EFFECTS OF VARIETY, MATURITY STAGE, STORAGE CONDITIONS AND PERIOD ON THE PHYSICO-CHEMICAL PROPERTIES OF POTATOES

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ABSTRACT

Potato (*Solanum tuberosum)* is one of the most promising crops that contribute to achieving food security in Kenya. Potato varieties *Markie's* and *Shangi* have been released to farmers for production purposes. Therefore, the objective of this study was to determine the processing suitability of the two potato varieties grown in Nyandarua County (-0.39941^o S,36.489516^o E). Potatoes were evaluated for their physicochemical properties, usually used to measure their quality. Tubers were subjected to different storage conditions to determine post-harvest changes in the physicochemical properties and determine the most suitable maturity stage for processing. The results revealed effects (P<0.001) due to the interaction between variety and maturity stages on the physical properties. Further, based on chemical properties, an interaction effect (P<0.001) was observed between the variety and maturity stage, with variety *Shangi* showing high levels of starch content with a mean of 49 mg/100 g. There was no difference (P>0.05) in total sugar and ascorbic acid content across the maturity stages. The storage results revealed a difference (P<0.001) in starch content in the variety *Markies*. There was no difference (P>0.05) between ascorbic acid and total sugars observed during storage. In terms of stability during storage variety, *Markies* was more stable and had a longer shelflife than *Shangi*. Therefore, based on physicochemical properties, the two varieties could be a good source of raw materials for the industry.

Keywords: Potato, Maturity stage, Processing, Total sugars, Storage conditions.

INTRODUCTION

The potato (*Solanum tuberosum L.)* is a precious crop in agricultural production. It combines an extraordinarily high yield potential, adaptability to different climatic conditions, and a high nutritional value with a high range of utilization (Andre *et al*.,2014). It is the world's number one non-grain food commodity, rated the 4th most important food crop after rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), and maize (*Zea mays* L.) (Stephen Laititi, 2014). In Kenya, the potato is a strategic food security crop second to maize, with a production of 2-3 million tonnes worth about KES 40-50 billion each year and engaging a large population of Kenyan farmers in production. This compares well with maize production of 38 million 90 kg bags worth KES 120 billion. Consumption of potatoes has steadily increased in the developing countries where potato is an important source of food, employment and income (Lutaladio *et al*., 2009).

Potato products are widely consumed in Kenya due to their diversity in fast food outlets. Food varieties range from chips, crisps, baked potatoes, and mashed potatoes, among many other potato products. Potatoes are a good source of energy. It is also a good source of starch that finds application in the paper industry, pharmaceuticals, food thickeners, binders in soups, and adhesives in the textile industry. It has a high potential to mitigate food insecurity and improve nutrition due to the ability of the crop to adapt to various environmental conditions. (National Potato Council of Kenya, 2018).

Potato tubers varieties are characterised by tuber shape, number, depth of the eyes, texture, colour of the flesh, maturity type, disease resistance, cooking quality, composition and starch type, as supported by Camire *et al*. (2009). Therefore, potatoes can specifically be bred for functional and nutritional qualities due to their varying physical and chemical characteristics. Potato processing companies appear to face common challenges due to a lack of processing varieties where the available ones are considered expensive to grow (Gladys, 2015).

The potato tuber is a living entity that continues to respire and thus effective management protocols that slow down these processes are needed. Appropriate storage practices are required to increase tuber dormancy and reduce

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post-harvest losses. The physical properties of crops are considered critical factors for designing packaging, processing, conveying, and grading system. Therefore, the objective of this study was to determine the effects of variety, maturity stage, and post-harvest changes during storage and storage period on Physico-chemical properties and processing suitability of potato varieties *Markie's* and *Shangi* grown in Nyandarua, Kenya.

MATERIALS AND METHODS

This study entailed a comparative assessment of potato varieties *Markie's* and *Shangi* which were planted across two locations under the same agronomic practices in Nyandarua county. The area receives an average annual rainfall of up to 1600mm (Figure 1) with a predominant clay loam soil type. The study was conducted in a randomised complete block design (RCBD) in three replicates for the purpose of sampling.

