Composition, pasting and thermal properties of flour and starch derived from amadumbe with different corm sizes

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Abstract Amadumbe, commonly known as taro is a traditional southern African tuber crop. In this study, the effect of corm size: large, medium and small on composition and functional properties of amadumbe flours and starch isolates was determined. With the exception of iron and zinc, the basic chemical composition of amadumbe flours was not affected by differences in corms size. Amadumbe flours contained substantial amount of carbohydrates and limited contents of protein and fat. However, flours derived from large and small corms had iron contents (approx. 3 mg/100 g), which was 3 times that of medium corms. Large corms flour had the highest Zn content (2.6 mg/100 g). Amadumbe corms showed polygonal and small sized (1–5 µm) starch granules containing varying levels of amylose (13–16%). Starch isolates showed reflective peaks at 15° (2θ) and doublet at 17° and 18° typical of A-type starches. Peak viscosity, gelatinisation temperatures and final peak viscosity significantly varied among amadumbe corm types possibly due to variation in amylose contents. Flour mineral content, starch amylose and functionality differ with corm types.

Keywords Amadumbe · Taro · Starch · Flour · Corm size · Functionality

Introduction

Amadumbe (*Colocasia esculenta*), commonly known as taro, is an underutilised tuber in Southern Africa (Naidoo et al. 2015). In South Africa, amadumbe is mainly cultivated for subsistence (Naidoo et al. 2015). The corms are rich in starch, which may vary between 10 and 36%, depending on variety and growth location (Falade and Okafor 2013; Naidoo et al. 2015). Thus, amadumbe has potential as an alternative starch source to commercial starch sources such as maize and potato starches in various industrial applications. Nutritionally, amadumbe corm contains a water soluble mucilage (3–19%) (Jiang and Ramsden 1999; Njintang et al. 2014) and a high content of resistant starch (52–64%) (Naidoo et al. 2015). The high resistant starch content of amadumbe corm suggests it may be used in the development of low glycaemic food. Therefore, there is an opportunity for the commercialisation of locally grown crops such as amadumbe for the production of starch and flour for various industrial applications.

Various factors including corm size and growing conditions may influence the composition of amadumbe flour and derived starch thereof (Tattiyakul et al. 2006). The influence of corms size on functionality of amadumbe grown at the same location was previously reported by Falade and Okafor (2013). According to these authors, starch extracted from large taro corms showed high swelling power, solubility and final viscosities compared to starch obtained from small corms. The amylose contents of these starches correlated positively with their final viscosities (Falade and Okafor 2013). However, in a research conducted elsewhere, no correlation was found between corm size and composition of amadumbe flour (Tattiyakul et al. 2006). These differences in data from literature

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suggest that the influence of corm size on composition could be dependent on growth location.

Furthermore, the size of corms may be important for commercialisation application and utilisation of amadumbe corms depending on the regions where these tubers are grown. For instance, taro pricing is based on corm size in countries such as Thailand and small sized corms (60–100 g) are reportedly not suitable for commercial use (Tattiyakul et al. 2006). However, Vinning (1995) reported that small sized corms are preferred by Japanese consumers for local utilisation. Since corm size is a determinant factor in the commercialisation of amadumbe, it may be important to have scientific information on composition and structure of starch isolates to understand functionality and for specific application.

In Southern Africa, cultivated amadumbe corms come in a range of sizes and is currently limited to traditional usage such as boiling and baking. The knowledge of composition and functionality of flour and starch extracted from corms of varying sizes is important to facilitate their utilisation. Earlier studies on amadumbe grown in South Africa considered the starch properties of cultivated and wild types (Naidoo et al. 2015) as well as the impact of genotypes and growth locations on composition and functionality of the flours (Mawoyo et al. 2017). Another reports focused mainly on water use and drought resistance of locally grown varieties in South Africa (Mabhaudhi et al. 2013). So far, previous studies did not consider the effect of corm size as in most cases a single variety was used. Information on the physicochemical properties of flour, thermal properties and crystalline patterns of starch in relation to corms size, especially from amadumbe grown in Southern Africa is lacking in literature. Hence, this study investigated the influence of corm size on physicochemical properties of amadumbe flours and starch component. This research further clarified whether corms size is an important consideration in the selection of amadumbe for flour and starch processing.

