Heliyon 10 (2024) e31148

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Chemical, structural, and techno-functional characterization of yam (*Dioscorea*) flour from South West Ethiopia

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ARTICLE INFO

Keywords:
Chemical
Flour
Morphology
Pasting properties
Yam (*Dioscorea*)

ABSTRACT

Yam (*Dioscorea* spp.) is a versatile tuber crop that holds nutritional, cultural, and economic values. Yam is a major source of carbohydrates for tropical Countries and provides various nutrients and health benefits. This study aims to characterize the chemical, structural, and thermal properties of yam flour using various analytical techniques such as scanning electron microscopy (SEM), X-ray diffraction (XRD), and thermal analysis. Additionally, the pasting and rheological properties of yam flour were evaluated, as they are crucial for product development and enhancing the value of this unconventional vegetable. D. cayenensis complex had the highest total starch (64.63 ± 1.61 %) and soluble sugar (4.95 ± 0.46 %) content, which was significantly higher than other yam species. The amylose content of yam flours showed significant ($p < 0.05$) differences among the yam species. *D. cayenensis* flour exhibited significantly the highest peak (2923.66 cP) and steak back viscosity (2097.66 cP) among the yam species associated with their greater amylose content. There were notable variations in pasting and gelatinization parameters among the species. The peak temperatures of *D. bulbifera* and *D. cayenensis* complex were significantly ($p < 0.05$) higher than *D. cayenensis* and *D. rotundata* flours. The rheological measurements of yam flours demonstrated solid-like behavior with varying intensities. Furthermore, the morphology of tuber yam flour particles was oval to ellipsoidal shaped, with some appearing ovoid, and the smaller granules appearing spherical. The X-ray diffraction showed that all yam flours exhibit a B-type pattern. This study provide a better understanding of this unconventional vegetable's potential applications in the food industry and contribute to its value addition.

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[1] This paper is dedicated to the memory of our dear co-author Tarekegn Berhanu Esho, who passed away while this paper was being peer-reviewed.

https://doi.org/10.1016/j.heliyon.2024.e31148
Received 28 December 2023; Received in revised form 8 May 2024; Accepted 10 May 2024
Available online 11 May 2024
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1. Introduction

Root and tuber crops are the main drivers in achieving food security as they produce starchy tuberous roots and are consumed as human food, animal feed, and manufactured food products [1]. Most tropical countries are home to the cultivation of root and tuber crops to fill food and economic gaps [2]. Furthermore, citizens of these countries also use them by adding values to enhance their nutritional content, industrial use, and therapeutic attributes [3]. The main root and tuber crops include sweet potato, yam, cassava, taro, Irish potato, and yautía. Farmers in Asia, Africa, Latin America, and the Caribbean who have limited resources, use these crops primarily for food and income [4,5].

Yam belongs to the genus *Dioscorea* and family Dioscoreaceae [6] and serves as a staple crop in West Africa. Globally about 600 species are described with a wide geographic distribution in sub-tropical and tropical climates [7]. During times of food scarcity, it is regarded as a famine food and is important to small and marginalized rural families and groups living in forests [8]. After cassava and sweet potatoes, it is the third most significant tropical root and tuber crop. It is a high-value crop that accounts for 10 % of all roots and tubers produced in West Africa [9].

Yam's potential as a food source is credited to its high levels of carbohydrates, including fiber and starch which provide 300 million people in the tropics with about 200 dietary calories per day [10]. Proteins, lipids, vitamins, and minerals are among the additional dietary advantages it offers [9]. Although yam tubers have not been used extensively in industry and have only been used as a traditional domestic foodstuff, there are many different traditional applications for this crop, which offers greater potential for use. Yam is eaten in many different ways, such as food made from raw tubers that are fried, crushed, boiled, or stewed, or they can be boiled and dried and processed into yam chips. Often, tubers are dried and ground into flour for use in a variety of food products [9,11].

