Physicochemical, functional and pasting properties of cassava starch: Potential of developing flexible packaging film

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Received: 15 February, 2024 **Accepted**: 05 March, 2024 **Published**: 21 May, 2024

ABSTRACT

Developing multipurpose flexible packaging mainly from starch film is essential both from food safety and environmental issues. Starch has various functional, pasting, and physicochemical properties. A study was conducted to evaluate the physicochemical, functional, and pasting properties of Qulle (Q) and Kello (K) cassava starch and develop plastic film. A Completely Randomized Design with the main responses such as vital proximate composition, viscosity profiles, water absorption capacity, oil absorption property, and film strength was employed. All data analysis were performed using Design Expert software version 7.0.0. The result showed K starch moisture of 11.4%, ash 1.1%, fat 0.11%, protein 0.52%, fiber 0.01%, and carbohydrate 86.85%. Q cassava starch moisture was 10.6%, ash 0.13%, fat 0.13%, protein 0.35%, fiber 0.09%, and carbohydrate 88.7%. The proximate parameters showed a significant difference between Q and K's starches at $p < 0.05$. The amylose of Q starch was 26.29 % and K was19.16%, which were significantly different ($p < 0.05$). Variations in amylose affected the functional properties of starches. The peak and breakdown viscosities of K starch were higher indicating that the final viscosity and peak temperature of Q starch affects its application. The functional and pasting parameters of Q and K starches varied significantly ($p < 0.05$). The plastic film developed from Q starch had low moisture, water absorption capacity, high transparency, tensile strength, and water solubility. It is concluded that Q cassava starch-based film is recommended for multipurpose flexible packaging. Overall, the functional and pasting properties of Q and K starches are influenced by amylose and proximate composition which impact their applications.

Keywords: Cassava varieties; Functional property; Industrial application; Plastic film
DOI: https://dx.doi.org/10.4314/ejst.v17i1.2

INTRODUCTION

Cassava is the second most important staple food for energy in Sub-Saharan Africa providing up to 285 calories per day (Benesi et al., 2004). Even if the introduction of the crop to Ethiopia is not well documented, it is believed to have been introduced to Ethiopia in the middle of the nineteenth century (Tassew, 2007). It is popular in southern Ethiopia where it is used for food, feed, and as source of income for many rural and urban

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households. Currently, it is expanding to all parts of Ethiopia because of its drought tolerance and higher yield, especially, the two late maturing (12-18 months) cassava varieties namely Qulle and Kello.

In Ethiopia, the cultivation of cassava is mainly for its edible tubers. It serves both as a food security and a cash crop for small-scale farmers. Regardless of these benefits, in Ethiopian, cassava has been neglected for numerous reasons by researchers and policymakers for many years and it's also considered as a food of people with low per capita income (Feyisa, 2021). Nevertheless, recently, a few researchers and institutions have tried to conduct studies on cassava, especially on expanding the cultivation in areas with different climatic conditions (Tadesse, 2022) to evaluate productivity, diversifying cassava consumption by blending with teff flour for Injera baking as well as substitution of cassava flour with wheat flour for multipurpose baking (Girma et al., 2021). Besides, there are studies conducted on the physicochemical characteristics, functional and pasting properties of cassava worldwide in order to determine the particular functional and pasting properties of individual starches for industrial purposes. For example, the physicochemical characteristics of cassava starch was studied in Uganda (Nuwamanya et al., 2010). Nuwamanya et al. (2010)reported that amylose was positively correlated with starch content and negatively with the swelling power and solubility of cassava flour; showing the genetic and biochemical differences as crucial factors for actual applications. Cornejo-Ramírez et al. (2018) also reported that high amylopectin with short lateral chains favors hydration through hydrogen bond for good gel whereas starch with smaller granules increase water uptake of the starch flour due to larger superficial area and fair surface pores. Other studies also focused on the chemical, physical, rheological, pasting and function of cassava starch although these studies lacked some practical lab scale work like testing the verities of cassava starch for specific end – use. Considering this point, to our knowledge, no research work has been conducted on comparing cassava varieties' physicochemical characteristics specifically Qulle and Kello in order to develop biofilm for bio-packaging materials. Therefore, this study was carried out to assess and compare the physicochemical characteristics, pasting and functional properties of Qulle and Kello cassava varieties with the objective of determining their potential application for multipurpose biodegradable packaging.

MATERIALS AND METHODS

Raw material collection, preparation and starch extraction

The roots of Qulle (Q) and Kello (K) cassava varieties (Figure 1A and B) used for starch extraction in this study was obtained from Hawassa Agricultural Research Center (HARC), Hawassa, Ethiopia. The fresh roots were washed, peeled and chopped into

small pieces (Figure 1A and B), and then pulverized in a blender after mixing the proper amount of chopped cassava roots with water (material to water ratio) at room temperature. Then, the starch was extracted according to the procedure described by Shadrack Mubanga et al. (2019) with a few modifications. The pulp of the two cassava varieties was suspended and stirred in potable water in the ratio of 1:10 and the mixture was filtered using a filter cloth. The collected filtrate was allowed to sediment and the sediments were washed. The extracted starch was washed, sun-dried for 48 hours (at a temperature of 21 ºC and relative humidity of 80%), packed in airtight plastic bag and kept at room temperature for further analysis. All the chemicals and reagents used in this study were of analytical grade.

