

In vitro digestibility and some physicochemical properties of starch from wild and cultivated amadumbe corms



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ABSTRACT

Amadumbe, commonly known as taro, is an indigenous underutilised tuber to Southern Africa. In this study, starch functional properties and *in vitro* starch digestibility of processed products from wild and cultivated amadumbe were determined. Starch extracts from both amadumbe types had similar contents of total starch (approx. 95%). Wild and cultivated amadumbe starch granules were polygonal and very small in size ($2.7 \pm 0.9 \mu\text{m}$). Amylose content of wild amadumbe (20%) was about double that of cultivated (12%). By DSC, the peak gelatinisation temperatures of wild and cultivated amadumbe starches were 81 and 85 °C, respectively. The slowly digestible starch (SDS); 20% and resistant starch (RS); 64% contents of wild amadumbe appeared slightly higher than those of cultivated. Processing amadumbe into boiled and baked products did not substantially affect SDS and RS contents. Estimated glycaemic index of processed products ranged from 40 to 44%. Thus, amadumbe, both wild and cultivated, present some potential in the formulation of products for diabetics and weight management.

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1. Introduction

Amadumbe (*Colocasia esculenta*), commonly known as taro, is grown for its edible corms throughout subtropical and tropical regions of the world. As a rich source of carbohydrates and energy, it is one of the staple foods in the developing countries of Africa, the West Indies and Asia (Liu, Donner, Yin, Huang, & Fan, 2006). In South Africa, amadumbe is regarded a traditional food crop cultivated by rural farmers in KwaZulu-Natal for subsistence. Beside the cultivated one, amadumbe also grows in the wild. Cultivated amadumbe (*Colocasia esculenta* var *esculenta*) is grown on dry land and consists of poorly developed stolons. However, wild amadumbe (*Colocasia esculenta* var. *stolonifera*) is adapted to wetland and possesses well-developed stolons.

The production and consumption of amadumbe in Africa is significantly low compared to other tuber crops such as cassava and yam (Ugwu, 2009). The starch content of amadumbe is similar to that of yam and sweet potato (Ugwu, 2009). Microscopically, starch isolated from amadumbe corm has been found to be polygonal and irregularly shaped (Aboubakar, Njintang, Scher, & Mbofung, 2008; Jane et al., 1992). The starch granules of amadumbe appeared very small ($1\text{--}5 \mu\text{m}$) compared to those of other roots and tubers

(Jane et al., 1992). Aboubakar et al. (2008) investigated the starch properties of six varieties of taro. The amylose contents of taro starches (16–30%) have been found to vary among varieties. By Differential Scanning Calorimeter (DSC), a single endothermic transition was generally observed for taro starch, with peak temperature of gelatinisation ranging from 67 to 85 °C depending on varieties and composition of starch (Aboubakar et al., 2008; Perez, Schultz, & Pacheco De Delahaye, 2005; Srikaeo, Mingyai, & Sopade, 2011). Taro contains mucilage (approx. 10%) (Hong & Nip, 1990), which may influence its starch thermal behaviour. According to Huang, Lai, Chen, Liu, and Wang (2010), the addition of mucilage substantially increased the temperature of gelatinisation of taro starch, a phenomenon which was attributed to competition for water between starch and the mucilage. Other functional properties such as swelling power, foaming capacity and water absorption capacity of taro starches have been reported to vary with cultivars and sources (Falade & Okafor, 2013, 2014). Reports on viscosity and water absorption capacity of amadumbe starch suggest that it may be beneficial as a thickening or gelling agent when applied to certain foods (Moorthy, 2002).

Further, there is growing interest in starch digestion kinetic due to the increase in life style related diseases such as diabetes and consumers' awareness of the relationship between food, nutrition and health. Nutritionally, starch is classified into rapidly digestible starch, slowly digestible starch and resistant starch (Englyst, Kingman, & Cummings, 1992). Resistant starch is associated with

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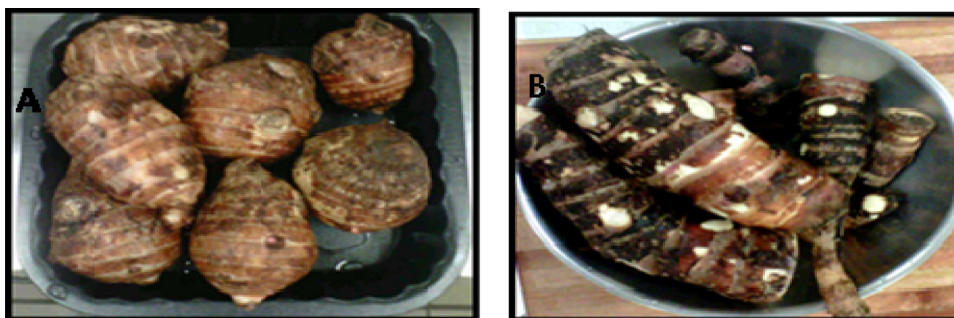


