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Research Application Summary

Characterization of potato starch isolated from four potatoes varieties grown in Kenya

Buzera, A.K.,[1,2*] Adoyo, G. O.,[2] Nkirote, E.G.,[2] Orina, I. N.[2] & Sila, D.N.[2]

[1]Faculty of Agriculture and Environmental Science, Université Evangélique en Afrique (UEA), P.O. Box 3323 Bukavu, Sud-Kivu / RD Congo
[2]Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology (JKUAT), P.O. Box 62000-00200 Nairobi, Kenya
***Corresponding Author:** arielbuzera@gmail.com

Abstract

In Kenya, there is a wide range of variability of potato cultivars with different physical and chemical properties. These differences define the nature of their starch characteristics which influence their suitability for processing. The present study was conducted to characterize potato starch from four popular potato varieties grown in Kenyan namely: Shangi, Unica, Dutch robjin, and Wanjiku. The tubers were characterized physico-chemically (specific gravity, dry matter content, starch content, and moisture content). Other properties determined included the starch yield (%), particle size, and microstructural characteristics. The Dutch robjin variety had the highest specific gravity (1.081g/cm^3), dry matter (21.9%), and starch content (13.96%) while Unica had the lowest specific gravity (1.076g/cm^3), dry matter (17.19%) and starch content (12.98%). Particle size analysis revealed that the native starch extract consisted of particles that exhibited a normal distribution curve. The average diameter of the starch granules was 39.06, 39.56, 41.78, and 44.01 µm for Dutch robjin, Shangi, Unica, and Wanjiku, respectively. It was observed that when the size of the particle decreased, the percentage of starch content increased. Furthermore, starch granules revealed oval shapes for all the varieties. These differences in physico-chemical properties might indicate pronounced differences in the functional properties of the starch derivatives.

Keywords: Dry matter, potato, particle size, specific gravity, scanning electron microscope, starch

Résumé

Au Kenya, il existe une grande variabilité de cultivars de pommes de terre avec des propriétés physiques et chimiques différentes. Ces différences définissent la nature et les caractéristiques leur amidon, qui leur tour influencent leur aptitude à la transformation. La présente étude a été menée pour caractériser l'amidon de pomme de terre de quatre variétés populaires de pomme de terre cultivées au Kenya, à savoir : Shangi, Unica, Dutch robjin, et Wanjiku. Les tubercules ont été caractérisés sur le plan physico-chimique (gravité spécifique, teneur en matière sèche, teneur en amidon et teneur en humidité). D'autres propriétés ont été déterminées, notamment le rendement en amidon (%), la taille des particules et les caractéristiques micro-structurelles. La variété Dutch robjin avait la gravité spécifique la plus élevée (1,081g/cm3) ainsi que la teneur la plus élevée en matière sèche (21,9%) et en amidon (13,96%) tandis que la variété Unica avait la gravité spécifique la plus basse (1,076g/cm3) ainsi la teneur la plus basse en matière sèche (17,19%) et en amidon (12,98%). L'analyse de la taille des particules a révélé que l'extrait d'amidon natif était composé de particules qui présentaient une courbe de distribution normale. Le diamètre moyen des granules d'amidon était de 39,06; 39,56; 41,78 et 44,01 µm pour Dutch robjin, Shangi, Unica et Wanjiku, respectivement. Il a été observé que lorsque la taille de la particule diminuait, la teneur en amidon augmentait. En outre, les granules d'amidon ont présenté des formes ovales pour toutes les quatre variétés. Ces différences dans les propriétés physico-chimiques pourraient indiquer des différences prononcées dans les propriétés fonctionnelles des dérivés de l'amidon.

Mots clés : Amidon, matière sèche, pomme de terre, taille des particules, gravité spécifique, micros-cope électronique

Introduction

In Kenya, potato (*Solanum tuberosum* L.) is ranked as the second most important food crop after maize. The average production in Kenya is estimated at 7 to 10 tons per hectare as compared to a global average yield of 17 tons per hectare (FAOSTAT, 2011). Potatoes are produced for direct consumption (domestic, restaurants, or hotels) or used as a raw material for the processing of various products. Starch is the most abundant component of potato and accounts for 60 to 80 % of potato dry matter (Lizazaro *et al*., 2015). Starch is used for improving the texture and consistency of many foodstuffs because of its thickening and gelling properties. Potato starch can also find application in textile, cosmetics, paper, adhesive, and pharmaceutical industries.