Yam is one of the most important crops that grow in the South, Southwest, and Western parts of Ethiopia. Ethiopian yams are becoming more popular nowadays because of their economic and nutritional benefits [12]. In addition to this, selling gathered tubers enhances several livelihoods and supplies food for domestic consumption in densely populated areas of the country [13]. Previously, the diversity, agronomic, genetic, ethnobotany composition, and indigenous biosystematics classifications of different wild and cultivated Ethiopian yam species have been reported by Worojie et al., [12]; Mulualem et al., [13]; Bekele et al., [14]; Worojie et al., [15]; Mengesha et al., [16]; Tamiru et al., [17]. A significant portion of many Ethiopians' traditional food systems comes from yam crops. In particular, the South and South Western regions of the nation have a long history of cultivating and using them [12]. The pasting, biochemical, physicochemical, and functional properties of Ethiopian *Dioscorea* species are reported by Mulualem et al., [18]; Tamiru et al., [19]; Ayele et al., [20]; Argaw et al. [21], but information on the structural, thermal, and techno-functional characteristics of *Dioscorea* species is very limited. In addition to this, by measuring and comparing the structural and chemical properties of yam flours, the study provides important insights into how this type of tuber can be utilized in food processing. This information can guide food scientists, manufacturers, and product developers in optimizing the formulation and processing conditions for various food products that incorporate yam flour as an ingredient [5]. Understanding the structural features helps researchers comprehend the functional behavior of flour in food systems, such as its thickening, gelling, or stabilizing abilities. So favorable chemical, physical, and structural characteristics may aid the utilization of yam in the home and food-related industries. Thus, this work aimed to determine the chemical, structural, thermal, pasting, and rheological properties of yam flour collected from Southwest Ethiopia.

2. Materials and methods

2.1. Sample collection and preparation

A total of 10 kg of fresh yam tubers from different yam species were collected from the Jimma Agricultural Research Center in Southwest Ethiopia. Each species was represented by yam tubers of small-medium and big sizes. The weights of the yam tubers collected for each species are as follows: D. *bulbifera* (SC4): 6.00 kg (small-medium size) and 4.00 kg (big size), D. *cayenensis* (A): 4.55 kg (small-medium size) and 5.45 kg (big size), D. *rotundata* (AC-04): 3.91 kg (small-medium size) and 6.09 kg (big size) and D. *cayenensis* complex (CH-21): 3.80 kg (small-medium size) and 6.20 kg (big size). Samples were transported to the Addis Ababa Science and Technology University's Department of Industrial Chemistry Laboratory in Addis Ababa, Ethiopia immediately after collection. Yam flour was prepared by cleaning, peeling fresh yam with tap and distilled water, sliced into smaller pieces, and freeze-dried (Zirbus, VaCo-2, 4672302, Germany) for 56 h at −50 °C. The dried slices were milled into powder using an electric grinder and passed through a mesh of 600 μm. The milled samples were sealed in ziplock polyethylene bags and kept in a freezer at −20 °C for further analysis.

2.2. Determination of starch and sugar content

The phenol-sulfuric acid colorimetric assay method was used to determine the soluble sugar and total starch content of yam flour following Chow and Landhäusser's [22] procedure with minor modification. To a clean centrifuge tube 0.2 g of yam flour, 1 mL of ethanol, 2 mL of distilled water, and 10 mL of boiling ethanol were added. Following a 10 min, 2000×*g* centrifugation (Funke Gerber, 3680-2616, Germany) at 25 °C, the liquid was vortexed. After adding 9 mL of distilled water and thoroughly mixing, the amount of soluble sugar in the supernatant was calculated by measuring the absorbance at 490 nm with an ultra-violet spectrophotometer (Jasco Inc., V-630, Japan). The calibration curve was drawn using glucose standard and the results are expressed on a dry weight basis. The starch content of the residue was determined using hydrolysis with perchloric acid. The extract was allowed to cool to room temperature, combined with 2.5 mL of concentrated sulfuric acid, and its absorbance was also measured at 490 nm.

2.3. Determination of amylose content

The amylose content of yam flour was determined using the method of Arueya and Ojesanmi [23] with slight adjustments. About 500 mg of yam flour was weighed into a 50 mL volumetric flask, to which 0.5 mL of 100 % ethanol and 4.5 mL of 1 M NaOH were added, mixed and the starch was gelatinized by heating the mixture in boiling water for 10 min. Following cooling, 1 mL of distilled water was added to the solution. After that, 0.5 mL of 1 M acetic acid and 1.0 mL of 0.2 % iodine solution were added to 2.5 mL of the solution in the 50 mL volumetric flasks. The absorbance was measured at 620 nm by ultra-violet spectrophotometer (Jasco Inc., V-630, Japan) after the final solution had been diluted to the appropriate level with distilled water. The amylose content was calculated using Equation (1):

$$\text{Amylose content }(\%) = 3.06 * \text{A} * 20 \tag{1}$$

where A is the absorbance reading at 620 nm, 3.06 is the predetermined gradient of the standard amylose calibration curve, and 20 is the dilution factor.