Fig. 1. Amadumbe corms from cultivated and wild sources. A: cultivated: *Colocasia esculenta* var *esculenta*, B: wild: *Colocasia esculenta* var *stolonifera*.

slow digestion in the human small intestinal tract. This slow breakdown of starch and absorption of glucose aids in the reduction of many diseases including obesity and diabetes (Liu et al., 2006). Aboubakar et al. (2008) observed a negative linear correlation between amylose contents of taro starch and the extent of starch hydrolysis. According to these authors, taro varieties with high amylose showed reduced starch hydrolysis. Other studies on pea flours suggested that the low digestibility of high amylose starch may be attributed to amylose retrogradation and resistant starch (RS) formation (Skrabanja, Liljeberg, Hedley, Kreft, & Björck, 1999). Amylose, which exists in double helical chain, is presumably not accessible to the amylase enzyme. RS content of taro (52%) was reportedly higher than those of maize, mung bean and modified starches (Barnabe, Srikao, & Schluter, 2011). The resistant starch contents of purified taro starch (98%) with 10% amylose content has been found to increase by 16 folds following the applications of heat, enzymatic debranching and retrogradation (Simsek & El, 2012). Approximately 51% of RS was reported following these treatments. All these findings demonstrate the potential health benefits of amadumbe corms, especially in the development of low to medium GI foods.

Many studies, including those described above, have demonstrated that the susceptibility of starch hydrolysis by amylase enzymes may vary with botanical origins, structure and composition of starch. There is limited information available on the starch properties of amadumbe cultivated in South Africa, while the wild amadumbe from South Africa has not been studied at all. In order to increase utilisation of amadumbe crop, it is necessary to have the knowledge of the functional properties of its major component which is starch. Hence, this research investigated the digestibility and functional properties of cultivated and wild amadumbe, starch and processed products.

2. Materials and methods

2.1. Materials

Two types of indigenous Southern African amadumbe, cultivated (*Colocasia esculenta* var *esculenta*) and wild (*Colocasia esculenta* var *stolonifera*) were used. These were obtained in Durban, KwaZulu-Natal province, South Africa. Collection and identification of amadumbe samples were done by Prof Baijnath from the University of KwaZulu-Natal, Durban, South Africa. Amadumbe from both sources are shown in Fig. 1.

All chemicals and solvents used were of laboratory grade. Pepsin from porcine gastric mucosa (3000 U/mg) was purchased from Sigma–Aldrich (St. Louis, MO). The glucose oxidase assay kit, enzymes α -amylase from *Bacillus* species and amyloglucosidase, guar gum and potato starch were purchased from Sigma–Aldrich (St. Louis, MO).

3. Methods

3.1. Preparation of amadumbe flour and starch

Freshly harvested amadumbe corms were washed, peeled, rewashed and sliced into a thickness of 3 mm. Peeled corms were dried at 50 °C for 48 h in a hot air oven (D-37520, Thermo Fisher Scientific, Germany). Dried slices were then milled into flour using a warring blender (Model: 8010S, Torrington, USA) and sieved (screen size: 180 μ m) to obtain fine flours, which were then stored at 4 °C until analysed.

Starch was extracted following methods described by Singh, Voraputhaporn, Rao, and Jambunathan (1989) with few modifications. Briefly, amadumbe flour was dispersed in water (1:10), stirred at room temperature for 6 h. The mixture was sieved (screen size: 180 μ m) to separate non-starchy components and the resulting filtrate was allowed to settle at room temperature for 24 h. Thereafter, the slurry was centrifuged (using Ependorf 5810R Centrifuge, Germany) at 14000 $\times$ g for 20 min and the supernatant discarded. The centrifugation step was repeated until the supernatant was almost colourless. The remaining sediment representing the starch fraction was dried at 50 °C for 24 h in hot air oven (D-37520, Thermo Fisher Scientific, Germany). Starch yield was calculated as the ratio of the starch obtained to the amount of flour used. Starch was packed, sealed and kept at 4 °C until analysed.