Materials and methods

Materials

Three types of amadumbe tuber differentiated by the size of their corms as: large (diameter = 133 ± 8.92 mm, length = 260 ± 9.35 mm), small (diameter = 33 ± 8.34 mm, length = 70 ± 6.57 mm), and medium (diameter = 76 ± 11.97 mm, length = 128 ± 9.03 mm) were used in this study. Amadumbe samples were collected from Jozini, KwaZulu-Natal province, South Africa. Fifty corms from each amadumbe types were used to dimensional analyses.

Preparation of amadumbe flour and starch

Flours and starches were prepared as previously described (Naidoo et al. 2015). Briefly, freshly harvested amadumbe corms were washed, peeled, re-washed and sliced into a thickness of 3 mm. Sliced amadumbe were dried at 50 °C for 48 h using a hot air oven (D-37520, Thermo Fisher Scientific, Frankfurt, Germany). The dried amadumbe slices were milled and sieved (screen size: 180 µm) to obtain flours, which were stored at 4 °C until analysed.

Starch was extracted by dispersing amadumbe flour in water (1:10). The mixture was stirred at room temperature and sieved (180 µm) to separate non-starchy components and the filtrate was allowed to settle at room temperature for 24 h. Thereafter, the slurry was centrifuged (Ependorf 5810R, Frankfurt, Germany) at $14,000 \times g$ for 20 min and the supernatant discarded. The remaining sediment (starch fraction) was dried at 50 °C for 24 h in an oven (D-37520, Thermo Fisher Scientific, Frankfurt, Germany). Starch yield was calculated as the ratio of the starch obtained to the amount of flour used. Starch was stored at 4 °C until analysed.

Chemical composition of amadumbe flour

Moisture, fat and ash contents were determined using AOAC (2000) methods. Protein content was determined by the Kjeldahl method ($6.25 \times N$) and total carbohydrate was calculated by difference. Fibre content namely acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined by standard laboratory procedure (Olagunju et al. 2018).

Mineral content of amadumbe flour was determined as described by Amonsou et al. (2014) using Inductively Coupled Plasma (ICP) spectroscopy (Model). Samples were acid-digested by the addition of 1 mL of 55% (v/v) HNO_3 .

Microscopy

Starch granule morphology was examined using a scanning electron microscope (EVO 15 HD, Carl Zeiss, Jena, Germany) with an accelerating potential of 4 kV. Briefly, a thin layer of the starch granule was mounted on the aluminium specimen holder with double-sided tape. Starch samples were coated with a thin film of gold for 2 min with a thickness of about 30 nm (Naidoo et al. 2015).

Colour

Tristimulus L, a, and b parameters of amadumbe starch were determined as reported by Oyeyinka et al. (2015) after standardization using a calorimeter (Colour Flex EZ

Eco 150, Hunter Lab, Virginia, USA). Snapshots in duplicates were taken and values were read directly from a digital print. Averages of the readings were computed and reported.

Amylose contents

Amylose content of amadumbe starches were determined using the iodine binding method previously reported (Oyeyinka et al. 2015). Starch samples (20 mg) were weighed and dispersed in 10 mL of 0.5 N KOH for 5 min. The dispersed samples were brought to 100 mL with distilled water. 10 mL starch stock solution was mixed with 5 mL of 0.1 N HCl and 0.5 mL iodine reagent and brought to 50 mL with distilled water. (Iodine reagent was prepared by dissolving 20 g of potassium iodide and 2 g of resublimed iodine in 100 mL of water. A 10 mL portion of the mixture was diluted in another flask and brought to 100 mL with distilled water) The absorbance of the blue colour was measured at 625 nm using a spectrophotometer (Jenway 7305 Bibby Scientific, London, UK) after 5 min.