The use of starch in food application is largely determined by its properties mostly associated with its physico-chemical properties and the structure of its granules. The morphological characteristic of starch granules depends on the mechanisms of starch accumulation which is determined by the quality of raw material (Zabolotets *et al*., 2019). Different potato varieties exhibit variability in size, color, and chemical composition which might be attributed to differences in the genetic factors, climatic conditions, type of soil, which have an impact on the starch suitability for processing.

The size of the granules has an important effect on the quality of starch. Larger particles flow better and have a good mixing ability than smaller ones. Small granules gelatinize slowly and have high water absorption capacity than larger ones (Li *et al*., 2016). Therefore, it is important to characterize potato starch to determine its functionality and consequently its potential application. This study therefore determined the physico-chemical and morphological characteristics of four popular potato varieties grown in Kenya so as to improve potato utilization and value addition.

Materials and methods

Four popular potato varieties grown in Kenya namely Shangi, Unica, Wanjiku, and Dutch Robjin were procured from a farm in Nyandarua County. These varieties are high-yielding and are among the most utilized domestically and industrially.

Physical and chemical analysis of raw potato tubers

Specific gravity was measured by weighing 2 kg of potatoes in air and then re-weighing them in water.

The specific gravity was calculated using Equation 1:

$$\text{Specific gravity} = \frac{\text{weight in air}}{\text{weight in air} - \text{weight in water}} \qquad \text{eq.1}$$

Dry matter content (DM) (%) was assayed by drying 5g of potato slices in aluminum containers in the oven (105 ±2 C, 24 hours) until constant weight. The specific gravity was calculated using Equation 2:

$$\text{Dry matter (\%)} = \frac{\text{weight of the sample after drying}}{\text{Initial weight of the sample}} \times 100 \qquad \text{eq.2}$$

On the other hand, Total starch content (%) was estimated from a specific gravity value using Equation 3 as reported by Yildrim and Tokusoglu, 2005:

$$\text{Starch (\%)} = 17.546 + 199.07 \times (\text{specific gravity} - 1.0988) \qquad \text{eq.3}$$

Potato starch extraction. Cleaned potato tubers were manually peeled. The starch was extracted according to the method described by Singh and Singh (2001), using one (1) kg of each potato variety. The potatoes were fractionated and placed in distilled water containing sodium metabisulfite (35 g/100L). The starch was allowed to settle, decanted then filtered. The solution containing settled starch was washed several times with distilled water until the effluent was a clear liquid. The starch paste was placed in a hot air oven at 40 ºC for 24h. The dry starch was passed through an attrition mill to reduce the particle size, sieved using a 100 mesh, and, finally, stored in Ziplock bags.

The amount of starch produced from 1 kg of potato was weighed. The percentage yield of potato starch was calculated as shown below:

$$\text{Starch yield (\%)} = \frac{\textbf{Weight of starch after Drying (g)}}{\textbf{Weight of potato tubers (g)}} \times 100 \qquad \text{Eq. 5}$$

Particle size distribution of potato starch. A laser diffraction particle size analyzer (SALD-2300; Shimadzu Corporation, Kyoto, Japan) equipped with a sampler (SALD-2300 Cyclone Injection Type Dry Measurement Unit SALD-DS5) was used. This device is capable of measuring particle size in the range of 17 nm to 2500 µm. A small amount of starch was placed into a hopper and suctioned across the laser beam by pressing an ejector button. The particle size distribution was determined by the light intensity distribution pattern of scattered light generated by a sample irradiated with a laser. The results were recorded by Wing SALD II software (version 3.1.0, Shimadzu, Kyoto, Japan).

Morphological characteristics of potato starch. The structure of the potato starch extract was determined using a Scanning Electron Microscope model JCM-7000 NeoScope Benchtop SEM (JEOL Ltd, Tokyo Japan). Potato starch was suspended on an aluminum stub using double-sided adhesive tape. An accelerating potential of 15 kV and a magnification of 300 X were used during micrography.