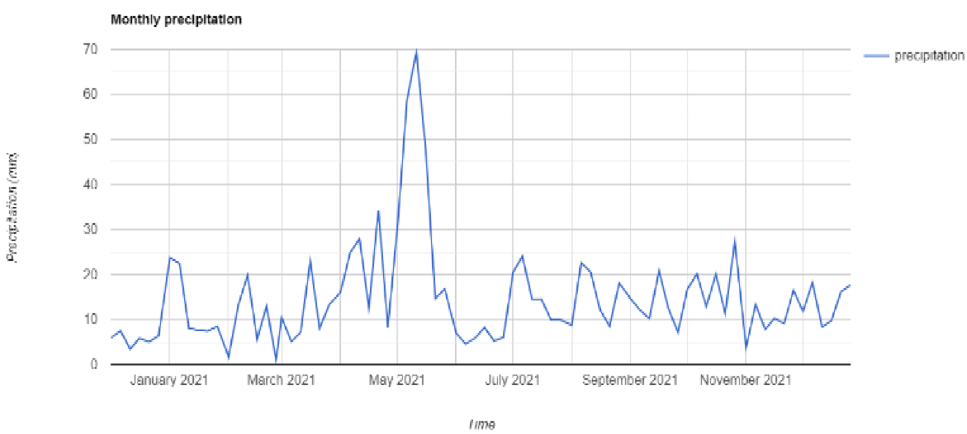

Figure 1: Rainfall data for the growing period in 2021

Sampling

Maturity is defined by the chronological state and the actual age in terms of months used to indicate processing quality (Pinhero and Yada, 2016). Because of the different growth phenology of the two varieties, sampling was done at different times, as described by Abong (2015). For variety *Shangi,* sampling was done at the first maturity stage when flowering occurred between 55-60 days after sprouting, the second maturity stage (dehaulming) at 70-75 days, and the third maturity stage (maturity/harvesting) when the plant attained 75-85 days. For variety *Markie's* sampling was done when plants flowered at 75-90 days after sprouting, dehaulming at 90-104 days, and maturity/harvesting at 105-120 days.

The main components evaluated were quality traits, a complex set of external and internal traits required for fresh and processed potatoes. External traits include; tuber flesh colour, size, shape index, number of eyes and specific gravity. Internal traits include starch, moisture, simple sugars, and ascorbic acid. These traits have a direct impact on the processing quality of potatoes.

Determination of physical properties

A sample of 20 tubers of similar size was selected from varieties *Shangi* and *Markie's* from Kipipiri and Githioro locations, Nyandarua county. Samples were collected when the tubers attained the aforementioned maturity stages to analyse the physical properties.

Specific gravity was determined using the method described by Abedi, *et al.* (2019). From a sample of 20 tubers, the mass of the tuber in air and the mass of water displaced by the tuber were determined and computed using the following formula:

$$Sg = m/mw$$

Where *Sg* = specific gravity, *m*= mass of the tuber, and *mw* = mass of water displaced.

Tuber flesh colour was determined using the method adopted from Wang (2015) using a handheld Minolta colour meter (Model CR-200, Osaka, Japan). From a sample of 20, each tuber was cut into two pieces, and the L* (lightness), a* (redness), and b* (yellowness) values were determined directly from the colour meter. Calculations for the hue angle and chroma were done following the method by Wang (2015) using the a*and b* values.

Mean tuber weight was determined from a sample of 20 tubers from each plot using the method described by Zheng *et al.* (2016) using an electronic scale (Model Shimadzu Libror AEG-220).

Mean size of tubers was determined by measuring dimensions from a sample of 20 potato tubers using a Vernier calliper (Mituyoyo-Japan) with an accuracy of 0.01mm (Bubeníčková *et al.,* 2011). Size in terms of linear dimensions was 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).

Tuber shape was determined by calculating the shape index (I) of the measured tubers following the formula

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

Where *I*= shape index, *D* = tuber width, *L* =Tuber length, *T* = tuber thickness. Potato was considered as spherical if I was ≤1.5 and classified as oval shape if I ≥1.5.

Eye number*:* Mean number of eyes was determined from a sample of 20 tubers by counting the total number of eyes in each tuber from the test varieties.

Tuber texture was evaluated by measuring the firmness using a penetrometer (Compac-100, model CR-100, Sun scientific Co. Ltd Japan), with a maximum loading of 10 kg at the three stages of maturity. The penetrometer was fitted with a 5 mm piercing probe, which was allowed to penetrate the tuber to a depth of 15 mm, at different points. The tuber texture was expressed in Newton's (N) force.

Determination of chemical properties

Moisture content was determined by drying 5 g of the sample in an oven at 105 ºC to constant weight according to AOAC Method 930.04 (1995). The proportion of moisture content was then calculated as shown below:

$$MC\ \% = W0-W1/W0 \times 100$$

Where MC= moisture content, W0= weight before drying and W1 = weight after drying

Simple sugars analyses was done using the method described by Abong and Kabira, (2011). Approximately 5 g of fresh blended potato was weighed into 50 ml conical flasks (QF) and approximately 20 ml ethanol (C_2H_5OH) was added and swirled to mix. The mixture was refluxed at 100 °C for 1 hour, and the resulting slurry was filtered into a 50 ml conical flask to obtain the filtrate. The solvent was evaporated to dryness at 80°C using a rotary evaporator. The dried sample was reconstituted with 2 ml of distilled water (dH_2O) and acetonitrile (CH_3CN) in a ratio of 1:1. The sample was then filtered with 0.45 µm filters, and 20 µl injected into the Liquid Chromatograph (Shimadzu LC 20A series with RID 10A detector) and separated at 30°C using CTO 10ASVP column oven at 1ml/min flow rate of Acetonitrile:water (75:25). Sugars present were identified and their concentration calculated by comparing samples with standards of fructose, glucose, and sucrose and expressed as mg/100 g fresh weight.