X-ray diffraction

X-ray diffraction patterns of the starch samples were determined using a diffractometer (PANanalytical, Eindhoven, North Brabant, Netherlands) as described by Oyeyinka et al. (2015). Samples were equilibrated at 25 °C and relative humidity of 100%, in a low temperature incubator (MTIE10, Labcon, Pretoria, South Africa) for 12 h to account for differences in moisture content of the samples. Equilibrated samples were scanned over a region of 4–40 (2 θ)° at a scanning speed of 0.06°/min and operating conditions of 45 kV, 40 mA and CuK α 1 (0.154 nm).

Pasting properties of flour and starch

The pasting properties of amadumbe flour and starch were examined using a Rapid Visco-Analyzer (RVA 4500, Perten Instruments, Sydney, Australia) as previously reported (Oyeyinka et al. 2016). Briefly, samples (2.8 g) were weighed into the test canister containing 25 mL of distilled water. The mixture was agitated by mixing manually before inserting the canister into the instrument. Starch was stirred at 960 rpm for 10 s before the shear input was decreased and held constant at 160 rpm during the subsequent heating and cooling cycles.

Thermal properties of starch

The gelatinisation temperatures of the starch samples were determined using a differential scanning calorimeter (SDT Q600, New Castle, USA) coupled with a thermal analysis

data station and data recording software. Starch (3 mg) was weighed into the aluminum DSC pan and distilled water (12 μ L) added with a microsyringe before the pan was sealed using a DSC punch sealer. The pans were allowed to equilibrate at 25 °C for 2 h prior to the DSC analysis. Samples were scanned from 10–110 °C at a heating rate of 5 °C/min. An empty pan was used as reference for all measurements (Naidoo et al. 2015).

Statistical analysis

All analyses were performed in triplicate. Data were analysed using analysis of variance (ANOVA) and means were compared using the Fisher Least Significant Difference (LSD) test ($p < 0.05$).

Results and discussion

Proximate composition of amadumbe flour

With the exception of the moisture content, the proximate composition of flours obtained from different amadumbe corms were significantly ($p < 0.05$) different (Table 1). Although carbohydrate was the major component of amadumbe flours, large corm had significantly ($p < 0.05$) higher carbohydrate content (82%) compared to medium and small corms (average of 76%). Amadumbe flours were generally low in protein, fat, ash and fibre contents when compared to their carbohydrate values, respectively. Previous research by Tattiyakul et al. (2006) found that the carbohydrate contents of taro corms were not affected by corm size but rather by growth location. The proximate composition data of amadumbe flours are in agreement with previous reports (Falade and Okafor 2015; Naidoo et al. 2015; Tattiyakul et al. 2006).

Mineral composition of amadumbe flour

Potassium (0.59–1.47 g/100 g) was the most abundant mineral element and this was independent of amadumbe corm sizes (Table 2). Our finding is in agreement with previous reports on taro corms (Lewu et al. 2010; Ndabikunze et al. 2011). High levels of potassium in human diet is important for the protection against life-threatening diseases such as hypertension, cardiac dysfunctions and osteoporosis (Lewu et al. 2010). The potassium level of the large amadumbe corm was substantially lower (about 2.2 times) than those of small and medium corms. Adequate levels of potassium have been found to enhance drought resistance, water-use efficiency and plant growth under drought conditions (Eakes et al. 1991). Since these corms were grown in the same location and under the similar

Table 1 Amadumbe flour composition, yield, colour, amylose content and relative crystallinity of amadumbe starch extract