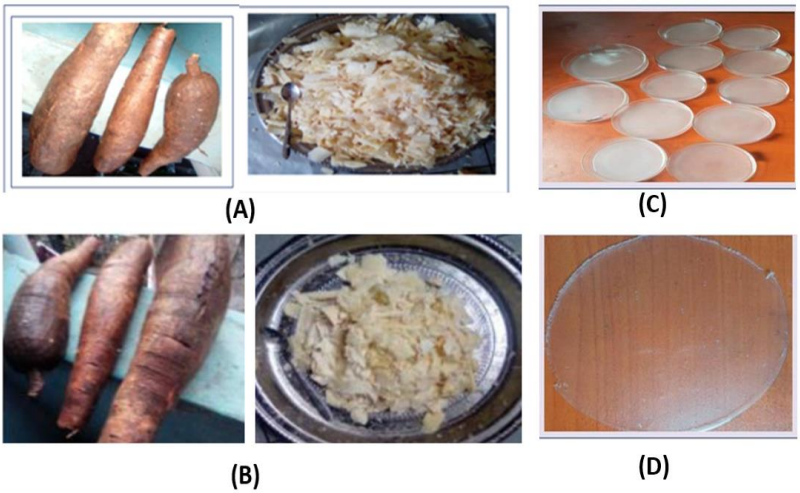

Figure 1. Raw materials: A) Qulle cassava root, B) Kello cassava root, C) Casting of the mixed films (D) Representative dried film (Both cassava varieties starch-based film has the same appearance)

Proximate composition of the isolated starch

Moisture content

The moisture content of the isolated starch from both cassava varieties (Q and K) were determined using eqn. (1) according to the AOAC, 2012) method 925.10 by drying of about 3 g starch sample of each cassava variety at 135 °C for 3 h in an oven (700 LT, Italy).

$$\text{Moisture } (\%) = \frac{\text{Wi} - \text{Wf}}{\text{Wi}} \text{ x } 100 \qquad \text{eqn. 1}$$

Where Wi: weight of cassava starch sample before drying, W_f: final weight of sample after drying.

Ash content

The ash content of starch cassava which measures the mineral content of the starch was determined using (AOAC, 2012) method 923.03 by taking about 3 g sample after carbonization and ignition at 550 °C for 3 h. in the muffle furnace (Model: VF2 Chesterfield, UK).

$$\text{Ash content}(\%) = \frac{W1-W2}{W1} \text{x } 100 \qquad \text{eqn. 2}$$

Where, W1: weight of cassava starch before ashing, W2: weight of ash

Crude fat

The crude fat content was determined using standard (AOAC, 2012) method 920.39 by taking about 2 g of cassava starch sample in a Soxhlet extraction unit using diethyl ether as a solvent.

$$\text{Crude fat } (\%) = \frac{W1-W2}{W3} \text{x } 100 \qquad \text{eqn. 3}$$

Where, W1: weight of cassava starch sample, W2: weight of fat beaker and W3: weight of beaker with extracted residue.

Crude protein

Protein content was determined using the Kjeldahl method as described in AOAC (2012) by taking about 2 g of the cassava sample and using the conversion factor protein (%) = N% × 6.25

Crude fiber

The crude fiber content of the sample was determined by using Gerber (AOAC, 2012) method after successive digestion of 1.5 g (W1) weighed sample with 200 ml of 1.25% sulfuric acid and then boiled for 30 minutes followed by filtration (75 micron) under suction pressure. The residue was washed with hot distilled water to remove the acid. The residue was then boiled in 100 ml, 28% of KOH under reflux for 30 min and filtered under suction. The insoluble was washed with hot distilled water to remove the alkaline and quantitatively transferred to pre-ignited weighed ashing crucible (W2). The insoluble was dried in a hot air oven (model: 700LT, Italy) at 130 °C for 2 h., and then cooled in the desiccator. The sample was then carbonized in a crucible, ashed in a muffle furnace (Model: VF2 Chesterfield, UK) to subtract ash from the fiber, cooled in a desiccator and re-weighed (W3).

$$\text{Crude fiber } (\%) = \frac{W1 - W2}{Ws} \text{x } 100 \qquad \text{eqn. 4}$$

Where, W1: weight of crucible with fiber after drying, W2: weight of crucible with ash and Ws: sample dry weight.

Carbohydrate

The carbohydrate content of the cassava starch was calculated by the method of difference; that is carbohydrate (%) = 100 - (protein value + fiber value + moisture value + ash value).

Pasting and functional properties of the isolated starch

The amylose and amylopectin content and the functional properties of the starch were determined using established methods and procedures. The measured functional properties are: the swelling power of starch, water solubility, water and oil absorption capacity. The pasting profile properties of the starch were also assessed using Rapid Visco Analyzer (RVA) (Model: RVA4500, Perten instrument, Australia) according to procedures established by (Schierbaum (2007). Cassava starch from both varieties (Q & K) samples (4 g each) was mixed with 25 ml of distilled water in a canister and using a stirring plastic paddle the suspension was mixed continuously during the heating and cooling process of the RVA. After setting the rotating speed of the paddle to 160 rmp, then the pasting profiles of the starch and RVA parameters (pasting temperature, peak viscosity, breakdown viscosity, final viscosity, setback viscosity, and peak time) were automatically computed and recorded.