Statistical analysis. Data were subjected to analysis of variance using statistix 10.1 and means were separated using LSD test ($P<0.05$).

Results and Discussion

Physico-chemical properties of raw potato tubers. There was a significant difference in the specific gravity of the four potato varieties. Dutch robjin variety had the highest specific gravity (1.081) while Unica had the lowest (1.076) as shown in Table 1. Unica variety had lower starch content and higher water content compared to other varieties. In contrast, the Dutch robjin variety exhibited the highest dry matter (DM) and starch content. The specific gravities fall in the range of 1.076 to 1.112 as reported by Tsegaye *et al*. (2018) for potato varieties grown in Eastern Ethiopia. Specific gravity is positively correlated with starch content, total solids, and dry matter, thus considered as one of the most practical indices for potato quality (Mohammed, 2016). Specific gravity is commonly used in food industries for a quick estimation of dry matter content and starch content.

Many factors may affect the dry matter and starch content of potato tubers. The differences among the four varieties for dry matter, specific gravity and starch content might indicate that genetic factor is important in influencing starch properties. Mohammed (2016) found that dry matter and starch content of potatoes were influenced by genetic factors, location, season, soil type, irrigation, and harvesting period.

Starch Yield (%). As shown in Figure 1, a significant difference (P<0.05) was observed in starch yield extracted from the four varieties. Dutch robjin has the highest percentage (11.23%) while Unica had the lowest (9.73 %). The high amount of starch recorded for the Dutch robjin variety correlates well with its high specific gravity and dry matter content.

Table 1. Specific gravity, dry matter, total starch, and moisture of potato variety tubers

Varieties	Specific gravity (g/cm^3)	Dry matter (%)	Total Starch (%)	Moisture (%)
Shangi	1.080 ± 0.003^{ab}	18.804 ± 0.494^{b}	13.791 ± 0.584^{ab}	81.529 ± 0.531^{b}
Wanjiku	1.078 ± 0.002^{ab}	18.844 ± 0.329^{b}	13.307 ± 0.362^{ab}	81.156 ± 0.329^{b}
Dutch robjin	1.081 ± 0.002^{a}	21.900 ± 0.505^{a}	13.960 ± 0.416^{a}	78.100 ± 0.505^{c}
Unica	1.076 ± 0.003^{b}	17.194 ± 0.247c	12.983 ± 0.623^{b}	82.806 ± 0.247^{a}

Results are the means of triplicate determinations ± standard error. Means with different superscripts in the same row are significantly different (p< 0.05)

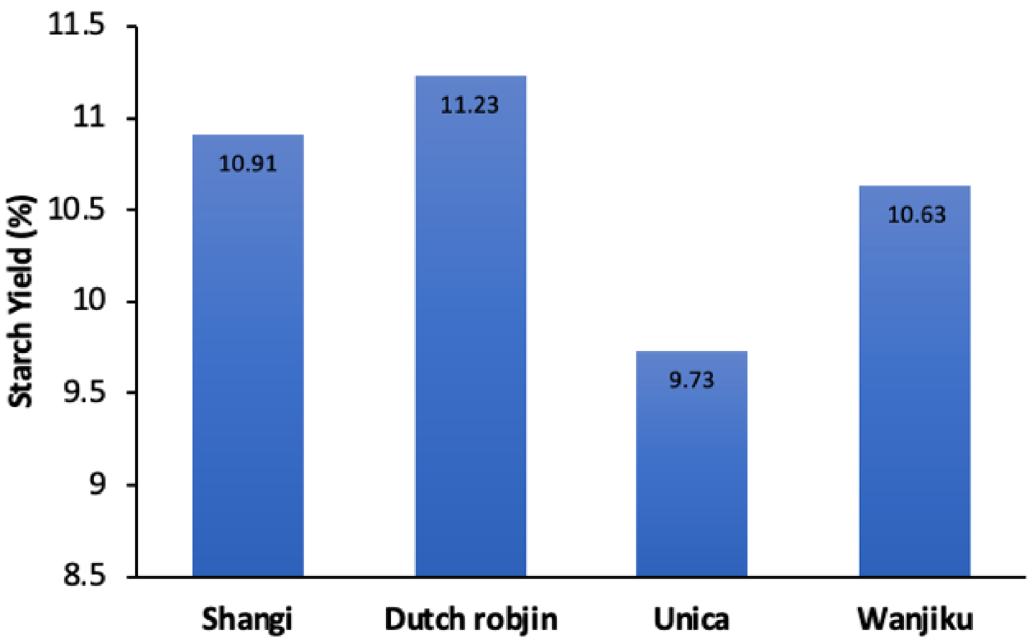

Figure 1. Percentage yield (%) of potato starch isolated from four potato varieties

Low starch extraction rates can reduce the attractiveness of potato varieties as a raw material for starch isolation.