Parameters	Corm size		
	Small	Medium	Large
Flour			
Moisture	7.97 ^a ± 0.14	7.89 ^a ± 1.49	8.71 ^a ± 0.16
Protein	4.86 ^a ± 0.13	4.82 ^a ± 0.01	2.46 ^b ± 0.09
Fat	1.08 ^a ± 0.19	0.56 ^b ± 0.16	0.58 ^b ± 0.16
Ash	4.15 ^a ± 0.26	3.29 ^b ± 0.14	2.14 ^c ± 0.12
ADF	3.16 ^a ± 0.13	2.71 ^a ± 0.33	1.47 ^b ± 0.34
NDF	3.76 ^a ± 0.13	3.47 ^a ± 0.26	2.33 ^b ± 0.29
Carbohydrate	77.26 ^b ± 1.71	75.02 ^b ± 0.05	82.31 ^a ± 0.40
Starch			
Yield (%)	32.00 ^a ± 1.50	24.00 ^c ± 0.40	28.00 ^b ± 1.20
L	96.94 ^a ± 0.01	96.34 ^a ± 0.03	96.34 ^a ± 0.01
a	0.09 ^a ± 0.01	0.04 ^b ± 0.01	0.10 ^a ± 0.14
b	0.99 ^b ± 0.03	0.89 ^b ± 0.02	1.14 ^a ± 0.01
Amylose contents (%)	13.71 ^b ± 0.01	15.68 ^a ± 0.01	12.74 ^c ± 0.02
Relative crystallinity (%)	41.99 ^b ± 0.21	35.58 ^c ± 0.94	45.36 ^a ± 0.76

Mean ± SD. Mean with different superscript along the row are significantly different ($p < 0.05$)

ADF acid detergent fibre, NDF neutral detergent fibre

Table 2 Mineral composition of amadumbe flours as influenced by corm size

Minerals	Corm size		
	Small	Medium	Large
Ca*	0.09 ^a ± 0.00	0.11 ^a ± 0.00	0.05 ^b ± 0.00
Mg*	0.08 ^a ± 0.00	0.09 ^a ± 0.00	0.07 ^b ± 0.00
K*	1.47 ^a ± 0.02	1.14 ^b ± 0.02	0.59 ^c ± 0.03
Na*	0.06 ^a ± 0.00	0.04 ^b ± 0.01	0.03 ^b ± 0.00
K/(Na + Mg)*	3.25 ^a ± 0.12	2.29 ^b ± 0.03	1.82 ^c ± 0.04
P*	0.18 ^a ± 0.00	0.09 ^c ± 0.00	0.12 ^b ± 0.00
Zn**	0.65 ^b ± 0.01	0.33 ^c ± 1.48	2.63 ^a ± 0.05
Cu**	0.02 ^b ± 0.31	0.13 ^a ± 0.90	0.02 ^b ± 0.31
Mn**	0.33 ^b ± 1.53	0.43 ^b ± 0.07	0.55 ^a ± 1.54
Fe**	2.49 ^a ± 1.49	0.87 ^b ± 0.14	2.52 ^a ± 1.50

Mean ± SD. Mean with different superscript along the row are significantly different ($p < 0.05$)

*g/100 g, **mg/100 g

agronomic conditions, it seems that there was competition for potassium absorption and utilisation during growth among the amadumbe corms. Large corms presumably used more potassium during growth than the small and medium corms, resulting in lower values after processing.

Other mineral elements including Zinc Copper, Manganese and Iron are present in minute quantities (< 0.2 g/100 g). However, large amadumbe corm showed the highest content of Zinc (approx. 26 mg/kg), which was

about 4 and 8 times higher than those of small corms and medium, respectively. The iron contents of large and small corms (approx. 25 mg/kg) were about 3 times that of medium amadumbe corms. Lewu et al. (2010) found significant variations in the potassium (0.32–0.78 g/100 g), magnesium (0.29–0.36 g/100 g), sodium (0.04–0.121 g/100 g) and calcium (0.028–0.036 g/100 g) content of seven accessions of taro tubers grown in different environments. Many factors, including growth location and variety may be responsible for the observed variation in mineral profiles.