2.4. Morphology of yam flour

The morphologies of yam flour were determined as described previously by Trancoso-Reyes et al. [24], using a field emission scanning electron microscope (FE-SEM S-4700; Hitachi, Tokyo, Japan), and for each yam flour, images were taken at different magnifications.

2.5. Yam flour crystallinity

The crystallinity pattern of yam flour was investigated using an X-ray diffractometer (XRD7000; Shimadzu Corporation, Japan) at a scan speed of 3°/min and the 2θ range was scanned between 5° and 80°, according to the method of Chen et al., [25]. The relative crystallinity of the yam flour was also quantitatively estimated after calculating the ratio of the diffracted area to the overall area.

2.6. Determination of thermal properties of yam flour

Thermal properties were measured following the procedure reported by Syed et al. [26], with minor modifications using a differential scanning calorimeter (DSC-SKZ1053B, Mettler-Toledo, Switzerland). About 10 mg of yam flour (dry basis) was weighed in a cerium crucible and mixed with 70 % distilled water. After a 2 h equilibration period at room temperature, indium was utilized to calibrate the differential scanning calorimeter (DSC) analyzer, while an empty crucible served as a reference. At a rate of 10 °C/min, samples were heated from 30 °C to 200 °C. The temperatures of onset (To), peak (Tp), conclusion (Tc), and gelatinization enthalpy (ΔH J/g, dry weight) were measured.

2.7. Determination of pasting properties of yam flour

The pasting characteristics of yam flour were assessed using Rapid Visco Analyzer (RVA 4500, Perten Instruments, Australia) with the method outlined by Zou et al., [27]. In a canister, distilled water was combined with yams to make a 12 % well-blended slurry. The suspension was heated to 90 °C for 3.42 min after settling for 1 min at 50 °C and kept there for an additional 2 min. After 3.88 min, the temperature was lowered to 50 °C and maintained for another 2 min. The rotational speed was kept constant at 160 rpm for the duration of the process after being held at 960 rpm for the first 10 s. The variables breakdown viscosity (BV), final viscosity (FV), setback viscosity (SV), peak viscosity (PV), trough viscosity (TV), and pasting time (Pt) were determined.

2.8. Rheological characteristics of yam flour

The rheological characteristics of yam flour were assessed using a modular compact rheometer (MCR-102, Anton Paar, Austria) following the method reported by Chen et al., [25]. A 25-mm parallel stainless-steel plate with a 1−mm plate gap was used. Before being measured in the range of 0.1–100 rad/s at a constant strain of 0.2 % at 25 °C, the tested yam suspension was made by combining 8 % of yam flour with distilled water, heating it in a water bath (Gerber Instruments, WB-22, P.R.C) for 1 h, and letting it cool to room temperature. Loss factor (tan δ), elastic modulus (G'), and viscous modulus (G'') were recorded.

2.9. Data analysis

The IBM Statistical Package for Social Science (SPSS) software, version 26.0 (IBM, New York, USA), was used to perform an analysis of variance (ANOVA). Data obtained was subjected to a one-way Analysis of Variance (ANOVA) and significant differences were reported at a 95 % confidence level using Tukey's test. All the measurements were done in triplicate.

Table 1
Total starch, sugar, amylose contents, and thermal properties of yam flour of Southwest Ethiopia.