Starch content was analysed by Anthrone Direct Acid hydrolysis (AOAC 1980:13.056) method. Carbohydrates were first hydrolysed into simple sugars using dilute hydrochloric acid (HCl) to dehydrate glucose to hydroxymethylfurfural. This compound reacts with anthrone to form a green-coloured product with an absorption maximum of 630 nm. Approximately 5 ml of 2.5 M HCL was added into a tube containing approximately 100 g of sample and boiled in a water bath for 3 hours. Then cooled to room temperature. This was neutralised with sodium carbonate (Na_2CO_3) until the effervescence ceased. The solution was made up to 100 ml and centrifuged. Then 0.5 ml and 1 ml aliquots were taken from this solution for analysis. Standards were prepared by taking 0, 0.2, 0.4, 0.6, 0.8, and 1 ml of the working standards of glucose. The volume was made up to 1 ml in all the tubes, including the sample tubes, by adding H_2O. 4 ml of the anthrone reagent was then added, and the solution was heated for 8 minutes in a boiling water bath and cooled rapidly. The green to dark green colour readings were read at 630 nm using a UV-VIS Shimadzu 1800 spectrophotometer. A standard curve was plotted and the graph was used to calculate the amount of carbohydrates present in the sample and the results multiplied by a factor of 0.9 to give the % starch content in the sample as shown below:.

Amount of carbohydrate present in 100 mg of the sample

$= [\ g/vv\ x100]\ x\ 0.9$

Where *g* =amount of glucose, *v*= volume of the test sample

The ascorbic acid content in the samples was determined by the HPLC method as described by Vikram *et al*. (2005). Approximately 2g of the blended sample was weighed and extracted with 0.8% metaphosphoric acid. This was made up to 20 ml and centrifuged at 10000 rpm at 4 ^{o}C. The supernatant was filtered and diluted with 10 mL of 0.8% metaphosphoric acid (HPO_3). It was then passed through a 0.45 µm filter, and 20 µL injected into the HPLC fitted with Shimadzu SPD 20AD detector. Various ascorbic acid standards were also made to make a calibration curve. The mobile phase was 0.8% metaphosphoric acid at a flow rate of 1.2 mL/min and a wavelength of 266.0 nm.

Determination of post-harvest changes during storage.

Approximately 25 kg varieties *Markies* and *shangi* were stored at two different storage conditions (ware and cold storage). The store condition for ware storage was a dark room at 18^{o}C, and cold storage was maintained at 5^{o}C at 95% relative humidity (RH). Sampling for physical and chemical analyses was done on monthly basis using the methods described above. Visual evaluation for sprouting and greening effects was done at an interval of seven days for four months.

Statistical analyses

A separate analysis of variance was conducted for all the obtained data. Means were separated using Fisher's LSD whenever the main effects were significant at a 95% confidence level.

RESULTS AND DISCUSSION

Physical characteristics are considered critical factors for designing the packaging, processing, conveying and grading systems, as described by Abedi *et al.* (2019). The results of this study, as tabulated in (Table I) showed) effect ($P<0.001$) due to interaction between variety and maturity in texture and weight of tubers from Githioro location. Tuber weight was highest at the third maturity stage with a mean of 147.70g for *Markies* and 150.95g for *shangi* from Kipipiri location. Tuber weight is important as it is one of the major indices for determining the yield of produce, and potatoes are usually sold on a weight basis. The results were within the range of a study done on an average weight of tubers for processing by Rahman (2017).

The geometric properties of the tubers in both varieties increased with the maturity stage. However, there was no difference ($P<0.05$) in the length of tubers between the two locations. Effects ($P<0.001$) effects from the interaction between variety and maturity stage were observed for the width and thickness of tubers from the Kipipiri location. The results were comparable with the findings from the study conducted by Rahman (2017) on the desired tuber geometric properties for processing.

There was no difference ($P>0.05$) in shape index, the tuber shape for both varieties *markies* and *shangi* were oval. Tuber shape varies and is measured by the ratio between length and width. Long tubers are used for french fries, while round ones are preferred for crisps, as per a study report (Werij, 2011). The shape also plays a key role in the designs of machines (Wayumba, Choi and Seok, 2019)**.**

There was no difference ($P>0.05$) in the number of eyes though *shangi* had a higher number of eyes than *Markie's,* which had fewer and shallow eyes. The number of eyes and eye depth is a varietal characteristic where varieties with shallow eyes are most preferred for processing because losses incurred during processing are lower, as per a report by Noe *et al*. (2019) and (Rahman *et al.* 2017).

There was no difference ($P>0.05$) in the specific gravity of the two varieties. At the third maturity stage, the specific gravity was highest with a mean value o of 1.10 and 1.27 from the Githioro and Kipipiri locations, respectively. This compared well with results obtained by Evelyne (2021) and Wayumba (2019). Specific gravity is a quick indicator of potato quality for processing. Therefore, good quality potatoes should have a specific gravity value of more than 1.08, as Kabira and Lemaga (2003) reported**.**

TABLE I- PHYSICAL PROPERTIES OF POTATO VARIETIES OF *MARKIE'S* AND *SHANGI* EVALUATED ACROSS 2 LOCATIONS AT 3 MATURITY STAGES IN NYANDARUA COUNTY.

