):48-55.

Ngobese NZ, Workneh TS, Alimi BA, Tesfay S (2017). Nutrient composition and starch characteristics of eight European potato cultivars cultivated in South Africa. Journal of Food Composition and Analysis 55: 1-11.

Ogolla JA, Abong GO, Okoth MW, Kabira JN, Imungi JK, Karanja PN (2015). Levels of acrylamide in commercial potato crisps sold in Nairobi County, Kenya. Journal of Food and Nutrition Research 3(8):495-501.

Okello J, Zhou Y, Kwikiriza N, Ogutu S, Barker I, Schulte-Geldermann E, Atieno E, Ahmed J (2016). Determinants of the use of certified seed potato among smallholder farmers: the case of potato growers in Central and Eastern Kenya. Agriculture 6(4):55.

Rahman MM, Roy TS, Chowdhury IF, Afroj M, Bashar MA (2017). Identification of physical characteristics of potato varieties for processing industry in Bangladesh. Bangladesh Journal of Botany 46(3):917-924.

Raigond P, Singh B, Dutt S, Kumar S (2020). Potato: Nutrition and food security (P. Raigond, B. Singh, S. Dutt, & S. K. Chakrabarti (eds.)). Springer Singapore. Available at: https://doi.org/10.1007/978-981-15-7662-1

Sato H, Koizumi R, Nakazawa Y (2017). Data in Brief Data on the weights, specific gravities and chemical compositions of potato (Solanum tuberosum) tubers for food processing from different areas of Hokkaido , Japan. Data in Brief 11:601-605.

Soboka S, Asefa G, Beriso M (2017). Effect of varieties and growing environments on tuber yield, nutritional and process quality of potato grown in Bale Highlands, South Eastern Ethiopia. International Journal of Agricultural Research, Innovation and Technology 7(2):18-21.

Spence C (2015). On the psychological impact of food colour. Flavour 4(1): 1-16.

Taiy RJ, Onyango C, Nkurumwa A, Ngetich K, Birech R, OOro P (2016). Potato value chain analysis in Mauche Ward of Njoro Sub-County , Kenya. International Journal of Humanities and Social Science 6(5):129-138.

Tsikrika K, O'Brien N, Rai DK (2019). The Effect of high pressure processing on polyphenol oxidase activity, phytochemicals and proximate composition of Irish potato cultivars. Foods 8(10): 517.

Wayumba BO, Choi HS, Seok LY (2019). Selection and Evaluation of 21 Potato (Solanum tuberosum) breeding clones for cold chip processing. Multidisciplinary Digital Publishing Institute 8(98):2-9.

Wijesinha-Bettoni R, Mouillé B (2019). The contribution of potatoes to global food security, nutrition and healthy diets. American Journal of Potato Research 96(2):139-149.

Wszelaczyńska E, Pobereżny J, Lamparski R, Kozera, W, Knapowski T (2020). Effect of potato tuber biofortification with magnesium and the storage time on the content of nutrients. Journal of Elementology 25(2):687-700.

Yang Y, Achaerandio I, Pujolà M (2015). Classification of potato cultivars to establish their processing aptitude. Journal of the Science of Food and Agriculture 96(2):413-421.

Zheng SL, Wang LJ, Wan NX, Zhong L, Zhou SM, He W, Yuan JC (2016). Response of potato tuber number and spatial distribution to plant density in different growing seasons in Southwest China. Frontiers in Plant Science 7(365):2-9.