Parameters	*D. bulbifera*	*D. cayenensis*	*D. rotundata*	*D. cayenensis* complex
Total starch (%)	52.97 ± 1.10^{b}	55.54 ± 1.32^{b}	53.31 ± 0.82^{b}	64.63 ± 1.61^{a}
Amylose (%)	16.92 ± 0.77^{c}	23.53 ± 0.85^{a}	19.85 ± 0.85^{b}	19.45 ± 0.78^{b}
Sugar (%)	3.15 ± 0.15^{b}	2.36 ± 0.02^{c}	4.35 ± 0.23^{a}	4.95 ± 0.46^{a}
Onset temperature (°C)	53.80 ± 0.96^{ab}	59.13 ± 2.85^{a}	47.23 ± 1.89^{b}	58.76 ± 3.84^{a}
Peak temperature (°C)	88.80 ± 0.00^{a}	81.03 ± 1.35^{b}	71.70 ± 0.00^{c}	87.36 ± 1.35^{a}
Conclusion temperature (°C)	113.00 ± 1.15^{a}	100.93 ± 3.17^{b}	105.20 ± 5.55^{ab}	109.06 ± 1.98^{ab}
Gelatinization enthalpy (J/g)	5.39 ± 0.21^{a}	2.22 ± 0.37^{c}	2.30 ± 0.27^{c}	3.74 ± 0.31^{b}

All data were means ± standard deviation of triplicate measurements. In the same row, the number who carried the same superscripts is not significantly different at $p < 0.05$.

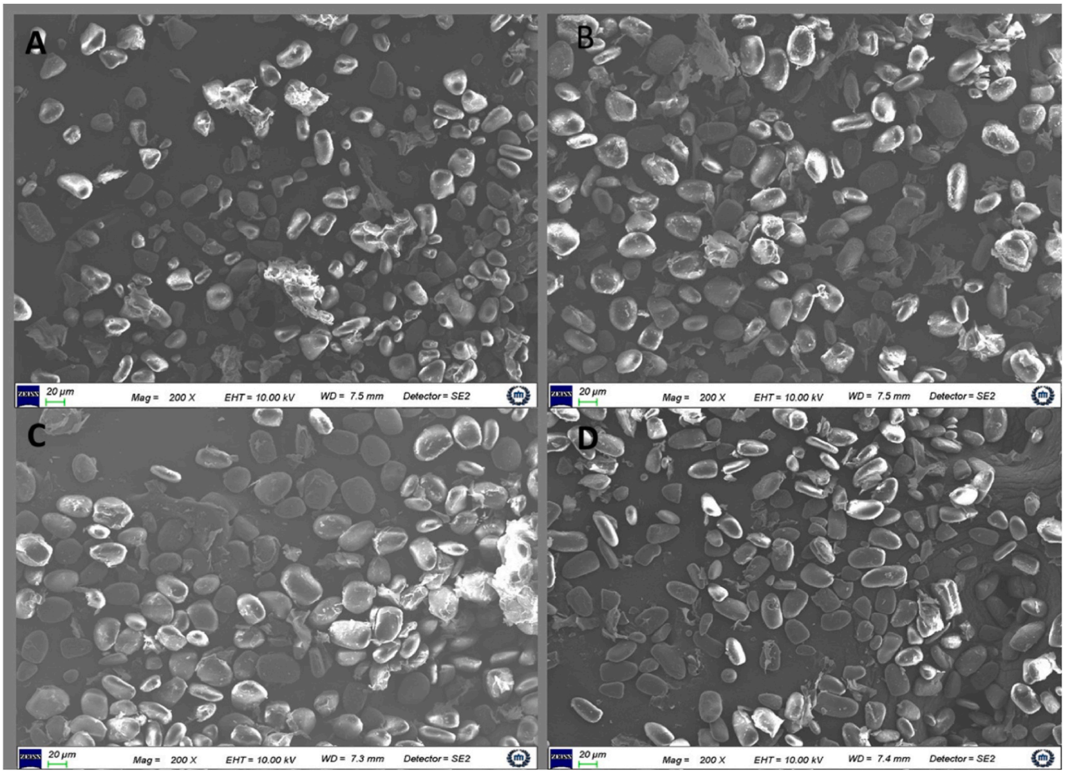

Fig. 1. Scanning electron micrographs of yam flours of A) *D. bulbifera* B) *D. cayenensis* C) *D. rotundata* D) *D. cayenensis* complex collected from Southwest Ethiopia.

3. Results and discussion

3.1. Chemical composition

The total starch, amylose, and soluble sugar contents of yam flour are displayed in Table 1. The total starch content of yam flour in this study ranged from 52.97 to 64.63 %. The total starch content of *D. cayenensis* complex (64.63 %) was significantly ($p < 0.05$) higher than other yam species. The lowest starch content was obtained from *D. bluferia* (52.97 %). The yam flours used in this investigation had lower starch content as compared to 65 yam accessions (65.2 %–76.6 %) reported by Muluneh Tamiru et al. [19]; and two tuber crops (cassava and Canna) reported from Indonesia (77.4 % and 77.1 %), respectively [28]. However, it is higher than root and tuber crops reported by Luz et al.; [29]. The high starch content of yam flour makes it a possible source of starch when compared to other starchy plants that have been documented. This suggests that yam tubers would make excellent crops for starch substitutes.