Preparation and characterization of edible bio-packaging film

The films were prepared using a casting technique following the method described by (Adamu et al. (2017). To develop the film, a film-forming solution (FFS), a viscous material that is formed from a combination of extracted starch, water, and glycerol are required. Film-forming solutions were prepared by mixing 5 g of extracted starch in 70 ml of water and 40 g of glycerol per 100 g of starch under constant stirring for 10 minutes at room temperature. The suspension solutions were then heated at 70 ºC using hot plate while constantly stirred to get a uniform bubble-free filmogenic solution. The FFS was poured into petri dish and dehydrated in an oven (Model: 700 LT, Italy) at 50 ºC for 24 hours to obtain transparent and flexible film as shown in Figure 1C. After two days, the film was cooled and peeled off from the petri dish and kept at room temperature for further characterization.

The film thickness was measured by using an electronic digital micrometer (Model: Mitutoyo Co., Japan), i.e., digital micro-meter 0-25 mm-0.001 mm, digital thickness gauge 0-10 mm-0.0011 mm action 2.8 software. The methodology for verification of the thickness consisted primarily of cutting 2 samples 10 mm × 10 mm size each of the starch variety films. Under each sample 10 measurements were taken using the digital micrometer. For the readings do not coincide on the same point read, ran up was done on an anti-clockwise movement on the surface of the sample, from the center towards the periphery, simulating a “snail” or helical. Later on, other film samples with the

same characteristics of the above (2 new samples of films of each cassava starch variety), 10 measurements were taken using the millesimal thickness meter. These values were tabulated in order, as it was in the measurements. Then the tensilestrength and elongation at break of the film was examined using the standard method ASTM D882-02 with a texture analyzer (Model: TA Plus, lloyed instruments).

The detail is that the film specimen was cut into rectangular strips (15 mm width ×100 mm length). Then samples were clamped between grips at a distance of 50 mm and force deformation was recorded during extension at 10 mm per min. The recorded dimensions of the film samples (thickness and width) were fed into the computer and the tensile strength was automatically calculated by the computer software. Finally, the strain-stress curve was drawn to determine the Young's modulus. The moisture content of the film was also determined. The water solubility of the film was determined as follows. The film samples were cut into square pieces of 4.0 cm^2 and accurately weighed to record the dried film mass. The films were placed into a beaker with 50 ml distilled water for 24 h with slow mechanical stirring using a shaker at room temperature. Samples were then removed from the water by filtration and dried in electrical oven (105 ºC for 24 h). The percentageof solubility of the film was calculated according to equation (5):

$$\text{Water solubility} = \frac{\text{Initial dry weight} - \text{Final dry weight}}{\text{Initial dry weight}} \times 100 \qquad \text{eqn. (5)}$$

For measuring the color of the bio-films, ASTM D2244-02 using D65 standard illuminant and 10 degrees viewing angle was applied using Spectrophotometer (Model: CM-600d Spectrophotometer, Japan). Prior to measuring the film color, the colorimeter was calibrated using a standard white plate. Then, the color measuring was performed by placing the film specimen on spectrophotometer sample holding section and measures the color parameters of the film following the standard set by Commission International d'Eclairage (CIE) (González Sandoval et al., 2019). The bio-film transparency was determined by using UV– Vis's spectrophotometer (Model: UVD 3200, Labomed, Inc.) at a wavelength of 600 nm. The transparency value of each film was calculated by using Equation (6):

$$\text{Transparency} = \frac{\text{Absorbance at 600 nm}}{\text{X}} \qquad \text{eqn. (6)}$$

Where: X = Film thickness (mm)

The water vapor transmission rate (WVTR) of the bio-film was determined using Desiccant Method (Syarifuddin et al., 2017). Petri dishes of size 10 cm diameter were used to determine the water vapor permeability of the film. The film was first cut into circular disks larger in size than the inner diameter of the Petri dishes. Then, the Petri

dishes were placed on a horizontal platform. Anhydrous calcium chloride as a desiccant with 0% relative humidity was placed inside the Petri dish. Then, the film was placed on top of the Petri dish and sealed. Then the sealed Petri dish was weighed and kept in a desiccator containing 70% concentration of sodium chloride for 72 h. Data obtained from the recorded weight of the cup was used to generate a linear regression graph. The slope calculated from this linear graph divided by the area of the film (m^2) represents the water vapor transmission rate of the film, equation (7).

$$\text{Water vapor Transmission} = \frac{\Delta \boldsymbol{m}}{\Delta \boldsymbol{t} \text{ x } \boldsymbol{A}} \qquad \text{eqn. (7)}$$

Where, $\Delta m/\Delta t$ is the moisture gain weight per unit time (g/h), and A is the exposed surface area of the film (m2).