`P value		Markie's			Shangi			
	Location	**Stage 1**	**Stage 2**	**Stage3**	**Stage 1**	**Stage 2**	**Stage 3**	**P-Value**
Trexture	Githioro	3.92±0.08^{ab}	3.74±0.05^{bc}	3.74±0.73^{bc}	3.67±0.06^{c}	3.76±0.06^{bc}	4.08±0.08^{a}	<0.001
	Kipipiri	3.92±0.04	4.13±0.05	4.13±0.04	4.11±0.04	4.16±0.05	4.35±0.06	0.117
Weight (g)	Githioro	76.55±2.62^{c}	83.58±5.06^{abc}	90.3±2.8^{a}	44.65±3.21^{d}	80.36±3.20^{bc}	86.5±2.58^{ab}	<0.001
	Kipipiri	78.9±4.86^{c}	112.73±.60^{b}	147.7±5.07^{a}	61.3±2.69^{d}	103.4±2.80^{b}	150.95±.67^{a}	0.04
Specific gravity	Githioro	1.19±0.02	1.060±.02	1.070±.02	1.04±0.02±	1.09±0.01	1.10±0.02	0.035
	Kipipiri	1.14±0.05	1.16±0.07	1.25±0.08	1.08±0.01	1.10±0.02	1.27±0.04	0.697
Length (mm)	Githioro	69.45±.01	67.37±3.2	69.672±0.22	56.7±52.5	61.9±1.66	65.23±1.23	0.345
	Kipipiri	71.33±2.14^{c}	78.07±1.35^{bc}	91.4±1.85^{a}	58.12±1.55^{d}	75.83±1.33^{b}	89.32±2.87^{a}	0.01
Width (mm)	Githioro	41.522±2.33^{b}	40.741±.03^{b}	47.83±1.19^{a}	38.76±1.73^{b}	46.29±1.45^{a}	46.75±1.45^{a}	0.033
	Kipipiri	44.21±0.98^{c}	46.77±0.67^{cd}	49.19±0.72^{b}	40.95±0.82^{d}	45.98±0.81^{c}	53.14±1.04^{a}	<0.001
Thickness (mm)	Githioro	45.13±2.45	46.67±1.93	52.21±0.92	44.9±2.00	53.31±1.54	51.44±1.17	0.067
	Kipipiri	48.43±1.09^{d}	52.48±0.62^{c}	56.26±0.84^{b}	44.13±0.82^{c}	51.24±0.62^{c}	60.28±1.12^{a}	<0.001
Shape index	Githioro	1.5±0.06	1.61±0.03	1.6±0.07	1.29±0.04	1.33±0.05	1.37±0.06	0.204
	Kipipiri	1.6±0.03	1.6±0.03	1.7±0.03	1.4±0.03	1.6±0.04	1.6±0.06	0.087
No. of eyes	Githioro	6.4±0.47	7.11±0.31	7.2±0.29	9.3±0.36	8.5±0.33	9.3±0.45	0.123
	Kipipiri	7.49±0.33d	7.39±0.21c	9.27±0.19a	9.78±0.24a	9.9±0.26b	11.22±0.34d	0.554
lightness	Githioro	67.84±0.75^{a}	54.07±2.53^{c}	60.64±0.98^{b}	60.16±1.47^{b}	52.46±1.92^{c}	50.9±1.02^{c}	0.035
	Kipipiri	50.28±1.08	54.14±0.82	70.16±0.60	67.96±0.62	62.74±1.49	50.28±1.0	<0.001
Redness	Githioro	-7.12±0.17^{d}	-5.14±0.34^{ab}	-5.91±0.13^{c}	-5.48±0.18^{bc}	-4.87±0.21^{a}	-5.33±0.21^{abc}	0.004
	kipipri	-5.59±0.15^{d}	-5.06±0.36^{bc}	-6.89±0.09^{a}	-6.15±0.26^{c}	-4.98±0.16^{ab}	-4.60±0.13^{a}	<0.001
Yellowness	Githioro	29.13±0.72	19.62±0.67	27.95±3.93	21.86±0.97	17.84±0.58	18.07±0.06	0.085
	Kipipiri	20.41±0.42^{a}	19.07±0.33^{c}	26.86±0.30^{b}	24.2±0.44^{cd}	23.86±0.47^{b}	20.18±0.71^{a}	<0.001
Chroma value	Githioro	30±0.73	20.34±0.66	28.68±3.89	22.54±0.99	18.5±0.61	19.42±0.64	0.085
	Kipipiri	21.17±0.44^{d}	19.88±0.34^{c}	27.73±0.31^{b}	25.02±0.45^{cd}	24.4±0.48^{b}	20.81±0.65^{a}	<0.001
Hue angle	Githioro	44.16±0.03	43.96±0.29	44.1±0.66	44.1±0.04	43.98±0.03	43.88±0.02	0.425
	Kipipiri	43.96±0.03	43.82±0.02	44.08+0.02	44.04±0.02	44.36±0.03	43.32±0.98	0.262

Means followed by the same letters are not different across the row (P<0.05)

Colour is an important quality attribute that influences consumer perception with lightness attributed to higher quality, as reported by Rahman (2017). An interaction effect (P<0.001) between variety and maturity stage on lightness, redness, yellowness, and chroma in tubers from the Kipipiri location. This would suggest that location could affect the flesh colour of the potatoes, as reported by Gilsenan et al. (2010). There was a difference (P<0.001) in chroma values for tubers from Kipipiri location. Tubers from this location would be attributed to higher quality because of the high L*values. Bordoloi (2012) reported that high values of L* are associated with whiteness, b* yellowness, and –a* darkness. Chroma is also an indicator of colour intensity, and hue angle signifies product colour.