The yam flour's amylose concentration in this study varied significantly ($p < 0.05$), ranging from 16.92 % (*D. bulbifera*) to 23.53 % (*D. cayenensis*). The average amylose contents of yam flours in this study were lower than those reported by Bolanle Otegbayo et al. [30]; (18.98 % in *D. bulbifera,* 22.05 % in *D. rotundata*, and 22.06 % in *D. cayenensis*). However, the amylose contents of *D. cayenensis and D. rotundata* were higher than taro (5.95 %), yam (*D. alata*) (14.60 %), and sweet potato (18.12 %) [31]. The amylose content can

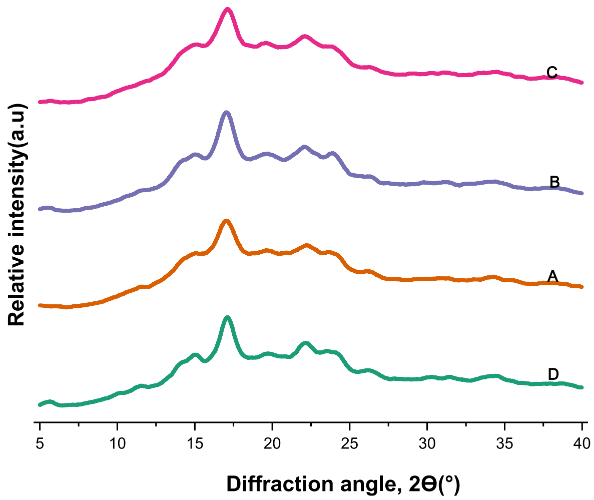

Fig. 2. The XRD pattern of yam flour of Southwest Ethiopia. A) *D. bulbifera* B) *D. cayenensis* C*)* *D. rotundata* D) *D. cayenensis* complex.

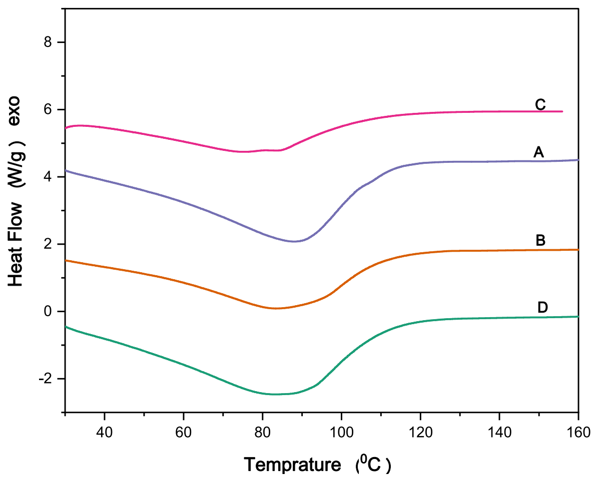

Fig. 3. The DSC thermogram of yam flour of Southwest Ethiopia. A) *D.bulbifera* B) *D. cayenensis* C*)* *D. rotundata* D) *D. cayenensis* complex.

vary among different yam species and even within the same species due to a variation in variety, growing conditions, and processing methods. The starches from yam tubers with higher amylose content can be used in soups, gum candies, or as an additive to increase dietary fiber without affecting the taste and quality of the products. The soluble sugar content of yam flour in this study ranged from 2.36 (*D. cayenensis*) to 4.95 % (*D. rotundata*) and this result is lower than the sugar content of tuber crops reported [25,26]. Patients with diabetes may benefit from yam flour's low sugar content.