The water absorption of the bio-film was performed in accordance with ASTM D-570–98. Hence, the film sample was first dried for 24 h at 40 °C, cooled in a desiccator and then the film was cut into a piece with 2.5 ×2.5 cm width and weighed in air-dried condition, which was finally soaked in distilled water for 24 h at room temperature. The Fourier Transform Infrared (FTIR) Spectroscopy of the film was examined using Thermo- Scientific FT-IR instrument (Model: SMART iTX, Thermo scientific).

Statistical data analysis

A Completely Randomized Design comprising of two varieties of cassava cultivars (Kello and Qulle) was used for physicochemical, functional and pasting property studies. Quantitative data analysis was carried out using Design Expert statistical analysis Software Version 7.0.0. All samples were performed in triplicate and results presented in mean ± standard deviation. The obtained data was subjected to a one-way statistical analysis of variance (ANOVA) to test for the difference among the two cassava varieties at a significance level of $p< 0.05$ by applying the least significant difference (LSD) test.

RESULTS AND DISCUSSION

Proximate composition of starch from cassava varieties

The moisture, ash, protein, crude fiber, and carbohydrate composition of starches from Kello and Qulle cassava varieties is shown in Table 1. Moisture content, ash, protein, and carbohydrate contents showed a significant difference between the two cassava varieties ($p < 0.05$). Starch from Kello had more moisture content than Qulle starch variety. This moisture content is affected by the duration of grounded raw cassava root exposed to thermal or sunlight, ambient temperature, humidity, and air condition of

the environment. Besides, the structural nature of the starches' microstructure had also affected the water uptake or loss during the process (Sasaki and Matsuki, 1998). Results from previous studies show that the range of moisture content of cassava starch varied between 10 to 12.2% where the drying condition was at ambient temperature. Hence, the obtained moisture content of Kello and Qulle cassava starch within this range. Interestingly, the current result shows lower moisture content compared to the results cited in the different studies for cassava regardless of varieties as clearly shown in Table 1. Moreover, the ash content of starch was calculated and found as 11.4% for K and 10.6% for Q, respectively. This finding is nearly similar to the ash content reported in the work of (Shadrack Mubanga et al., 2019).

Table 1. Proximate analysis of the two cassava varieties' starch (dry basis), (%)

Proximate parameters	**Cassava Varieties**	
	Kello	**Qulle**
Moisture	11.4±0.245a	10.6±0.286ab
Ash	1.1±0.124b	0.13±0.004d
Fat	0.11±0.004b	0.13±0.005b
Protein	0.52±0.008b	0.35±0.004d
Crude fiber	0.01±0.004b	0.09±0.012b
Total carbohydrate	86.85±0.241c	88.7±0.082cb

Note: All values are means of three replicates with standard deviations. The values within a row with different letters are significantly different at $p < 0.05$ by LSD test.

On the other hand, the crude fiber content was determined and found that the Qulle cassava starch was higher than Kello cassava starch. However, crude fiber content of both varieties fell with range reported before, i.e., 0.10 – 0.15% (Ayetigbo et al., 2018). The protein values of the two cassava varieties were in consistent with other previous findings. For example, the observed values for crude protein were between 0.28 - 0.52% for starches from the different varieties of cassava (Nuwamanya et al., 2010). And also, when compared with other roots and tubers, cassava roots show the lowest protein content (1–3%) ona dry basis (Ayetigbo et al., 2018). Similarly, the value obtained for crude fat (0.01 for K & 0.09% for Q) (Table 1) is nearly consistent with the average values of 0.1% for different varieties of cassava but, somewhat less than the cassava starch crude fat contents from previous reports, i.e., 0.37% and 0.79% (Eke-Ejiofor, 2015). Increased fat content has been shown to increase starch textural characteristics and viscosity, hence improving starch quality (Eze, 2020). Furthermore, the carbohydrate contents of both varieties were calculated and found to be high. The results of this study in terms of carbohydrates were found to be greater than values ranging from 83.92 to 85.55% for several cassava varieties (Agbemafle, 2019). The literature classifies cassava root as a high-calorie food with a high percentage of carbohydrates (80–90% dry basis) consisting almost entirely of starch (Ayetigbo et al., 2018).

Amylose contents of isolated starch

Table 2 summarizes the amylose and amylopectin contents as well as the functional properties of the isolated cassava starches. The amylose content of Kello (19%) significantly varied from the amylose content of Qulle starch (26%) ($p< 0.05$). Differences in amylose and amylopectin contents are associated with genotype or variety differences (Doué et al., 2014). The amount of amylose in starch indicates the kinds of starch. When amylose content is 0–2%, it is waxy, 3–15% it is semi-waxy starch, 15–35% and > 40% it is normal or regular starch (Shadrack Mubanga et al., 2019). Consequently, the type of isolated starch of the cassava varieties (Kello & Qulle) can be classified as normal or regular starches.

Functional properties of cassava varieties' starch

The functional properties of the isolated starch viz swelling power, water absorption capacity, oil absorption, and water solubility significantly varied between the two cassava varieties ($p < 0.05$) (Table 2). The swelling power of Kello and Qulle starches was found to be 7.6 and 5.3 g/g, respectively.