The chemical properties refer to the internal quality traits which may impact processing, they include starch content, simple sugars, ascorbic acid and moisture content, and the results are outlined in (Table II). There was no difference (P>0.05) in starch content across the three maturity stages. *Shangi* at maturity stage 3 from Kipipiri location recorded the highest mean value of 49.21 mg/100 g compared to Githioro location, which recorded a mean value of 19.96 mg/100 g. The range values of 19-49 mg /100 g observed in this study are comparable to those observed by Ndungutse *et al.* (2019). However, there were interaction effects (P<0.001) between variety and maturity stages from Kipipiri location

No difference (P>0.05) was observed for ascorbic acid content. However, variation in ascorbic acid content was observed across the maturity stages. This could be attributed to cultural practices when managing potatoes, genetic makeup, and location, as Burgos (2009) described. Ascorbic acid content was lower in both varieties than the recommended levels of 46 mg/100 g in fresh tubers. There was no difference (P>0.05) along the three maturity stages in glucose, fructose, and sucrose evolution. Total sugars gradually reduced with the lowest sugar content observed at the third maturity stage. There are locational effects on sugar content in the potato, and this could be due to the nutrition management of the potato plant when growing, as supported by Naumann (2020). In this study, ecological factors could have influenced the content of simple sugars such as fructose and glucose across the two locations. The concentration of sugars varies from one potato variety to another, and environmental conditions play an important role in sugar accumulation which was also reported by Ndungutse (2019). However, a high amount of sugar in potatoes is undesirable during processing due to the formation of acrylamide, a by-product of the Maillard reaction considered a potentially carcinogenic product and harmful to human health (Ogolla, 2013).

Prior to consumption, the storage of potatoes depends on moisture content. Difference (P<0.001) was observed in moisture content in the two storage conditions on the two varieties. There was no difference (P>0.05) in ascorbic acid content, although a gradual decline was observed. Bandana (2015) reported that ascorbic acid content is affected by storage conditions as well as the duration of storage. There was a difference (P<0.001) in starch content in *Markies* variety, where an increase was observed after the second month of storage and later declined in the fourth month in both storage conditions. *Shangi* showed a steady increase at ware storage, but starch content increased in the second month and later decreased at cold storage. This could be attributed to starch hydrolysis into sugars. No difference (P>0.05) in total sugar content in the potato varieties tested. In *shangi*, the total sugars declined gradually in both storage conditions (Abong, 2015). The results are as tabulated in Table III.

TABLE II- CHEMICAL PROPERTIES OF POTATO VARIETIES *MARKIE'S* AND *SHANGI* EVALUATED ACROSS 2 LOCATIONS AT 3 MATURITY STAGES IN NYANDARUA COUNTY

Variety		Markie's			Shangi			
Parameter	**Location**	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 1**	**Stg 2**	**Stage 3**	**P-Value**
Starch	Githioro	30±3.11	12.1±1.57	24.5±2.4	20.25±4.23	13.53±0.80	19.96±1.61	0.128
	Kipipiri	21.14±1.23^{bc}	44.38±6.60^{bc}	21.86±4.49^{a}	14.83+3.19^{c}	31.63±2.05^{b}	49.21±1.16^{a}	<0.001
Ascorbic acid	Githioro	15.71±0.97	1.43±0.12	15.81±1.15	19.08±0.09	11.15±2.71	18.21±0.36	0.052
	Kipipiri	15.66±0.55^{c}	5.59±0.32^{d}	8.06±0.5^{b}	17.28±0.71^{dc}	6.63±0.58^{c}	12.85±0.57^{a}	0.004
Glucose	Githioro	29.34±6.79	44.54±9.79	31.0±6.60	46.45±3.54	40.58±9.87	63.56±0.46	0.076
	Kipipiri	39.4±1.98^{d}	21.25±0.88^{bc}	11.76±1.56^{a}	22.89±3.65^{d}	17.35±1.81^{c}	6.95±1.4^{b}	0.003
Fructose	Githioro	96.88±8.47	115.64±23.1	9.85±1.9	32.7±719	79.71±23.4	13.98±0.81	0.081
	Kipipiri	13.51±1.6^{c}	14.68±0.18^{c}	23.34±1.70^{b}	16.89±1.35^{c}	23.61±3.06^{b}	39.62±2.55^{b}	0.006
Sucrose	Githioro	19.4±0.72	49.3±2.43	37.04±5.52	28.2±1.05	51.63±16.66	70.27±4.32	0.18a
	Kipipiri	83.8±1.74	30.48±8.58	3.55±0.69	110.42±26.25	19.86±7.26	5.15±0.80	0.259
Total sugars	Githioro	145.6±1.87^{ab}	209.5±15.64^{a}	77.9±13.34^{c}	107.4±4.27^{bc}	171.9±49.9^{ab}	147.8±15.06^{bc}	0.034
	Kipipiri	136.72±3.64	66.41±8.47	38.65±2.24	150.2±26.78	60.81±4.64	51.72±3.45	0.676
M.C (%)	Githioro	83.19±0.07	79.4±1.17	83.06±1.94	81.22±0.76	79.47±1.67	80.27±o,36	0.491
	Kipipiri	84.94±0.31^{a}	83.09±0.48^{ab}	82.41±0.37^{bc}	84.19±0.51^{d}	82.16±0.48^{c}	78.8±0.78^{c}	0.004

Notes: MC = moisture content, SI units = mg/100g, MS=months of storage, WS=ware storage, CS =cold storage

Means followed by the same letters are not significantly different across the row (P.0.05)

TABLE III- POST-HARVEST CHANGES IN CHEMICAL PROPERTIES ON POTATO VARIETIES MARKIE'S AND SHANGI AT WARE AND COLD STORAGE.