3.2. Morphology of yam flour

Results of SEM images of yam flours at a magnification of 200 × are shown in Fig. 1(A-D). The morphology of yam flours of *D. cayenensis* complex (Fig. 1D*)*, *D. rotundata* (Fig. 1C), and *D. cayenensis* (Fig. 1B*)* are similar and the shapes are more or less oval to ellipsoidal shaped [27] and to a lesser extent, oval with the smaller granules appearing spherical but *D. bulbifera* (Fig. 1A) yam flours are triangular [30]. The result of this study is consistent with the report by Zou et al., [27]. The granular sizes of the yam flour are *D. cayenensis* complex (16.1−27.0 μm), *D. rotundata* (12.8−33.8 μm), *D. cayenensis* (19.9−33.6 μm) and *D. bulbifera* (12.5−28.5 μm. The particle size of *D. rotundata* yam (28–47.25 μm) and *D. bulbifera* (33.25–49.5 μm) reported by B. Otegbayo et al. [30], were bigger as compared to the size of yam in this study (12.8−33.8 μm and 12.5−28.5 μm), respectively. The granule of yam flour in this study falls within medium to large size [30].

3.3. X-ray diffraction pattern of yam flour

The X-ray diffraction patterns of yam flours are displayed in Fig. 2 (*D. bulbifera* (A) *D. cayenensis (B), D. rotundata* (C), *and D.*

Table 2
Pasting properties of yam flour of Southwest Ethiopia.

Viscosity parameters	*D. bulbifera*	*D. cayenensis*	*D. rotundata*	*D. cayenensis* complex
Peak viscosity (cP)	2191.00 ± 49.00[b]	2923.66 ± 129.77[a]	2117.00 ± 146.04[b]	2788.33 ± 33.17[a]
Trough viscosity (cP)	1216.00 ± 30.19[c]	1956.33 ± 139.65[a]	1685.33 ± 21.45[b]	2055.66 ± 69.92[a]
Breakdown viscosity (cP)	975.00 ± 79.07[a]	1000.66 ± 35.16[a]	163.00 ± 10.44[c]	732.66 ± 39.11[b]
Final viscosity (cP)	2588.00 ± 43.48[c]	4087.33 ± 48.68[a]	3124.66 ± 169.70[b]	2289.33 ± 165.40[d]
Steak back viscosity (cP)	1372.00 ± 26.05[b]	2097.66 ± 140.89[a]	1072.66 ± 99.01[b]	233.66 ± 224.50[c]
Pasting time (min)	5.20 ± 0.35[ab]	5.46 ± 0.63[ab]	6.22 ± 0.76[a]	4.68 ± 0.07[b]
Pasting temperature (°C)	79.50 ± 0.00[a]	74.73 ± 0.63[c]	75.13 ± 0.67[c]	76.53 ± 0.40[b]

All data were means ± standard deviation of triplicate measurements. In the same row, the number who carried the same superscripts is not significantly different at $P < 0.05$.

cayenensis complex (D)). All yam flour has a diffraction peak of about 15°, 17°, and a connected double peak at about 22° (2θ) in the diffraction spectra. Thus yam flour had a typical B-type crystalline pattern and this result is in agreement with the previous reports [25, 26]. All yam flour has an amorphous peak at 20° (2θ) for amylose and lipids. The order of the relative crystallinity of yam flours among the *Dioscorea* species was: *D. rotundata* (41.95 %) > *D. bulbifera* (35.04 %) > *D. cayenensis* (33.34 %) > *D. cayenensis* complex (33.08 %). The difference in the relative crystallinity of yam flour may be attributed to different granule sizes or shapes, lengths, and molecular weights [32].

The relative crystallinity of the *D. cayenensis* complex is lower and it had a small granule size as compared to other yam species. The lower relative crystallinity of the *D. cayenensis* complex is related to the loose pack or less ordered branch chains and the amylose and amylopectin branch chains which occupy the amorphous region that leads to the bigger size of this region and caused the relative crystallinity to become lower [33]. Relative crystallinity is a measure of the crystal integrity of the crystalline region within the granule and varies with the molecular weight distribution of amylose and amylopectin. The relative crystallinity of yam flours in this study is in the same range (15–45 %) as reported from the *D. rotundata* yam from Nigeria [34].

3.4. Thermal properties of yam flour

The DSC was used to determine the thermal characteristics of yam flour (Table 1 and Fig. 3). Between yam species, there was a significant difference ($p < 0.05$) in onset temperature (To), peak temperature (Tp), conclusion temperature (Tc), and gelatinization enthalpy (ΔH) values. *D. bulbifera* had the greatest T_0 (88.80 °C) among the four yam species, whereas *D. rotundata* had the lowest T_0 (71.70 °C). When the hydrogen bonds between amylose and amylopectin break during the gelatinization process, water is absorbed, and the starch granules swell [35]. Granule size, the ratio of amylose to amylopectin, and intra− and inter−molecular pressures affect the temperature at which yam flours gelatinize [36].