3.2. Preparation of processed products

For the preparation of boiled amadumbe, washed and cleaned amadumbe corms (1000 g in 2.5 l of water) were boiled at approx. 100 °C for 40 min. Boiled amadumbe corms were then peeled, sliced (3 mm thickness) and dried at 52 °C for 24 h in a hot air oven (D-37520, Thermo Fisher Scientific, Germany). Dried slices were milled in warring blender (Model: 8010S, Torrington, USA) and the resulting flour was sieved (screen size 180 μ m) to obtain fine flours, which were kept in airtight plastic bag and stored at 4 °C until analysed.

To prepare baked amadumbe, washed and cleaned amadumbe corms were sliced (3 mm thickness) and then baked at 180 °C for 15 min. Baked amadumbe corms were processed into fine flours and stored in the same way as described above for boiled amadumbe.

3.3. Microscopy

Sample preparation for scanning electron microscopy (SEM) was done following standard laboratory procedures. A thin layer of the starch granule was mounted on the aluminium specimen holder by double-sided tape. Starch sample was coated with a thin film of gold, for 2 min with a thickness of about 30 nm and

Table 1Proximate composition of cultivated and wild amadumbe (g/100 g flour)¹.

Source	Moisture	Protein	Fat	Ash	CHO ²
Cultivated amadumbe flour	5.8 ^a ± 0.7	2.4 ^a ± 0.1	1.9 ^b ± 0.2	4.9 ^a ± 0.4	73.1 ^b ± 0.5
Wild amadumbe flour	7.4 ^b ± 0.4	2.9 ^b ± 0.2	0.9 ^a ± 0.1	5.9 ^b ± 0.3	70.8 ^a ± 0.9

¹ Mean ± SD (*n* = 3) is reported; means with different superscript letters in columns are significantly different (*p* < 0.05).² CHO: carbohydrate is reported by difference.

the micrographs were obtained (Li et al., 2014). Amadumbe starch samples were viewed with an EVO 15 HD SEM.

3.4. Proximate composition of amadumbe flour

Moisture, fat and ash contents were determined using AOAC (2000) methods. Protein content was determined by Kjeldahl method ($6.25 \times N$) and total carbohydrate was calculated by the difference.

3.5. Total starch content

The starch content of extract was determined using method described by Goñi, Garcia-Diz, Mañas, and Saura-Calixto (1996).

3.6. Apparent amylose content

Apparent amylose of cultivated and wild amadumbe starch was determined using the iodine binding method (Williams, Kuzina, & Hlynka, 1970).

3.7. Functional properties of flour and starch

The water absorption capacity was determined using methods described by Phillips, Chinnan, Branch, Miller, and McWatters (1988), solubility index by the method of Anderson, Conway, Pfeifer, & Griffin (1969), paste clarity by the method of Mir and Bosco (2014) and swelling power (50–90 °C) by the methods described by Osundahunsi, Fagbemi, Kesselman, and Shimoni (2003).

3.8. Thermal properties of starch

The gelatinisation temperatures of the starch samples were determined using a differential scanning calorimeter (SDT Q600, USA) coupled with a thermal analysis data station and data recording software. Starch (3 mg) was weighed into the aluminium DSC pan and distilled water (12 µl) added with a microsyringe before the pan was sealed using DSC punch sealer. The pans were allowed to equilibrate at 25 °C for 2 h prior to the DSC analysis. Samples were scanned at 10–110 °C with an interval heating rate of 5 °C/min. An empty pan was used as reference for all measurements.

3.9. In vitro digestibility

Digestibility of raw and processed amadumbe products, boiled and baked was done following the method of (Englyst et al., 1992). Glucose oxidase assay kit was used to analyse glucose content at G20 (glucose release after 20 min), G60 (glucose release after 60 min) and G120 (glucose release after 120 min). Potato starch, purchased from Sigma-Aldrich, was included as reference material. Nutritional starch fractions: RDS, SDS, and RS based on digestibility were calculated by combining G20, G65, G120 and TG (total glucose) and multiplying by a factor of 0.9. Predicted glycaemic index was estimated using $GI = 39.71 + 0.549HI$, HI: Hydrolysis index (Goñi et al., 1996)

3.10. Statistical analysis

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

4. Results and discussion

4.1. Proximate composition of amadumbe flours

As expected, carbohydrate (approx. 72%) was the major component in both cultivated and wild amadumbe flours (Table 1). Amadumbe flours were generally low in protein, fat and ash contents. The proximate composition of both wild and cultivated amadumbe flours are similar to values reported for taro flours (Kaur, Kaushal, & Sandhu, 2013; Ogunlakin, Oke, Babarinde, & Olatunbosun, 2012).