Table 2. Functional properties of the two cassava varieties' starch (dry basis)

Functional properties	**Corresponding cassava starch values**	
	Kello	**Qulle**
Amylose content (%)	19.16±0.147^{ab}	26.29±0.004cb
Swelling power(g/g)	7.56±0.012^{a}	5.32±0.008b
Water absorption (g/g)	9.83±0.001a	24.853±0.001b
Oil absorption (g/g)	19.94±0.012a	21.93±0.012b
Water solubility (%)	31.50±0.012b	36.90±0.047d

Note: All values are means of three replicates with standard deviations. Values in the same row with different letters are significantly different at $p < 0.05$ by LSD test.

Such differences might be related with the size of the starch granules, the number of interactions between amorphous and crystalline regions, and the molecular structure of amylose and amylopectin. These swelling power values are consistent with the values previously studied from six distinct cassava varieties ranging from 2.22 to 15.63 g/g (Onitilo et al., 2007). A swelling power value can be as high as 27.2 - 42.3) (g/g) (Shadrack Mubanga et al., 2019) while another study reported between 9.0 - 16.9 g/g at a temperature of 80 °C (Onitilo et al., 2007). On the other hand, the water absorption capacity (WAC) of Kello and Qulle starch was found 9.8 and 24.8g/g, respectively. The variation in WAC implies differences in hydrogen bonds formed among the starches, size, shape, structural features, and the degree of availability of water binding sites (Ayetigbo et al., 2018). These parameters are vital for flours produced from cassava in order to prevent dryness and tolerate heat during food industrial processing. Although cassava starch has the highest water absorption capacity, its practical application is

influenced by temperature which determines how starch interacts with water. For instance, in an aqueous medium at low temperature, native starch granules swell due to the diffusion and absorption of water in the granule amorphous regions (Donmez et al., 2021). The ability of starch to absorb oil is a measure of the emulsifying potentials of the starch. In this study, the oil absorption capacity (OAC) of Kello and Qulle starches was found to be 20 and 22 g/g, respectively. This OAC value was found to be higher than the values of some starchy foods such as bean starches (2.42–3.35 g/g) (Olu-Owolabi et al., 2011) which might be related to the granules statues of the starch that tie with the size and porosity of the granules and play a dominant role in the oil absorption process. Furthermore, the solubility power of the starches obtained from the Kello and Qulle cassava varieties was found to be 31.5 and 37%, respectively. These values are generally consistent with the previous reports on cassava starch solubility, i.e., 1.62–71.15% (Shadrack Mubanga et al., 2019). Similarly, another study reported the solubility of cassava starch with the ranges of 1.03 to 47.07% (Onitilo et al., 2007). This solubility power of starch is associated with the amylose and amylopectin interactions during the process. This is because during processing, starch granules swell and amylose leaches out (Olu-Owolabi et al., 2011).

Pasting properties of cassava varieties' starch

Starch functionality and application are associated with its pasting profiles. The pasting properties of the two cassava varieties' starch such as pasting temperature (PT), peak viscosity (PV), breakdown viscosity (BV), final viscosity (FV), setback viscosity, and peak time are presented in Figure 2 and Table 3.

Table 3. Pasting properties of the two cassava varieties' starch (dry basis)

Cassava Variety	Pasting property parameters and values					
	PT (°C)	PV (cP)	BV(cP)	FV(cP)	SB(cP)	Peak time(min)
Qulle	68.50cd	1550cd	691cd	1335cd	476cd	5.00a
Kello	67.85bd	1610bd	776cd	1296bd	462bd	4.87a

Note: All values are means of three replicates. Data within the same column, the values withdifferent letters are significantly different at $p < 0.05$ by the LSD test. Where: PT: Pasting temperature (^{O}C), PV: Peak viscosity (cP), BV: Breakdown viscosity, FV:Final viscosity (cP), and SB: Setback viscosity (cP)

Starch viscosity and pasting properties significantly varied between the two varieties ($p < 0.05$). The Peak viscosity of Kello starch was 1610 and Qulle 1550 cP (Figure 2, Table 3). The current values were higher than some previous findings on pasting properties of cassava starch (782.3– 983.5)cP (Shadrack Mubanga et al., 2019) and lower than others (3036.12 – 4139.52) cP (Nuwamanya et al., 2010). The presence of interfering non-starch components like crude protein and fiber could contribute for the higher peak viscosity values seen in Kello cassava starch. Similarly, the breakdown

viscosity of Kello starch was found to be 776 and is higher than the Qulle starch (691) cP.

