Mucilage chemical profile and antioxidant properties of giant swamp taro tubers

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Abstract The yellow (YP) and white (WP) sections of giant swamp taro (GST) contain 40.0 g/kg and 51.5 g/kg (dry wt) respectively of pure mucilage made up of D-glucose (44.95–78.85 %), D-galactose (8.70–25.35 %), D-mannose (3.20–10.45 %), D-arabinose (2.45–5.20 %) and small amounts of glucuronic acid and rhamnose. Arabinogalactan-proteins (5.30–8.83 g/kg) contain mainly arabinose and galactose (in a 1:1 proportion) and also significant amounts of rhamnose, xylose, glucuronic acid and mannose. Antioxidant activity of YP was higher than those of WP while chelating ability and reducing power increased with mucilages content. Generally YP and WP showed better reducing power (1.06 ± 0.35 at 5 mg/mL) than ascorbic acid (0.89 ± 0.22). WP and YP chelated ferrous ions by 20.0–76.0 % and 16.4–71.0 % respectively. Effective concentrations (EC_{50}) of mucilages (WP 1.28 ± 0.05 mg/mL; YP 1.42 ± 0.04 mg/mL) were lower than those of citric acid (1.58 ± 0.04 mg/mL). Generally mucilage from the WP and YP sections are excellent sources of chelating agents.

Keywords Giant swamp taro · *Cyrtosperma merkusii* · Mucilage · Arabinogalactan-protein · Monosaccharides · Antioxidant properties

Introduction

Giant swamp taro (GST), *Cyrtosperma merkusii*, is an important staple food widely grown in fresh water marshes of tropical regions (Englberger et al. 2008). In Cameroon it is cooked and eaten as such or in combination with other taro varieties such as *Colocasia esculenta* to satisfy the processed food needs of the population. Unlike the other varieties of taro such as *Colocasia esculenta*, *Alocasia macrorrhiza* (giant taro) and *Xanthosoma sagittifolium* (Hawaiian, American or New world taro) which are grown on dry land (Lewis 2000), *C. merkusii* is grown in fresh water marshes and swampy areas and generally produces tubers weighing between 1 and 5 kg.

One of the reasons for the use of GST in combination with other taros in the traditional processing of a food paste commonly consumed in Cameroon and known as *achu* is the fact that it contributes to the smooth textural feel of the processed food. According to Njintang et al. (2007) the smooth textural feel of *achu* is a function of the starch and mucilage contents of taro used in the preparation. Given the individual role each of these constituents plays in the food industry, the choice of taro for use in any given food process will be a function of the particular property unique to either constituents.

With particular reference to mucilage which is natural plant food gums, it has the property of being able to disperse easily and to increase viscosity thus producing a gelling effect. And because of this, they are increasingly being used in food process industries as food-thickening and gelling

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agents (Fedeniuk and Biliaderis 1994). In addition, these biopolymers are also being exploited for diverse purposes in food and pharmaceutical formulations due to properties such as water holding and binding capacity and stabilizing ability. In fact, depending on their specific physicochemical properties, mucilages are increasingly being used in different food processes in the meat, chocolate, ice cream and salad dressing industry. According to Kishk and Al-Sayed (2007), glycoproteins contained in mucilages are equally increasingly being sought after for their emulsifying role in certain food processes. The report of their role as potential immunological regulators (Showalter 2001) as well as antioxidants (Fan et al. 2007) in human health has further heightened the research interest on the different sources and characteristics of mucilage. This is achieved in some cases by activating the complement system and in other cases by enhancing the cytotoxic activity of natural killer cells, and this has been associated with their content in Arabinogalactan-proteins (AGP). Indeed research findings consistently showed AGP to be common characteristic components of plant mucilage, though in varying proportion depending on the plant material (Fincher et al. 1983; Harris et al 1992; Aprianita et al. 2009). Previous studies on taro *Colocasia esculenta* mucilage have used poorly defined extracts liable to contamination by other polysaccharides. The variety of extraction conditions for water-soluble taro mucilage used in previous studies further makes comparison difficult. In fact Gaind et al. (1968) extracted taro mucilage in aqueous solution at 100 °C. This was followed with the extraction method by El-Mahdy and El-Sebaiy (1984) using an extraction temperature of 70 °C, that of Lin and Huang (1993) and more recently Jiang and Ramsden (1999) which used extraction at 4 °C. The extraction procedure of taro mucilage using low temperature extraction (4 °C) is to be encouraged since it minimizes starch contamination and uses enzymatic hydrolysis to remove any residual starch. However, the fundamental question concerning the content, the composition and the properties of the AGP of taro in general and in particular GST is still to be answered. To the best of our knowledge, no such studies have been conducted.