4.2. Starch yield, total starch and apparent amylose

Starch yields and contents were determined following the starch extraction from wild and cultivated amadumbe. The starch yield (approx. 36%) and total starch content (approx. 96%) of wild amadumbe were very much similar to those of cultivated type (Table 2). The starch yield in this study is comparable to previous reports for taro starches (Jane et al., 1992; Nand, Charan, Rohindra, & Khurma, 2008). The relatively high total starch content for both the cultivated and wild amadumbe types is an index of purity. Similarly, high starch contents have been reported for taro flour after extraction (Jane et al., 1992; Simsek and El, 2012).

Amylose content of starch extracted from the wild amadumbe starch was substantially high (20%), about twice that of the cultivated type (Table 2). Amylose contents of starches may vary with botanical source and method of amylose content determination (Hoover, Hughes, Chung, & Liu, 2010). Aboubakar et al. (2008) reported variable amylose contents for six varieties of taro starches. The amylose contents of both amadumbe starches are within the range of values reported for taro starches (Nwokocho, Aviara, Senan, & Williams, 2009; Simsek and El, 2012; Srichuwong, Sunarti, Mishima, Isono, & Hisamatsu, 2005).

4.3. Starch morphology

Wild and cultivated amadumbe showed polygonal and irregularly shaped starch granules (Fig. 2), suggesting that these two types of amadumbe have compound starches. Amadumbe starch granules were very small in size, ranging from 2–7 µm.

Table 2Starch yield, total starch and apparent amylose of amadumbe (g/100 g)^a.

Source	Starch yield	Total starch	Apparent amylose
Cultivated amadumbe flour	35.0 ^a ± 1.0	94.3 ^a ± 2.0	12.0 ^a ± 0.7
Wild amadumbe flour	36.0 ^a ± 0.3	95.2 ^b ± 4.0	20.0 ^b ± 3.1

^a Mean ± SD (*n* = 3) is reported; means with different superscript letters in columns are significantly different (*p* < 0.05).

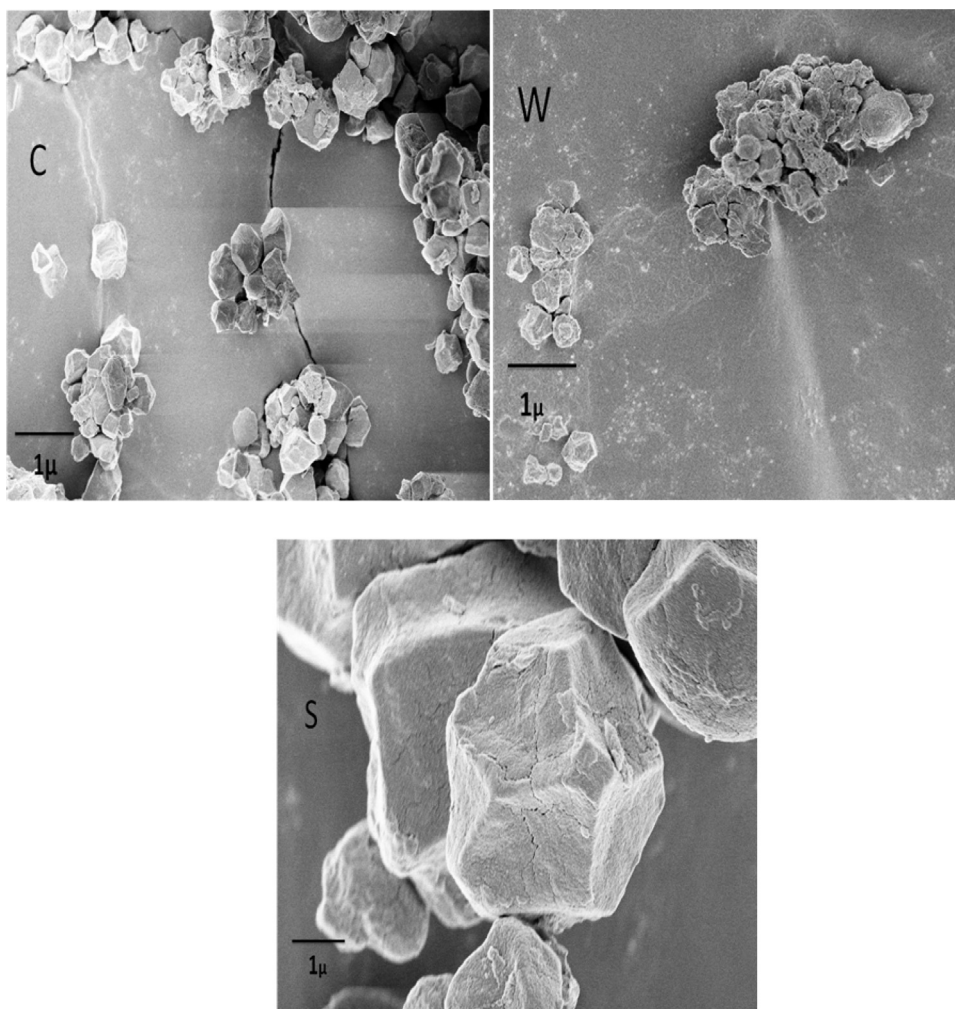


Fig. 2. Scanning electron micrographs of amadumbe starch C (cultivated starch), W (wild starch), S (Single granule showing polygonal structure of amadumbe starch).