		Markies						Shangi			
Parameter	**M.S** **S.C**	**0**	**1**	**2**	**3**	**4**	**P -Value**	**0**	**1**	**2**	P -Value
M.C	**WS**	82.72±0.64^{b}	79.54±0.54^{c}	85.15±0.10^{a}	84.7±0.11^{a}	84.81±0.21^{a}	<0.001	80.29±0.10^{b}	79.41±0.17^{b}	75.13±0.74^{c}	<0.001
	CS	82.72±0.64^{b}	85.36±0.44^{a}	84.68±0.11^{a}	85.35±0.07^{a}	85.08±0.19a		80.29±0.10^{b}	84.67±0.32^{a}	73.67±0.46^{d}	
VIT C	**WS**	8.06±1.22	8.9±0.43	2.16±0.04	1.81±0.34	0.23±0.02	0.885	11.27±0.48	6.00±0.19	2.17±0.06	0.523
	CS	8.06±1.22	9.63±0.94	3.14±0.48	1.55±0.03	0.48±0.03		11.27±0.48	7.54±0.26	3.14±0.48	
Starch	**WS**	33.96±3.78^{f}	48.9±10.72^{d}	142.23±0.57^{a}	123.2±3.67^{b}	34.53±0.59^{f}	<0.001	52.2±2.07^{d}	57.55±4.56^{d}	201.33±3.15^{a}	<0.001
	CS	33.96±3.78^{f}	65.44±1.52^{d}	107.65±3.41^{c}	109.82±2.33^{c}	31.59±3.78^{f}		52.2±2.07^{d}	104.43±2.15^{b}	69.16±3.15^{c}	
Glucose	**WS**	6.32±0.72^{b}	2.75±0.74^{bcd}	4.39±0.20^{bc}	4.36±0.23^{bc}	0^{d}	<0.001	3.19±1.07^{cd}	13.73±2.46^{a}	4.69±0.19^{c}	0.029
	CS	6.32±0.72^{b}	4.09±0.98^{bc}	25.54±2.70^{bc}	1.52±1.52^{cd}	1.36±1.36cd		3.19±1.07^{cd}	7.84±1.88^{b}	1.35±1.35^{d}	
Fructose	**WS**	23.74±2.09	12.66±2.01	2.48±1.25	3.41±0.21	3.49±0.08	0.973	30.43±2.56	9.17±1.82	2.49±1.25	0.096
	CS	23.74±2.09	16.17±9.06	2.74±1.34	3.88±0.16	3.55±0.10		30.43±2.56	17.78±2.77	4.58±0.25	
Sucrose	**WS**	3.67±0.85^{d}	14.41±2.51^{a}	3.97±0.33^{cd}	3.55±0.16^{d}	3.71±0.06d	<0.001	6.34±0.96^{b}	4.57±1.95^{b}	1.22±1.21^{c}	0.009
	CS	3.67±0.85d	6.83±0.81^{b}	7.95±0.49^{bc}	3.79±0.10^{d}	3.66±0.07^{d}		6.34±0.96^{b}	12.53±0.57^{b}	3.56±0.43^{c}	
Total sugars	**WS**	33.73±3.15^{a}	29.82±3.39^{a}	10.86±0.76^{b}	11.33±0.56^{b}	7.2±1.40^{b}	0.005	39.96±3.80	27.47±3.60	8.4±2.00	0.084
	CS	33.73±3.15^{a}	27.09±9.16^{a}	36.23±2.47^{a}	9.2±1.78^{b}	8.57±1.40^{b}		39.96±3.80	38.15±3.87	9.49±1.52	

Notes: MC = moisture content, Units of measure = mg/100g, MS=months of storage, WS=ware storage,CS =cold storage ,SC=storage condition. Means followed by the same letters are not significantly different across the row according to LSD.

There was no storage effect (P>0.05) on specific gravity. *Markies* in ware and cold storage recorded mean specific gravity values of 1.08 and 1.06, while Shangi recorded a mean of 1.08 and 1.13 in ware and cold storage, respectively. There was also no effect (P>0.05 on tuber texture and colour of the flesh in both storage conditions, as shown in Table 1V.