Particle size distribution of potato starch. The average diameter of the starch granules was 39.56, 44.01, 39.06, and 41.78 µm for Shangi, Wanjiku, Dutch robjin, and Unica, respectively as shown in Table 2 and Figure 2. Wanjiku exhibited the highest mean diameter. The other varieties were similar in size. The size of the starch granules falls in the range of 10 to 100 µm, which is the typical particle size distribution for potato starch used commercially (Manek *et al*., 2012). Larger particles flow better than smaller ones due to the high surface energy of small particles which makes them attracted to one another resulting in aggregation and resistance to flow.

Table 2. Particle size parameters of potato flour samples

Varieties	D10 (µm)	D50 (µm)	D90 (µm)	Average Diameter (µm)
Shangi	22.68±0.03	37.82±0.01	63.19±0.04	39.56±0.03
Wanjiku	27.28±0.02	43.65±0.03	68.82±0.08	44.01±0.02
Dutch robjin	24.49±0.09	39.22±0.11	61.81±0.02	39.06±0.04
Unica	22.68±0.05	41.42±0.01	77.58±0.04	41.78±0.05

- Results are the means of triplicate determinations ± standard error.
- D10 granule diameter for which 10 % of the volume consists of smaller granules, D50 granule diameter for which 50 % of the volume consists of smaller granules, D90 granule diameter for which 90 % of the volume consists of smaller granules.

As indicated in Figure 2, the starch granules exhibited unimodal particle size distribution indicating good homogeneity. The normal distribution curves show that the mean particle size of all the varieties is similar as indicated by the peaks of the curves.

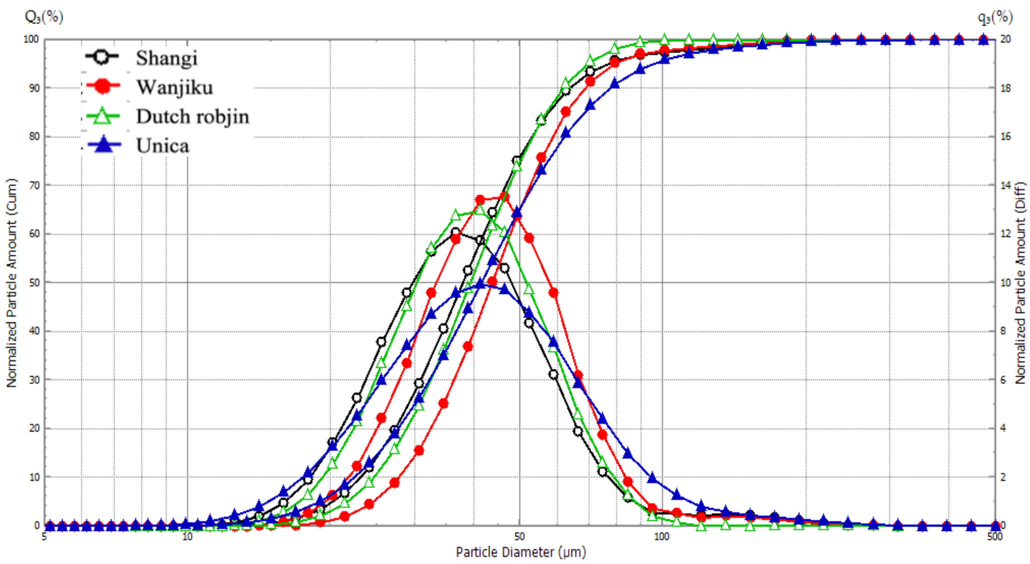

Figure 2. Cumulative undersize curves and particle size distribution curves of potato starches

The cumulative distribution curves depict a sigmoidal curve with Unica indicating the highest particle size in agreement with the results in Table 2. Particle-size of starch is important as it influences its chemical and functional properties. It was observed that the higher the particle size, the lower the starch content and vice versa.