However, wild amadumbe starch granules appeared remarkably smaller ($1.8 \pm 0.2 \mu\text{m}$), about half the size of those from cultivated amadumbe. Similarly compound and small sized starch granules have previously been reported for taro (Jane et al., 1992; Srichuwong et al., 2005). Although, much bigger starch granules, up to $20 \mu\text{m}$, have been reported by some authors (Aboubakar et al., 2008), generally, taro starches have been found to be smaller in size compared to starches from potato, cassava and corn (Huang et al., 2010; Srichuwong et al., 2005). According to Daniel and Whistler (1990), smaller granular starch provides better mouth feel as a lipid substitute. Thus, wild amadumbe starch has the potential as fat replacers in many food applications.

4.4. Functional properties

4.4.1. Water absorption and solubility index

The water absorption capacity (WAC) of cultivated and wild amadumbe flours was higher than those of their starches, respectively (Table 3). This may be due to the presence of non-starch components such as protein and mucilage in the flour (Kinsella & Melachouris, 1976). However, when comparing the flours between the two types, the WAC of wild amadumbe flour (approx. 419%) was much higher (twice) than that of cultivated amadumbe type. The high WAC of the wild amadumbe flour compared to the cultivated type may be due to its slightly higher protein and low fat contents of flour (Table 1). Also, the very small starch granules observed

for wild amadumbe starch compared to the cultivated type may have accounted for its higher water absorption capacity. Previous research indicated that smaller-sized starch granules, with larger surface area, have a more soluble effect and thus, may absorb more water (Moorthy, 2002).

Wild amadumbe flour showed a slightly higher solubility index (SI) than did the cultivated amadumbe flour (Table 3). But, the starch extracted from both amadumbe types showed similar SI. The SI of starches was much lower than those of their respective flours due to the presence of more non starchy components such as protein and mucilage in amadumbe flours. The high WAC taro flour compared to the isolated starch has previously been reported (Aboubakar et al., 2008). The low SI of the amadumbe starches compared to those of the amadumbe flours could be attributed to the semi-crystalline structure of the starch granules and hydrogen

Table 3
Functional properties of Amadumbe (g/100 g)^a.

Amadumbe source	Type	Water absorption %	Water solubility index %
Cultivated	Flour	$193.2^b \pm 5.8$	$24.5^b \pm 1.1$
	Starch	$162.8^a \pm 2.4$	$19.5^a \pm 1.8$
Wild	Flour	$418.7^d \pm 3.6$	$34.3^c \pm 4.3$
	Starch	$302.1^c \pm 1.9$	$19.8^a \pm 1.6$

^a Mean $\pm$ SD ($n=3$) is reported; means with different superscript letters in columns are significantly different ($p < 0.05$).

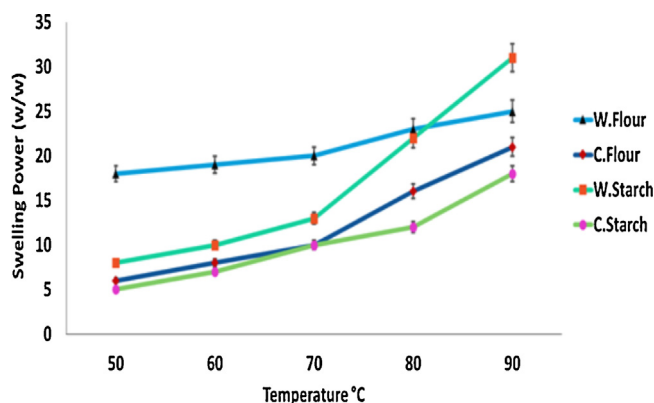


Fig. 3. Swelling power of cultivated and wild amadumbe. C: cultivated W: wild.

bonds formed between hydroxyl groups in the starch molecules (Eliasson & Gudmundsson, 1996). Recent studies on five varieties of cocoyam, showed that starches with larger granule size seemed to show low ability to absorb water compared to those with smaller granules size (Falade and Okafor, 2013). Thus, according to this report, starch with smaller granule size is expected to have low solubility. The difference in starch granule size between the wild and cultivated amadumbe did not seem to have any major influence on the solubility of their respective starches.