TABLE IV- POST-HARVEST CHANGES IN PHYSICAL PROPERTIES OF POTATO VARIETIES MARKIE'S AND SHANGI AT WARE AND COLD STORAGE

		Markies						**Shangi**			
Parameter	**M.S S.C**	**0**	**1**	**2**	**3**	**4**	**P-Value**	**0**	**1**	**2**	**P-Value**
Specific gravity	WS	1.17±0.05	1.1±0.03	1.12±0.04	0.92±0.08	1.08±0.04	0.158	1.21±0.06	1.22±0.07	1.08±0.05	**0.152**
	CS	1.17±0.05	1.07±0.02	1.09±0.04	1.08±0.02	1.06±0.02		1.21±0.06	1.07±0.04	1.13±0.02	
Texture	WS	4.18±0.11	3.76±0.09	3.7±0.05	3.47±0.07	3.63±0.05	0.592	4.48±0.06	3.19±0.09	2.99±0.09	**0.121**
	CS	4.18±0.11	3.84±0.09	3.73±0.07	3.55±0.11	3.48±0.03		4.48±0.06	4.48±0.06	3.55±0.09	
l*	WS	67.6±1.06	71.46±0.88	68.91±1.15	70.01±0.71	75.46±0.62	0.235	50.43±2.29	68.55±0.33	68.73±0.82	**0.931**
	CS	67.6±1.06	72.17±0.44	71.06±0.75	69.18±0.78	74.19±0.57		50.43±2.29	68.02±0.79	69.25±0.82	
a*	WS	-5.04±0.40	-5.63±0.14	-4.82±0.41	-6.92±0.09	-3.72±1.65	0.099	-5.7±0.09	-5.69±0.13	-5.69±0.13	**0.083**
	CS	-5.04±0.4	-5.92±0.64	-6±0.28	-6.77±0.23	-6.46±0.12		-4.71±0.33	-6.1±0.13	-6.65±0.14	
b*	WS	$24.2±0.62^{bc}$	$23.5±0.58^{cd}$	$22.2±0.51^{d}$	$23.76±0.54^{c}$	$23.51±0.4^{cd}$	0.014	21.36±1.62	23.86±0.44	22.29±0.54	**0.156**
	CS	$24.2±0.62^{bc}$	$27.26±0.71^{a}$	$24.91±0.65^{bc}$	$25.42±0.51^{b}$	$25.32±0.57^{b}$		21.36±1.62	25.59±0.49	26.37±0.88	
Chroma	WS	$24.76±0.61^{cd}$	$24.16±0.59^{de}$	$22.74±0.49^{e}$	$24.74±0.54^{cd}$	$24.32±0.39^{d}$	0.012	21.87±1.65	24.54±0.44	23.01±0.55	**0.151**
	CS	$24.76±0.61^{cd}$	$27.95±0.78^{a}$	$25.64±0.67^{bcd}$	$26.31±0.51^{b}$	$26.13±0.56^{bc}$		21.87±1.65	26.32±0.50	27.19±0.89	
Hue angle	WS	44.35±0.06	44.2±0.02	44.29±0.09	43.82±0.04	44.03±0.03	0.11	44.32±0.04	44.2±0.03	44.1±0.02	**0.922**
	CS	44.35±0.06	44.31±0.08	44.18±0.05	44.31±0.08	44.18±0.05		44.32±0.04	44.22±0.02	44.1±0.02	

Notes: MC = moisture content, units of measure= mg/100g, M.S=months of storage, SC = storage conditions, WS=ware storage, CS=cold storage Means followed by the same letters are not significantly different across the row according to LSD.

CONCLUSION

The tubers' internal and external traits that impact processing was analysed. Specific gravity is a quick indicator of potato quality, which was within the recommended range. Depth and number of eyes determine the extent of losses incurred during peeling processes, and *Markies* was found to have few shallow eyes. The two varieties met the recommended geometric properties for processing, and they had a uniform shape which is key in the designs of machines for automation. On the other hand, the reducing sugars were low at the third maturity stage. Low sugar content is an indicator of good processing quality. Markies variety had superior quality and stability at storage in both ware and cold storage conditions. This study provides valuable information for the potential use of *shangi* and *markies* varieties as raw materials for the processing industry and the scientific community

RECOMMENDATIONS

The two varieties *Markies* and *Shangi* are generally good raw materials for the food processing industry, and the preferred harvesting is at the third maturity stage.

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REFERENCES

Abedi, G., Shamsollah A., and Mohammad B. (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. doi: 10.17221/24/2018-RAE.

Abong', G. O., and J. N. Kabira. (2011). "Suitability of Two Established and Three Newly Released Kenyan Potato Varieties for Processing into Crisps and French Fries." *African Journal of Food, Agriculture, Nutrition and Development* 11(6):5266–81. doi: 10.4314/ajfand.v11i6. CITATIONS.

Abong, G. O., M. W. Okoth, J. N. Kabira, J. Ogolla, J. Ouma, C. W. Ngunju, and K. Oded. (2015). "Physico-Chemical Changes in Popular Kenyan Processing Potato Varieties as Influenced by Storage Condition." *Current Research in Nutrition and Food Science* 3(2):112–20. doi: 10.12944/CRNFSJ.3.2.03.

Andre, C M., Sylvain L., Christian I., Johanna Z., Cedric G., Yvan L., Jean F. H., Danièle E., and Lisa M.M. (2014). "The Potato in the Human Diet: A Complex Matrix with Potential Health Benefits." *Potato Research* 57(3–4):201–14. doi: 10.1007/s11540-015-9287-3.

AOAC, 1995. Aassociation of the official methods of analysis. Journal Of AOAC International Vol. 78, No. 3,1995. http://lib3.dss.go.th/fulltext/scan_ebook/aoac_1995_v78_n3.pdf

Bandana V. S., Pinky R., Brajesh S., and Kaushik S. K. (2015). "Ascorbic Acid Losses during Storage of Potato Tubers." *Potato Journal* 42(1):76–79.