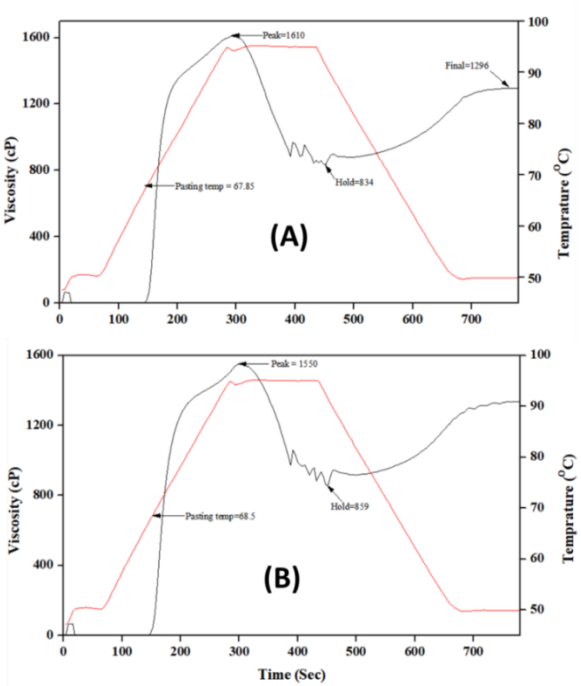

Figure 2. A pasting profile of starch isolated from A) Kello, B) Qulle

This value shows the behavior of the rate of gelling stability which is based on the nature of the product. The breakdown viscosity measures the degree of disintegration of granules or paste stability. Hence, at breakdown, swollen granules due to water penetration disrupt further and cause amylose molecules to leach out (Tsakama, 2010). The final viscosity value of Qulle starch (1335) was higher than the Kello starch (1296) cP. The differences in final viscosity between the two varieties could be due to variations in amylose and crude fat contents (hence higher in Qulle cassava) of the starches. These values are higher than the values obtained from various previously studied cassava varieties (462.0–569.7) cP. Besides, it was found that the values of this research are in agreement with other studies such as (145.96 - 227.17) RVU or (1751.52 – 2726.04) cP (Nuwamanya et al., 2010). The setback viscosity of the two cassava varieties' starch was generally lower (Q: 476, K: 462) cP (Table 3). The values obtained in this research are in agreement with the higher setback viscosity values of cassava starches (278.1– 487.0) cP reported before (Shadrack Mubanga et al., 2019). Generally, starch pasting properties are important in the characterization of starch and the difference observed between the two cassava varieties' starch provides necessary

information before utilizing these cassava varieties in the industry.

The pasting temperature of starches obtained from (K) was found to be 68.85 °C while from (Q) was 67.5) °C. These values are in agreement with the previously reported pasting temperature (64.54–70.54) ℃ (Shadrack Mubanga et al., 2019) of cassava starch. Differences in pasting temperature between the two cassava varieties could be related to differences in amylose content and starch granule sizes. As discussed above, Qulle starch had higher amylose content which makes it to have a higher pasting temperature. Thus, the pasting viscosity of the starches such as the final viscosity was affected. The peak time of the starch isolated from the two cassava varieties had a similar peak time, i.e., 5 min.

Physicochemical properties of the developed film

The moisture contents of the developed films (Figure 1D) prepared from the Kello (13%) and Qulle (12%) cassava starches were examined in order to estimate their water bonding capacity (Table 4).

Table 4. Mechanical and functional properties of the film

Properties	**Corresponding cassava starch values**	
	Kello	**Qulle**
Moisture content (%)	13.25±0.008a	11.62±0.012ab
Transparency (%)	11.62±0.008c	12.30±0.163c
Average thickness (mm)	0.13±0.021d	0.12±0.012d
Tensile strength	13.55±0.004cb	14.98±0.002bd
Percentage elongation (%)	72.46±0.001eb	59.22±0.002ed
Young‘s modulus (Y), MPa	23.12±0.001fb	32.33±0.01fd
Water absorption (%)	33.08±0.065gb	29.39±0.008gd
WVTR ($g/h.m^2$)	0.13±0.001g	0.14±0.002g
Water solubility (%)	26.37±0.21hb	28.85±0.005hd

Note: All values are means of three replicates. Data within the same column, the values withdifferent letters are significantly different at $p < 0.05$ by the LSD test.

This value of moisture content of the film falls within range of the values of cassava starch-based film for food packaging reported before(14.4 to 16.4%) (Prabha & Ranganathan, 2017). Since significant amount of moisture content in edible packaging of food will cause damage to the food products, moisture absorption must be considered. Hence, it is advisable to use food packaging that has a low moisture absorption rate (Luchese et al., 2018; Shreejaya sivadas, 2018). In this regard, both Qulle and Kello cassava starches could be utilized potentially to develop biodegradable packing, especially for food packaging at industry level.
Table 5 shows the results of the color parameters of the films investigated in the current

study. The L^* value of the Qulle film was higher than that of the Kello film which indicates that it is whiter than the Kello starch film. Color parameter is affected by starch varieties, starch granule size and shape as well as thickness (Table 5). Qulle starch film was lighter than Kello starch film. Both the films showed a^* values of around zero. This implies that the films derived from cassava starches showed a slight tendency towards negative values, i.e., towards a green color. Further, the average transparency of values of the films was evaluated and tabulated (Figure 1D). Being transparency is good because consumers generally prefer more transparent bio-edible food packaging films supposing that it is used for packaging purpose. Nevertheless, low transparency does not automatically imply poor quality and may not protect the food as efficiently from photo-oxidation-induced lipid oxidation (Luchese et al., 2018). As a result, Kello cassava starch-based films are less attractive when transparency is an issue, but they may have a benefit in protecting food that is susceptible to light damage.