Starch yield and amylose contents

Amadumbe starch yields (24–32%) (Table 1) were comparable to previous reports (Falade and Okafor 2013; Naidoo et al. 2015; Nand et al. 2008). The starch yield from small corms was slightly high compared to large and medium, suggesting a minor influence of corm size. The size of the corms does not seem to correlate with the level of starch in the corms. Similarly, Falade and Okafor (2013) reported intermediate starch yields value for bigger taro corms. The starch yield result from this study suggests that much of the carbohydrate formed in the large corm during growth were non-starchy components. Non-starch components (e.g. mucilage) could account for the larger proportion of the carbohydrate in large corms.

The amylose content of amadumbe starches varied significantly from approximately 13–16% (Table 1). Medium amadumbe corms had the highest amylose content

followed by small and large corms, respectively. The amylose content values are within the range (12–34%) reported for amadumbe starches (Aboubakar et al. 2008; Falade and Okafor 2013; Nwokocha et al. 2009; Sit et al. 2013). The influence of corms size on amylose content had previously been reported (Falade and Okafor 2013). The amylose contents (approx. 12–34%) varied significantly among corms of different size even though these were grown in the same location (Falade and Okafor 2013). Some researchers showed that the development of potato tubers was accompanied by a slight decrease in amylose content (Fujimoto et al. 1981; Suzuki et al. 1965). Variations in amylose content of amadumbe starches could be due to differences in the biosynthesis rate of amylose and amylopectin during growth (Noda et al. 1992).

Starch morphology and purity

The morphology of amadumbe starch granule was not affected by corm size (Fig. 1). Amadumbe corms showed polygonal and irregularly shaped starch granules, suggesting that these were compound starches. These granules were very small in size (2–5 μm). Previous studies reported small sized (2–7 μm) compound starch granules for amadumbe (Naidoo et al. 2015) or taro starches (Jane et al. 1992). The microscopic images of the starch granules showed the absence of fissures, suggesting that the extracted starch was relatively pure. Starch purity was confirmed by the closeness of its Lightness values (approx. 97%) to 100 (Table 1).

XRD of amadumbe starch

The crystallinity patterns of amadumbe starches were not affected by corm types. Amadumbe starches displayed the A-type diffraction pattern with strong peaks at 15° (2 θ), a doublet at 17° and 18° (2 θ) and a single peak at 23° (2 θ) (Fig. 2). Although the A-type crystallinity pattern is

Fig. 2 X-ray diffractograms of amadumbe starches

generally reported for cereal starches (Hoover et al. 2010), previous researchers have also found the A-type pattern for taro starches (Jane et al. 1992; Lauzon et al. 1995; Lawal 2005; Sit et al. 2013; Tattiyakul et al. 2006). The relative crystallinity (approx. 36%) of starch extracted from medium amadumbe corm was significantly lower than those from small and large corms (approx. 44%) (Table 3). This may be explained by the significantly higher amylose content of starch from the medium corms compared to the other two types (Table 1). Similar values of relative crystallinity ranging between 35–45% have been reported for taro starches (Sit et al. 2013).

Pasting properties of amadumbe flour and starch

Amadumbe flour and starch had similar pasting profiles. The pasting temperature (approx. 86 °C) of amadumbe flours was slightly higher than their corresponding starch extracts (approx. 84 °C) (Table 3). Differences in pasting temperature could be attributed to the presence of mucilage in the flour samples (Jane et al. 1992). The pasting temperature of amadumbe flour and starch are within the range (approx. 78–94 °C) reported for taro (Falade and Okafor 2013, 2015; Mawoyo et al. 2017; Sit et al. 2013).