Bordoloi A., Lovedeep K., and Jaspreet S. (2012). "Parenchyma Cell Microstructure and Textural Characteristics of Raw and Cooked Potatoes." *Food Chemistry* 133(4):1092–1100. doi: 10.1016/j.foodchem.2011.11.044.

Bubeníčková, A., J. Simeonovová, V. Kumbár, M. Jůzl, and Nedomová Š. (2011). "Mathematical Descriptive Characteristics of Potato Tubers ' Shape." *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 59(6):63–68.

Burgos, G., S. Auqui, W. Amoros, E. Salas, and Bonierbale M. (2009). "Ascorbic Acid Concentration of Native Andean Potato Varieties as Affected by Environment, Cooking and Storage." *Journal of Food Composition and Analysis* 22(6):533–38. doi: 10.1016/j.jfca.2008.05.013.

Camire M. E., Stan K., and Danielle J. D. (2009). "Potatoes and Human Health." *Critical Reviews in Food Science and Nutrition* 49(10):823–40. doi: 10.1080/10408390903041996.

Evelyne N. G., N. Sila D., Orina N. I., and Ariel K. B. (2021). "Physico-Chemical Properties of Selected Irish Potato Varieties Grown in Kenya." *African*

Journal of Food Science 15(1):10–19. doi: 10.5897/ajfs2020.2025.

Gilsenan C., Róisín M. B., and Catherine, B. (2010). “A Study of the Physicochemical and Sensory Properties of Organic and Conventional Potatoes (Solanum Tuberosum) before and after Baking.” *International Journal of Food Science and Technology* 45(3):475–81. doi: 10.1111/j.1365-2621.2009.02148.x.

Gladys M., Wachira K and Booker W. O. (2015). *Potato Market Assessment for East Africa 2015*.

Kabira, J. N., and Berga L. (2003). “Potato Processing. Quality Evaluation Procedures for Research and Food Industry Applications in East and Central Africa.” 20.

Lutaladio N. B., and Luigi C. (2009). “Potato: The Hidden Treasure.” *Journal of Food Composition and Analysis* 22(6):491–93. doi: 10.1016/j.jfca.2009.05.002.

National Potato Council of Kenya (2018). *Potato Production Handbook A Guidline for Farmers and Trainers*. Nairobi.

Naumann M., Mirjam K., Heike T., Andreas G., and Elke P. (2020). “The Importance of Nutrient Management for Potato Production Part II: Plant Nutrition and Tuber Quality.” *Potato Research* 63(1):121–37. doi: 10.1007/s11540-019-09430-3.

Ndungutse, V., Hilda V., Abdul K. F., and Peninah N. (2019). “Processing Quality of Selected Potato (Solanum Tuberosum l.) Cultivars Grown in Rwanda.” *Potato Journal* 46(1):48–55.

Noe W., Tata N.P., Nain C. W., Adjoudji O., Nossi E. J., Simo B., Yingchia Y., Nsongang A., Adama F., Mveme M., Dickmi V. C., and Okolle J. (2019). “Suitability of Different Processing Techniques and Sales Options for Irish Potato (Solanum Tuberusum) Cultivars in Cameroon.” 4(4).

Ogolla J A. (2013). “Acrylamide Contamination in Commercial Potato Crisps in Kenya: Levels of Intake and Effects of Processing Parameters in Local Cultivars.” UON.

Pinhero R., and Rickey Y. Y. (2016). *Postharvest Storage of Potatoes*. Second Edi. Elsevier Inc.

Rahman, M., Tuhin S. R., Imtiaz F. C., Mahfuza Afroj, and M. A. Bashar. (2017). “Identification of Physical Characteristics of Potato Varieties for Processing Industry in Bangladesh.” *Bangladesh Journal of Botany* 46(3):917–24.

Stephen L. M. (2014). “Potato Market Survey in Kenya: An Agricultural Product Value Chain Approach.” *International Journal Of Business And Management Review* 2(6):59–87.

Vikram, V.B., Ramesh, M.N., and Prapulla, S.G. (2005). Thermal degradation kinetics of nutrients in orange juice heated by electromagnetic and conventional methods, Journal of Food Engineering, 69 (2005), pp. 31-40

Wang S., Tong C., Chenjie W., Liu S., Wei W., Hong Y and Min C. (2015). “Effect of Particle Sizes of Soy Okara on Textural, Color, Sensory and Rheological Properties of Pork Meat Gels.” *Journal of Food Quality* 38(4):248–55. doi: 10.1111/jfq.12144.

Wayumba, B. O., Hyung S. C and Lim Y. S. (2019). “Selection and Evaluation of 21 Potato (Solanum Tuberosum) Breeding Clones for Cold Chip Processing.” *Foods* 8(3). doi: 10.3390/foods8030098.

Werij, J. S. (2011). *Genetic Analysis of Potato Tuber Quality Traits*.

Zheng S. L., Liang J. W., Nian X. W., Lei Z., Shao M. Z., Wei H and Ji C.Y. (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. doi: 10.3389/fpls.2016.00365.