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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 ± 0.9 μm). 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.

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 (1–5 μm) 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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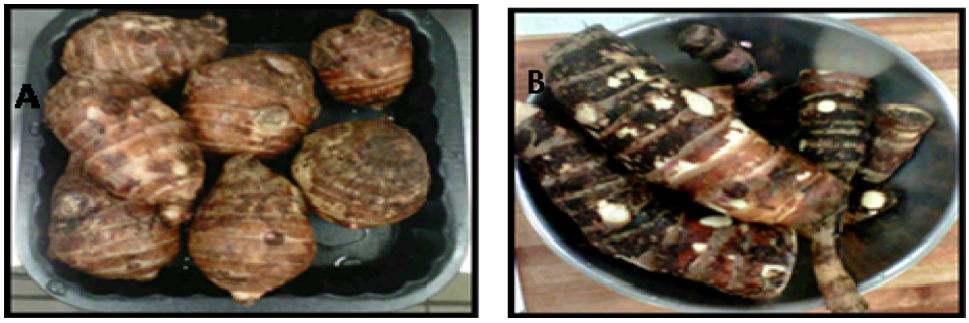

Fig. 1. Amadumbe corms from cultivated and wild sources. A: cultivated: *Colocasia esculenta var esculenta*, B: wild: *Colocasia esculenta var stolonifera*.

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, Srikaeo, & 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 μm) to obtained 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 μm) 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 × *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 μm) 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