Table 5. Observed average color parameters of the two-cassava starch edible films

Samples	**Cassava varieties**		**Literature values**
	Qulle	**Kello**	
L*	45.12 ±0.22	44.02±0.61	89.14
a*	-0.35±0.03	-0.49±0.10	0.82
b*	-3.07±0.09	-1.02±0.96	1.51
ΔE	44.26	45.19	--
Chroma (C*)	4.60	2.55	--

Note: All values are means of three replicates with standard deviations

Mechanical and functional properties of the film

Mechanical properties

The average thickness of the films obtained from Kello and Qulle starches were almost similar (Table 4). However, the small differences observed in thickness could be related to differential film drying kinetics which influences the ultimate thickness and structure of the film. Nevertheless, the thickness value of the films found in this study is quite good since it is below the maximum thickness of 0.25 mm. Thick edible packaging films of more than 0.25 mm are undesirable as they inhibit the interchange of gas caused by respiration, eventually making the product more vulnerable to deterioration (Domene-López et al., 2019). The tensile strength of the film developed from Qulle starch was relatively higher than the Kello one (Table 4A). Figure 3 further shows the strain-stress of the developed film where (A) represents Qulle film while (B) is Kello cassava starch film. The highest tensile strength value was obtained for Qulle starch film (Figure 3A). The film developed from Qulle cassava starch resists more pressure than its counter film. The reason for this is that Qulle cassava starch had higher amylose content than Kello cassava starch, thus, Qulle cassava starch content typically

has a higher number of crystalline domains which could be responsible for the higher tensile strength of the film (Domene-López et al., 2019).

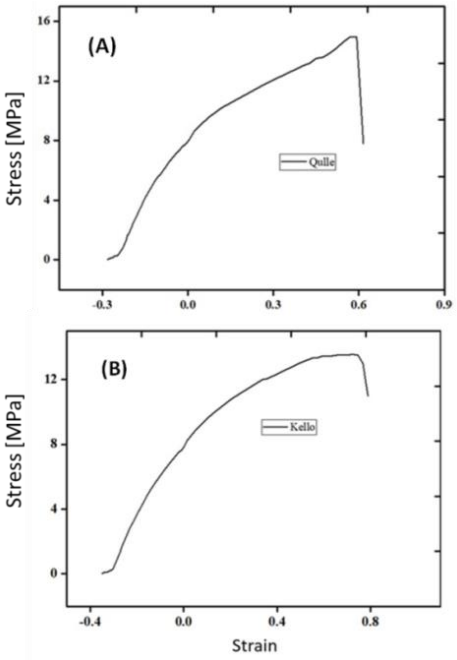

Figure 3. A stress-strain curve for A) Qulle film, B) Kello film

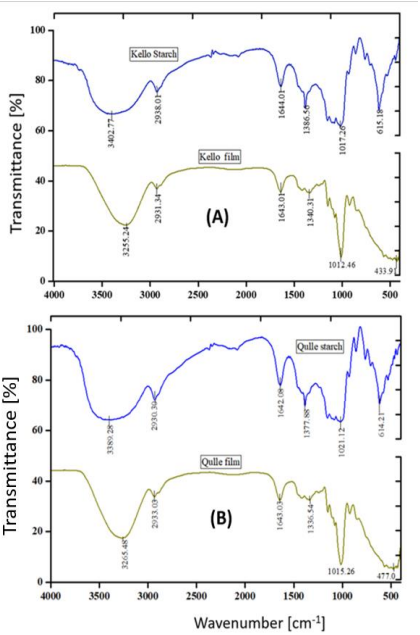

Figure 4. FTIR analysis of (A) Kello starch and its derived film (B) Qulle starch and its derived film

The standard of tensile strength of edible films could be at least 3.92 MPa (Luchese et al., 2018) which implies that both films meet the standards. The value of percentage elongation (E) of Kello cassava starch film is higher than the Qulle cassava starch as shown in the Table 4. The values of these findings are consistent with the Japanese Industrial Standard (JIS) which states that if the percentage elongation is less than 10%, it is not acceptable, but is so good if it is more than 50% (Standards, 2011). IThe edible film developed in this study could be used as primary food packaging since its elongation values of the films were high. The elasticity value (Young's modulus) is directly proportional to tensile strength and inversely proportional to elongation (Table 4). As stated in JIS, the minimum value of elasticity of ediblefilm is 0.35 MPa. A value of film elasticity less than 0.35 MPa in edible film can be caused by a number of factors, including a manual stirring technique that only employs a glass stirrer causing the mixture to be unevenly distributed in the solution. Thus, the film elasticity value in this study was found to be higher than the minimum standards.

Functional properties

The percentage water absorption values of the films presented in Table 4 are consistent with the values of cassava-based films (23.04 - 37.97%) reported by (Sivadas and Immanuel, 2018). The differences in water absorption of the two cassava varieties-based films could be due to differences in morphology such as being crystalline, amorphous, crude fiber fraction and orientation of the cassava starch. The ability of edible packaging films to absorb water is critical in determining their stability during packing andstorage.