Fig. 1 Micrographs of amadumbe starches extracted from amadumbe corms. S: small, M: medium, L: large

Table 3 Pasting properties of amadumbe flour and starch

Parameters	Flour			Starch		
	Small corm	Medium corm	Large corm	Small corm	Medium corm	Large corm
PV (RVU)	126.75 ^b ± 0.15	99.58 ^c ± 1.21	144.71 ^a ± 2.92	267.21 ^b ± 0.85	257.29 ^b ± 0.84	284.79 ^a ± 0.67
TV (RVU)	72.58 ^b ± 1.23	65.00 ^c ± 1.12	93.71 ^a ± 1.52	129.04 ^a ± 1.00	125.71 ^{ab} ± 1.47	122.92 ^b ± 0.47
BV (RVU)	54.17 ^a ± 0.12	34.58 ^b ± 0.16	51.00 ^a ± 2.84	138.17 ^b ± 1.85	131.58 ^b ± 1.36	161.88 ^a ± 1.14
SV (RVU)	26.33 ^b ± 0.25	21.25 ^b ± 0.14	50.12 ^a ± 1.12	80.92 ^a ± 1.65	77.25 ^b ± 0.71	81.08 ^a ± 0.06
FV (RVU)	98.92 ^a ± 1.14	86.25 ^a ± 1.20	143.83 ^b ± 1.19	209.96 ^a ± 0.65	202.96 ^b ± 0.18	204.00 ^b ± 0.54
PT (°C)	86.45 ^a ± 0.01	86.04 ^a ± 0.01	85.63 ^a ± 0.04	83.25 ^a ± 0.01	83.70 ^a ± 0.64	83.45 ^a ± 0.07
Peak time (min)	4.73 ^b ± 0.01	4.80 ^a ± 0.02	4.67 ^b ± 0.01	5.07 ^a ± 0.09	4.90 ^a ± 0.05	4.43 ^b ± 0.05

Mean ± SD. Mean with different superscript along the row are significantly different ($p < 0.05$)

PV peak viscosity, TV trough viscosity, BV breakdown viscosity, SV setback viscosity, FV final viscosity, PT pasting temperature

Amadumbe starch pasting temperature seems to be much higher compared to other tuber starches such as potato starch (64–69 °C) (Jane et al. 1999; Singh et al. 2018) and cassava starch (67–68 °C) (Nwokocha et al. 2009; Srichuwong et al. 2005). The difference in starch pasting temperature could relate to the small granule size of amadumbe starch. Smaller starch granules reportedly showed greater resistant to rupture and loss of molecular order (Dreher and Berry 1983).

Other pasting properties of amadumbe flours were generally lower than their starch counterparts (Table 3). Flour components other than starch, including proteins and mucilage could explain the difference in pasting properties. Large amadumbe corms with lower level of protein (Table 1) showed significantly ($p < 0.05$) higher peak viscosity compared with the small and medium corms (Table 3). Singh et al. (2014) also found that the presence of proteins in maize starch protected starch granules from swelling and disintegration, resulting in lower peak viscosities (Singh et al. 2014). Starch pastes with higher protein content presumably had more intact granules with less amylose leaching (Singh et al. 2014). The peak viscosity result of the starch extract is consistent with higher amylose (Table 1) and higher pasting temperature (Table 3) of medium amadumbe starch. Singh et al. (2010), similarly found correlations between peak viscosity, amylose content and pasting temperature of starch from 13 wheat varieties obtained in India. It has been suggested that amylose prevents swelling of starches during pasting by forming a barrier around the granules (Sang et al. 2008). Starches with high amylose contents showed low peak viscosity due to restricted swelling of starch granules (Oyeyinka et al. 2016). Furthermore, the high peak viscosity of flour from large amadumbe corm may be attributed to its mucilage content. Jane et al. (1992) working with flours and starches from five taro cultivars reported that taro flour with the highest mucilage content gave the highest peak viscosity.