4.4.2. Swelling power

The swelling power of both amadumbe flour and starch steadily increased at a temperature range between 70 and 90 °C, which may be associated with starch gelatinisation (Fig. 3). Previous research attributed the rapid increase in swelling of starch granules, at specified temperature range, to melting of starch crystallites, which confirms gelatinisation (Hoover & Sosulski, 1985). Wild amadumbe starch showed considerably higher swelling power than those of the cultivated type. Swelling power is measured as the weight of swollen granules, which is an indication of the hydration capacity of starch granules. Falade and Okafor (2013) observed that *Xanthosoma* spp., which had larger starch granules size showed remarkable swelling ability compared to those of *Colocasia* spp., with smaller granules. However, in this study, wild amadumbe starch granules which were smaller in size, showed better swelling capacity compared to the cultivated amadumbe, especially at temperature ranging from 70 to 90 °C. This observation may be attributed to difference in crystalline structures (Hoover, 2001) between the wild and cultivated amadumbe starches rather than the size of the granules. Further, it has been suggested that amylose content of starch restricts its swelling behaviour. However, in this study, wild amadumbe starch with high amylose content displayed high swelling ability compared to cultivated amadumbe with low amylose content. Previous studies by Kaur, Sandhu, and Lim (2010) observed a negative correlation, which was not significant, between swelling and amylose content of starches. Beside the amylose, the molecular structure of amylopectin and the magnitude of interaction within the amorphous and crystalline region may influence the swelling behaviour of starch (Singh, Singh, Kaur, Sodhi, & Gill, 2003). The degree of polymerisation (>35), that is high degree of long chain molecules in amylopectins have been found to contribute to increased swelling of starch (Sasaki & Mtasuki, 1998). Other non-carbohydrates content of starch such as lipids and phosphorous contents may also play a role (Hoover & Ratnayake, 2002; Singh et al., 2003). For instance, the high swelling power of potato starch compared to corn and wheat starches was attributed to its high phosphorus contents (Singh et al., 2003). According to Hoover and Ratnayake (2002), the swelling power of starch may be

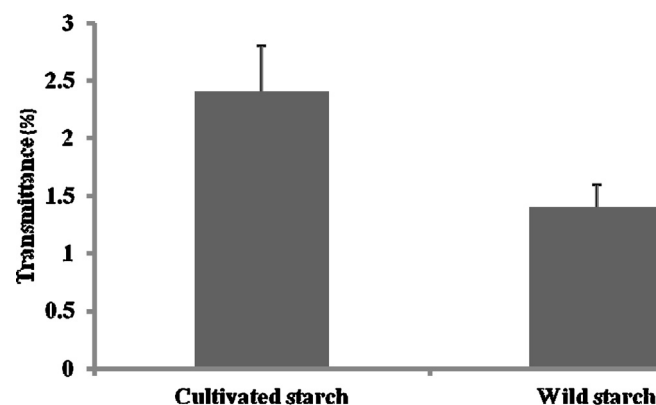


Fig. 4. Paste clarity of cultivated and wild amadumbe starch.

influenced by the presence of residual lipids. The variation in swelling powers of cocoyam, corn and water yam was attributed to minor components and fine structures of starches (Srichuwong et al., 2005). Previous studies, by Jane et al. (1990), have shown a significant variation in lipid and phosphorus contents of taro starches obtained from different varieties. The branch chain lengths of taro amylopectins have also been found to differ among varieties, with DP 16.8–18.4 and DP 37–40 for short and long chains, respectively. Thus the variation in swelling abilities between the cultivated and amadumbe starches, as observed in this study, may be attributed to differences in amylopectin molecular structures between the two starches and their minor component contents (e.g. lipids, phosphorus).

4.4.3. Paste clarity

The paste clarity of starch from cultivated amadumbe was high almost double that of wild amadumbe types (Fig. 4). The relatively higher paste clarity of cultivated amadumbe starch may be associated with its lower amylose content (Table 2). Previous studies reported that starches with lower amylose content are easily dispersed and exhibit higher transmittance and clarity (Craig, Maningat, Seib, & Hoseney, 1989; Swinkels, 1985). Cultivated amadumbe starch thus has the potential for application in foods that require much clearer paste such as fruit fillings and jellies (Mweta, Labuschagne, Koen, Benesi, & Saka, 2008).