The flour from *D. bulbifera* (Fig. 3A) has a substantially different gelatinization enthalpy (5.39 J/g) than *D. cayenensis* (Fig. 3B), *D. rotundata* (Fig. 3C) and *D. cayenensis* complex (Fig. 3D), other yam species ($p < 0.05$). The enthalpy of gelatinization serves as a useful metric for assessing the physicochemical characteristics of starch, including its crystallinity. The yam flours in this study (2.22–5.39 J/g) had comparable enthalpy as Chinese yam flours ranging from 2.17 to 3.18J/g [37] except *D. bulbifera* flour (5.39 J/g) and this low enthalpy values have been related to B−type crystallinity according to the report by Garcia et al. [38], because in B-type crystallinity the amylopectin clusters are less dense than A−type ones.

3.5. Pasting properties of yam flour

The pasting characteristics indicate how effective the flour will be in baking and brewing. According to Dereje et al. [39], pasting characteristics illustrate the paste's degree of viscosity, consistency, and molecular degradation. The pasting properties of the yam flour are displayed in Table 2. The pasting temperature of yam flour in this study ranged from 74.73 to 79.50 °C. When it comes to *D. bluferia* flour, the pasting temperature (79.50 °C) is significantly higher ($p < 0.05$) whereas the *D. cayenensis* yam exhibited a lower pasting temperature (74.73 °C). This result was lower as compared to the earlier report of Zou et al., [27]. The high pasting temperature of flour indicates that starch is resistant to degrading and swelling. Differences in pasting temperature among yam flours could be related to the granule size and the amylose contents. Similar results that support this result have been reported by Obidiegwu et al., and Otegbayo et al., [3,23].

One of the important pasting characteristics for starch processing is the trough viscosity. The higher values of trough viscosity were obtained from *D. cayenensis* complex (2055.66 cP) and *D. cayenensis* (1956.33 cP). This result indicates that the flours could be the best for starch consistency during prolonged cooking and for industrial advantage where the stable gel is desired since this kind of paste withstands stress when subjected to a hold period of constant high temperature and mechanical shear stress. The peak viscosity of yam flours varied from (2117.00–2923.66 cP) in four yam species and the lowest was obtained from *D. rotundata* (2117.00 cP) yam flour and the highest corresponds to *D. cayenensis* which was not significantly different ($p < 0.05$) from that of *D. cayenensis* complex. The higher peak viscosity exhibited by *D. cayenensis* flour could be attributed to its higher amylose content which is also observed in this study. These characteristics of yam flours are crucial for products needing a greater degree of gel stability after cooling and appropriate for uses requiring higher viscosities.

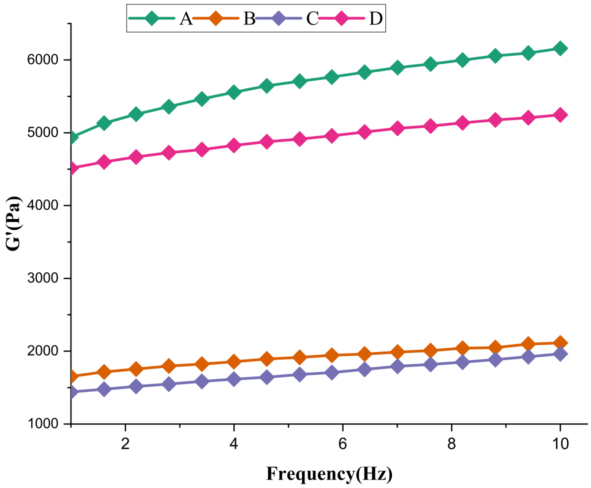

Fig. 4. Elastic modulus of yam flour of Southwest Ethiopia. A) *D. bluferia* B) *D. cayenensis* C) *D. rotundata* D) *D. cayenensis* complex.