The final viscosity (approx. 210 RVU) of starch from small amadumbe corm was slightly higher than those from medium and large corms (approx. 204 RVU) (Table 3). These values was comparable to those reported for five cultivars of taro grown in Nigeria (Falade and Okafor 2013), but much higher than the values (161 RVU) reported for Chinese taro starches (Jane et al. 1999). Variation in final viscosities values could be associated with varietal differences and the starch concentration used in the respective studies. High final viscosities of amadumbe starches suggest their potentials as thickening agents in food applications.

Thermal properties of amadumbe starch

Amadumbe starches showed significant ($p < 0.05$) differences in their thermal properties (Table 4). Starch extracted from medium amadumbe corm showed the lowest onset gelatinisation temperature (T_o), peak gelatinisation temperature (T_p) and conclusion gelatinisation temperature (T_c), while small amadumbe corm showed the highest T_o ,

Table 4 Thermal properties of amadumbe starches

Parameters	Corm size		
	Small	Medium	Large
T_o (°C)	76.83 ^a ± 0.53	67.83 ^c ± 0.88	72.00 ^b ± 1.13
T_p (°C)	84.92 ^a ± 0.13	77.05 ^c ± 0.01	82.46 ^b ± 0.52
T_c (°C)	88.70 ^a ± 0.70	81.70 ^c ± 0.40	85.70 ^b ± 0.24
ΔH_{gel} (J/g)	17.95 ^a ± 0.21	17.35 ^a ± 0.21	14.07 ^b ± 0.18

Mean ± SD. Mean with different superscript along the row are significantly different ($p < 0.05$)

T_o = onset gelatinization temperature, T_p = peak gelatinization temperature, T_c = conclusion gelatinization temperature, ΔH_{gel} = enthalpy of gelatinization

T_p and T_c . The gelatinisation temperatures of amadumbe starches are within values reported in the literature (Naidoo et al. 2015; Nwokocha et al. 2009; Srichuwong et al. 2005). Differences in the observed gelatinisation temperatures among amadumbe starches could be attributed to variation in amylose contents (Table 3). High gelatinisation temperatures have been previously associated with low amylose content (Naidoo et al. 2015). Other factors such as starch purity, the nature of interaction within the amorphous and crystalline region (Naidoo et al. 2015), and the distribution of amylopectin chains within starch granules may also influence the gelatinisation properties of starch (Noda et al. 1996). Singh et al. (2018), found that the gelatinisation temperatures of starch extracted from 42 potato cultivars grown in India showed a negative correlation with the proportion of short and medium chains of amylopectin, but a positive correlation with long chains. Long amylopectin chains (DP 19–30) are disrupted at higher temperatures while the short chains (DP 6–12) are disrupted by heat at relatively lower temperatures (Singh et al. 2018). Thus, it is probable that the presence of greater proportions of longer amylopectin chains contributed to the higher gelatinisation temperatures observed for starch from small amadumbe corm.

The gelatinisation enthalpy (ΔH_{gel}) (approx. 18 J/g) of starch from small and medium amadumbe corms were slightly higher than that observed for large amadumbe corm (approx. 14 J/g) (Table 4). Naidoo et al. (2015) working with starch isolated from cultivated amadumbe and amadumbe grown in the wild reported substantially higher ΔH_{gel} (approx. 28 J/g). Variation in ΔH_{gel} values may be attributed to differences in the extent of interactions between the double helices forming the crystalline region of the amadumbe starches (Zhou et al. 2004).

Conclusion

Amadumbe corms are good sources of starch and micronutrients such as potassium, iron and zinc. Amadumbe starches are generally characterised by low, but varying amylose contents and A-type crystallinity pattern. Functional properties such as peak viscosity, gelatinisation temperatures and final peak viscosity of starch vary significant among the three amadumbe types. These variations in starch pasting and thermal behaviour could be attributed to difference in amylose contents.

Compliance with ethical standards

Conflict of interest Authors declare no conflict of interest.

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