4.5. Thermal properties of starch

With the exception of the peak gelatinisation temperature (T_p), cultivated and wild amadumbe starch showed similar gelatinisation parameters (T_o (onset), T_c (conclusion), $T_c - T_o$ (gelatinisation temperature range) and ΔH (gelatinisation enthalpy) (Fig. 5). Cultivated amadumbe starch showed slightly lower T_p (80.6 °C) compared to the wild amadumbe starch (84.9 °C). Finding from this study is in agreement with reported gelatinisation temperature ranges for taro starch by some authors (Jane et al., 1992; Perez et al., 2005; Srichuwong et al., 2005). However, peak temperatures of gelatinisation (56–68 °C) reported for six varieties of taro (Aboubakar et al., 2008) were lower than the values obtained in this study. These differences in peak temperatures could possibly be attributed to differences in degree of crystallinity of starch from different sources (Hoover, 2001). Other factors such as granules size and purity of starch (e.g. presence of mucilage) after extraction may have influenced T_p . For instance, the gelatinisation temperature was found to increase with the addition of mucilage to taro starch due to competition for water (Huang et al., 2010). Further, amylose content of starch may influence its gelatinisation temperature (Stevens & Elton, 1971). Low amylose starch is expected to exhibit high gelatinisation temperature. The slightly high T_p values

Table 4
Nutritional starch fractions of cultivated and wild amadumbe.

Amadumbe Source	Type	RDS	SDS	RS	GI ^b
Cultivated	Raw	23.1 ^c ± 0.3	14.0 ^a ± 0.1	57.1 ^a ± 0.4	42.1 ^a ± 0.3
	Boil	16.3 ^b ± 0.2	24.0 ^c ± 0.2	54.0 ^a ± 0.1	43.3 ^b ± 0.6
	Bake	17.2 ^b ± 0.2	25.0 ^c ± 0.2	52.0 ^a ± 0.3	44.0 ^b ± 0.1
Wild	Raw	11.2 ^a ± 0.4	20.3 ^b ± 0.2	64.3 ^b ± 0.3	41.0 ^a ± 0.2
	Boil	15.0 ^b ± 0.3	19.0 ^b ± 0.3	61.2 ^b ± 0.2	40.4 ^a ± 0.5
	Bake	13.0 ^a ± 0.2	22.0 ^c ± 0.3	60.0 ^b ± 0.3	43.0 ^b ± 0.1

^a Mean ± SD (*n* = 3) is reported.

^b Estimated glycaemic index (GI) = 39.71 + 0.549 HI; means with different superscript letters in columns are significantly different (*p* < 0.05).

of wild amadumbe starch with high amylose content compared to the cultivated with low amylose may be attributed to number of factors. Beside the amylose, molecular structure and the nature of interaction within starch chain between the amorphous and crystalline regions may also influence hydration, the ability of starch granules ability to swell and thus, its melting behaviour during heating. [Aboubakar et al. \(2008\)](#) did not observe a clear cut pattern between amylose content and peak temperature of gelatinisation. According [Jane et al. \(1992\)](#), high amylose with longer chain length may exhibit high transition temperature. The ΔH observed for cultivated and wild amadumbe starch appeared higher than those reported for taro starches ([Jane et al., 1992](#)). This suggests that interactions between double helices forming the crystalline region in the amadumbe starch from this study are probably more extensive ([Zhou, Hoover, & Liu, 2004](#)). Consequently, the ΔH associated with dissociation and melting of the double helices would be of a higher order of magnitude in the amadumbe starch.

4.6. Digestibility of processed amadumbe products

In terms of nutritional starch fractions, slowly digestible starch (SDS) and resistant starch (RS) fractions of wild amadumbe were 20 and 64% respectively, which appeared slightly higher compared to the cultivated type (SDS: 14% and RS: 57%). However, after processing into boiled and baked amadumbe corms, the RS for both amadumbe slightly decreased ([Table 4](#)). The relatively higher RS for wild amadumbe corms compared to the cultivated type may be associated with the higher amylose content ([Table 2](#)). Previous research indicated that high amylose starch have higher resistance to digestive enzymes ([Hoover and Sosulski, 1985](#)). The RS contents of amadumbe starches compare favourably with literature ([Simsek and El, 2012](#); [Barnabe et al., 2011](#)). Taro starch has been found to contain the highest amount of RS (approx. 52 g/100 g dry sample) when compared to starches including maize, potato starch and some modified starches ([Barnabe et al., 2011](#)). [Simsek and El](#)

(2012) also reported up to 50% resistant starch for taro following treatments such as heating and enzymatic debranching. However, RS contents of untreated starches reported by these authors were lower than those of the reference samples (unprocessed taro) from this study. Unlike with [Simsek and El \(2012\)](#), who worked on purified starch (up to 98%), digestibility were done on crude flours. Possibly, the presence of mucilage in taro flour and other minor components such as protein and fat ([Table 1](#)) may have influenced the physical accessibility to enzyme and hence, their digestibility.