The water vapor transmission rate (WVTR) of the films developed from the two cassava varieties are given in Table 4. There is a small difference in water vapor transmission rate between the films due to the difference in film thickness. Kello cassava starch-based film was thicker and thus the water vapor transmission rate was found to be lower than Qulle cassava starch-based film. This enables the Kello cassava starch film to absorb more water from the environment and increase its nature of plasticity. Nevertheless, both films agreed with other practically reported work on film's WVTR for edible films (10 g/m^2/24 h or 0.416 g/m^2/h) (Racmayani and Husni, 2020). The water solubility values of the films obtained from the two cassava variety starches are indicated in Table 4. The differences observed in the water solubility of the films are due to the differences in thicknesses, in homogeneous and porous structure of the film. The water solubility value obtained is consistent with the cassava starch films (27.5%) reported before (Chiumarelli and Hubinger, 2014).The presence of functional groups of the film was assessed using Fourier Transform Infrared **(**FTIR) spectrum as shown in Figure 4.

Table 6 summarizes the most relevant information of the bands found in the FTIR spectra of cassava starches and their respective edible-films. The FTIR spectra analysis of starches and their edible films are clearly explained what each peak represents (Figure 2). The small differences in band structure shape and intensity observed (Figure 2A) and 2B in the fingerprint of starch in the FTIR spectra are as a result of the new interactions arising between the glycerol and film matrix. All peaks with high wave number (>3000 cm^{-1}) show hydrogen group, O—H, and H—bonds regardless of their concentrations in the starch and film matrix. Consequently, the starch and its derived films had no significance differences in their functional chemical groups (Figure 2).

Table 6. FTIR analysis of starches and their respective edible films

Wave number literature	Wave number (cm^{-1})				Assigned functional groups
	Kello starch	Qulle starch	Kellofilm	Qulle film	
3570–3200	3402.77	3389.28	3255.24	3265.48	Hydroxy group, H-bonded O-H stretch
3000 - 2840	2938.01	2930.30	2931.70	2933.03	C - H stretching
1648-1638	1644.01	1642.08	1643.01	1643.03	Alkenyl C = C stretch
1420-1330	1386.56	1377.88	1340.31	1336.54	Phenol or tertiary alcohol, OH bend
1400-1000	1017.26	1021.12	1012.46	1015.26	Strong C-F stretching
680-610	615.18	614.21	---	----	Alkyne C- H bend
500-430	------	-----	433.91	477.01	Aryl disulfides(S-S stretch)

CONCLUSION

Starch is an important constituent in many foods and plays a keyrole in achieving the desired viscosity in different industrial products. Because of its diverse sources, it differs in physicochemical, functional, and pasting properties which affect the various industrial utilization capacity. Considering this, the study was conducted to assess the functional and pasting properties of cassava varieties' starch and develop multi-purpose biodegradable film that can potentially be used for packaging. According to the study, the proximate composition, starch functional, and pasting property parameters showed a significant difference between the two cassava varieties ($p < 0.05$). The amylose content of the cassava starch is crucial factor that influence the functionality and viscosity of the starch and its respective film. From the findings, Qulle cassava starch showed higher amylopectin than Kello cassava starch which enhances the water absorption, oil absorption and water solubility properties, but decreases the swelling power regardless of the granule's behavior of the starch.

Although, the hydration capacity of starch favors swelling, in contrast to this, Qulle cassava starch had lower swelling power due to a relatively higher fat content, which could form a complex with amylose and prevent water binding. The amylose and amylopectin content are also affecting the temperature at which the viscosity of the starch begins and increase during a real-processing in industry. The pasting temperature and final viscosity of starch from Qulle cassava were relatively higher compared to Kello starch. The difference in paste properties in the starches is important for manufacturing of commercial resistant starches/ for bio-based packing among other uses. Moreover, we have developed a film and found that a film made from Qulle cassava starch has higher tensile strength and Young's module than Kello cassava starch based-film. Besides, a film based on Qulle cassava starch had relatively lower water absorption and higher water solubility than starch based on Kello. This helps to prevent an easy entry of water and its vapor into the film as well as to easily solubilize

the material whenever damped into the environment. Thus, it could be used to develop multipurpose biodegradable packagings specifically for food manufacturing sectors.

Overall, the starch isolated from Qulle cassava showed relatively better physicochemical properties, and functional and pasting properties that suggest a potential application for developing multipurpose flexible biodegradable packaging films. Consequently, this study provides insight for the scientific and industrial community to acquire know-how on the physico-chemical properties, effect of amylose content, and functional and pasting features of these cassava varieties (Q and K) starch.

ACKNOWLEDGMENTS

The laboratory facilities and other important materials were provided by Addis Ababa Science and Technology University (AASTU), Hawassa Agricultural Research Center, and Addis Ababa University (AAU). The authors would like to express heartfelt gratitude to the aforementioned institutions.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contributions

Desta Geta Kume: Investigation, data curation, writing original draft
Kumsa Delessa Kuffi: methodology, data evaluation and formal analysis
Lemessa Etana Bultum: guidance on original draft preparation, writing reviews and editing final manuscript
Shimeles Shumi Raya: conceptualization, supervision, writing reviews and editing

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