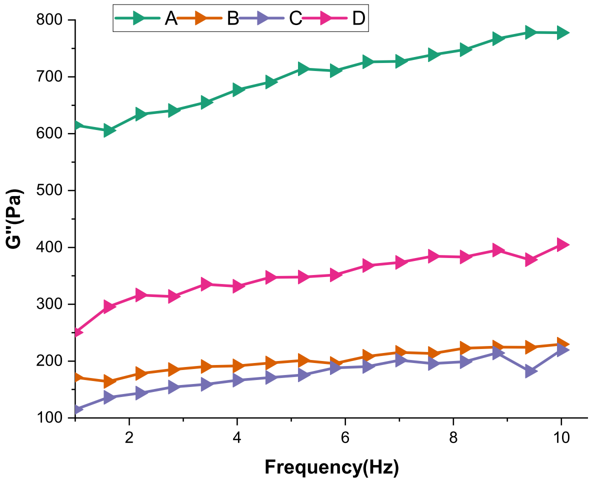

Fig. 5. Viscous modulus of yam flour of Southwest Ethiopia. A) *D. bulbifera* B) *D. cayenensis* C) *D. rotundata* D) *D. cayenensis* complex.

3.6. Rheological behaviors of yam flour

Rheological characterization of food materials is very important to monitor food quality and to evaluate process parameters [40]. Frequency scanning characteristics of yam flours were performed for all yam flours. The energy absorbed by the material and recovered after each cycle is represented by the elastic modulus G′ as shown in Fig. 4 (A (*D. bluferia*), B (*D. cayenensis*), C *(D. rotundata)* and *(D. cayenensis* complex) whereas the energy lost or dispersed during each sinusoidal deformation cycle is represented by the viscous modulus G″ as shown in Fig. 5 (A (*D. bluferia*), *B* (*D. cayenensis*), *C (D. rotundata) and D* (*D. cayenensis* complex). Viscoelastic shear-thinning behavior was observed in the viscous and elastic moduli results for all yam flours. As shown by the dominance of G′ over G″, the rheological behavior for minor deformations was primarily solid-like behavior (Figs. 4 and 5). *D. bulbifera* flour showed a stronger viscoelasticity behavior, indicating that the internal structure of *D. bulbifera* was close, and its energy recovery ability was stronger after being denatured by an external force [40].

For all examined samples, the loss tangent, or tan δ, measured the ratio between them (G″/G′), and when the frequency was raised, it was less than 1. This suggests the dominance of the elastic over the viscous behavior. The tan δ of *D. bulbifera* increased as scanning frequency increased, surpassing that of other yam species, suggesting that *D. bulbifera* had stronger elasticity and viscosity. The rheological profiles exhibited by yam flours in this study were similar to those of yam flours reported elsewhere [21,34,35]. The G′ of the *D. bulbifera* was higher than other yam flours and this indicates that their starches are flexible or extensible which affects their diet quality characteristics. So it can be used to predict the stretching capacity of yam foods such as pounded yams and these results are in alignment with those reported [30].

4. Conclusions

Variation in soluble sugar and total starch and amylose content of yam flour was observed in this study. Differences were also found in the morphological characteristics and thermal and pasting properties of yam flour from different species. The final viscosity of tuber yam (*D. cayenensis*) was significantly higher than other yam species which could be associated with its slightly higher amylose content. These characteristics of yam flours are crucial for products needing a greater degree of gel stability after cooling and appropriate for uses requiring higher viscosities. The aerial yam (*D. bulbifera*) flour showed a stronger viscoelasticity behavior as compared to the tuber yam. This study could provide important information for the production, processing, and industrial application of underexploited yam. Indeed, further studies are necessary to gain a deeper understanding of potential applications of starches derived from different *Dioscorea* species which can contribute to the development of innovative products, value addition, and utilization of these underutilized plant resources.

Funding

There is no funding information to declare about this research work.

Data availability

Data will be made available on request.

CRediT authorship contribution statement

Sosina Gebremichael Argaw: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tewodros Mulualem Beyene:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Henock Woldemichael Woldemariam:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Tarekegn Berhanu Esho:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Shiferaw Ayalneh Worku:** Investigation. **Hiwet Meresa Gebremeskel:** Investigation. **Kebede Nigussie Mekonnen:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing 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.

Acknowledgments

The authors would like to acknowledge Addis Ababa Science and Technology University for allowing them to use the facilities in the laboratories.

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