Scanning electron microscopy of potato starch. Potato starches from different varieties were generally oval. This observation compares with Sanchez-González *et al*. (2019) who reported oval and spherical shapes for potato starch. There was no visual difference in the morphologies of starch among the flour potato varieties. All the granules had an intact structure indicating no interference or modification. Potato starch granules are bigger than starch granules from other plants.

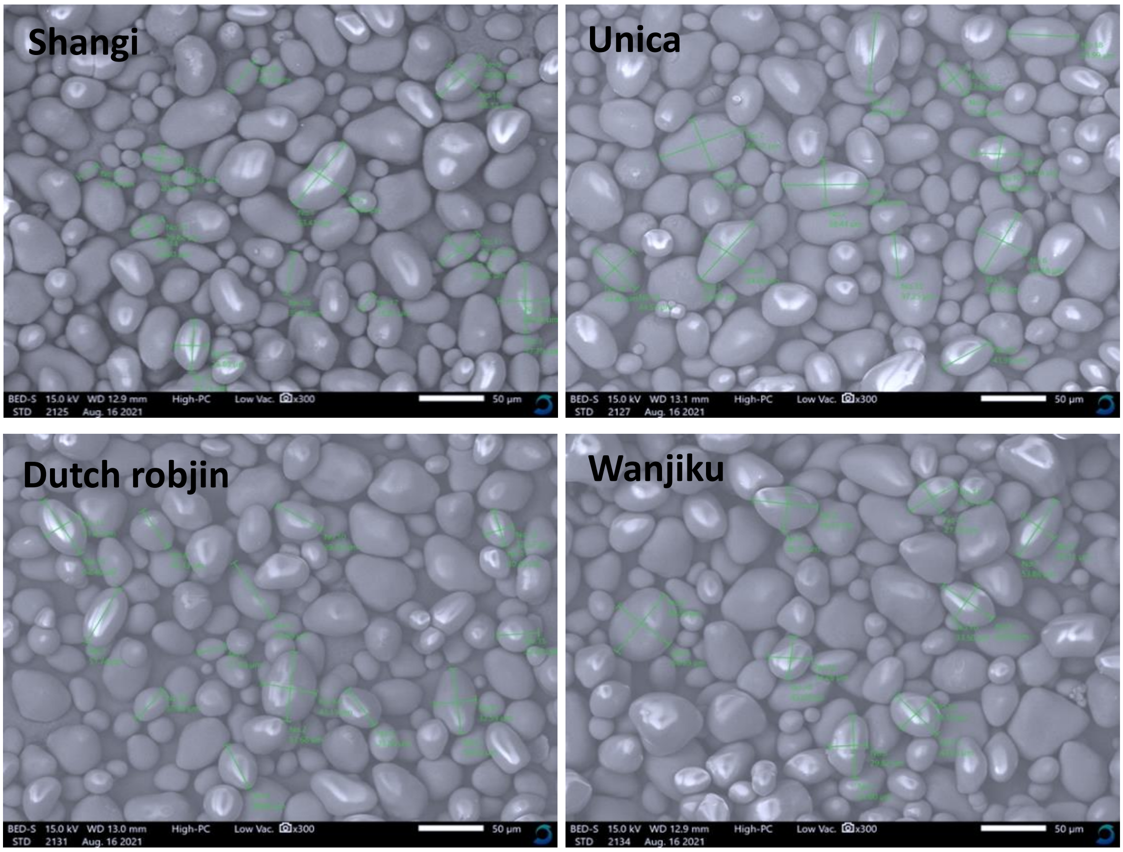

Figure 3. Scanning electron micrographs (SEM) of potato starch from different varieties

Conclusion

The four varieties studied differed in terms of their specific gravity, dry matter, starch content, and moisture content. Dutch robjin had the highest values for the physical parameters and recorded the highest starch content. Starch granules presented differences in their particle size distribution but displayed similar shapes (oval). The starch content decreased with the increasing size of the particles. Further research on the functional properties of the starch is needed to determine the suitability of each starch extract for specific applications.

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