Further, the RDS of cultivated amadumbe significantly decreased after boiling and baking whilst SDS values increased. On the other hand, RDS of wild amadumbe significantly increased after boiling and baking with no substantial variation observed in SDS fractions. Processing conditions may greatly influence starch digestibility. [Njintang and Mbofung \(2006\)](#) observed a definite increase in *in vitro* carbohydrate digestibility after pre-cooking and drying for short period, while longer cooking period (> 45 min) and drying temperature (> 60 °C) resulted in marked reduction in carbohydrate digestibility. Further, the variations in digestibility kinetics and nutritional starch fractions between the wild and cultivated may be attributed to an interplay of many factors including the source of starch/varieties, starch granules size, amylose/amylopectin ratio and amylopectin chain length as well as the presence of non-carbohydrate components ([Chung, Lim, & Lim, 2006](#); [Kaur et al., 2010](#)). [Kaur et al. \(2010\)](#) observed a negative correlation of RDS and SDS with relative crystallinity and a positive with amylose contents. It has been suggested that smaller sized starch granules may be more digestible than larger starch granules due to better contact between the enzyme and substrate ([Svihus, Uhlen, & Harstad, 2005](#)). Previous studies have shown that the molecular structures of amylopectin may differ according to taro varieties or types ([Jane et al., 1992](#); [Tattiyakul, Pradipasena, & Asavasaksakul, 2007](#)). [Tattiyakul et al. \(2007\)](#) reported differences in average chain length of amylopectin of starches extracted from small, medium, and large taro corms. Findings from these authors further suggested that amylopectin chain length can significantly influence the functional properties of starch. As described, wild amadumbe starch granules were very small in size compared to cultivated starch granules ([Fig. 1](#)). Differences in starch granules morphology and possibly, the variation in molecular structures of amylopectins between the wild and cultivated amadumbe starches contributed to observed differences in starch digestibility and nutritional starch fractions before and after processing.

The glycaemic indices (GI) of raw and processed amadumbe were very similar (approx. 42%) and these relate to starch digestibility. GI values of amadumbe appeared lower than those reported for taro corms ([Simsek and El, 2012](#); [Simsek & El, 2015](#)). Differences in the cultivar of taro used by these authors compared to those used in this study may have accounted for the variation in the GI. Based on the nutritional classification of foods, both raw cultivated and wild amadumbe have the potential in the formulation of products for diabetics and weight management ([Foster-Powell, Holt, & Brand-Miller, 2002](#)).

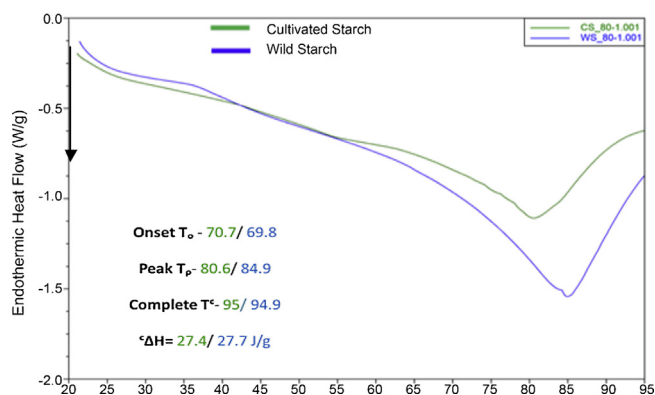


Fig. 5. Thermo-gram of cultivated and wild amadumbe starch. ^a Mean ± SD (*n* = 3) is reported, T_o , onset temperature; T_p , peak temperature; T_c , conclusion temperature; ΔH , enthalpy change.

5. Conclusions

Amadumbe corms consist of polygonal and very small starch granules. However, the wild amadumbe appears very different from the cultivated in terms of its amylose content and functionality. Wild starch contains high amylose content than the cultivated. Both amadumbe starches display a single endothermic peak, with the wild showing a slightly higher peak temperature of gelatinisation. Wild amadumbe starch seems to have a better water absorption capacity, which may be associated with its relatively high amylose content. Both raw and processed amadumbe represent good sources of SDS and RS, have low value of GI, and thus may be suitable as a functional ingredient in food applications.

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