In an attempt to investigate this issue, the present study was carried out to determine the content, the composition and the antioxidant properties of mucilages and AGP in Giant swamp taro sample.

Materials and methods

Production of GST flour Giant swamp taro tuber, freshly harvested from family farms in Ndong-Awing (Nord-West region of Cameroon) were transported to the laboratory and thoroughly washed with tap water, hand peeled and

separated into two parts, the central yellow flesh part and the white peripheral sheath part (Nguimbou et al. 2012), before drying in an air convection electric dryer (Rivera, France) set at 50 ± 2 °C. Once dried the slices were hammer milled (Culatti polymix, France) to pass through a 250 µm screen and the resulting powders coded as YP (yellow part) and WP (white part) were packed in polyethylene bags and stored in a refrigerator at 4 °C until required for analysis.

Proximate analysis of GST flours Flours were analysed for moisture (air oven method), fat (Soxhlet), ash (incineration method) and dietary fiber content following AACC standard methods (1990). Total proteins (Nx6.25) were determined using approved methods of Kjeldahl (AACC 1990) in semi automatic machine (GEHARDT, Paris, France). Total starch was evaluated essentially according to the AACC method (1999). The results were expressed as g/100 g of dry sample weight.

Extraction of mucilage from GST flour The crude water-soluble mucilage was extracted by mixing taro flour with water (1/3, v/w) and overnight stirring at 4 °C. The resulting mixture was centrifuged at 14,300 g for 20 min and the supernatant collected. The extraction was repeated following the same procedure using the pellet and a second supernatant was obtained. The two supernatants were combined, filtered, and concentrated at 60 °C under reduced pressure and lyophilized (freezing temperature –60 °C, FreezOne equipment 2.5 plus, pressure 0.2 mBar). Soluble protein was determined in crude taro mucilage by the method of Lowry et al. (1951) using a BSA standard.

Purification of crude GST mucilage Crude taro mucilage was purified to remove starch and free soluble proteins using standard methods. Essentially, the starch in the crude mucilage was hydrolysed following the method of Southgate (1991) by mixing with an enzyme solution of pH5.2 containing 5,000 units per mL of α -amylase (type VI-B from pig pancreas, Sigma Chemical Co), 5 units per mL of pullulanase (from *Klebsiella pneumoniae*, Sigma Chemical Co), 0.1 M sodium acetate and incubating for 16 h at 45 °C. Following this, trichloroacetic acid was added to a final concentration of 4 % to precipitate free soluble protein using the technique described by Lin and Huang (1993). The mixture was then stirred for 5 min, centrifuged at 10 000 g, 4 °C for 10 min. The supernatant was collected and ethanol added to a final concentration of 80 %. After agitation for 5 min, the polysaccharides were precipitated and collected by centrifugation at 10 000 g, 4 °C for 10 min. This precipitate was purified by repeatedly washing with 95 % ethanol and acetone. The purified fraction was then dissolved in 4 mL distilled water, filtered, dialyzed, and lyophilized. Samples were applied to a DEAE-Sepharose

CL-6B column (20×100 mm) eluted with water at 0.8 mL/min followed by a gradient of 0 to 1 M NaCl. Fractions (2 mL) were collected and analyzed for soluble protein. Peak fractions were pooled, concentrated, dialyzed and lyophilized (freezing temperature −60 °C, FreezOne equipment 2.5 plus, pressure 0.2 mBar).

Extraction of crude AGPs from GST flour The taro AGPs was extracted following the method of Schultz et al. (2002). 5 g of taro flour were suspended in 5 mL of buffer solution (50 mM Tris–HCl pH8, 10 mM EDTA, 0.1 % β -mercaptoethanol, 1 % (w/v) Triton X 100) at 4 °C for 4 h. The samples were centrifuged at 14 000 g for 10 min at 4 °C and the resulting supernatant treated with 5 volumes of absolute ethanol for 24 h at 4 °C before centrifuging at 14 000 g for 10 min at 4 °C to obtain pellets which were then suspended in 5 mL of Tris–HCl solution (50 mM, pH8). The mixture was then centrifuged at 14 000 g for 10 min at 4 °C, and the supernatant frozen (−60 °C) and lyophilized on a FreezOne equipment 2.5 plus at a pressure of 0.2 mBar. Three mg of dehydrated crude AGP was dissolved in 1 mL of 1 % NaCl solution and then quantified by rocket electrophoresis.

Rocket electrophoresis of taro AGPs This electrophoresis was carried out following the protocol described by Ding and Zhu (1997) using an agarose gel (1 %) 1 mm thickness (25 mM Tris, 200 mM glycine, pH8.4) containing 2 mg/mL of Yariv β -glucosyl (Yariv β -glucosyl is a red stain from the combination of α -aminophenyl), β -D-nitrogen glycosides in hydrochloric acid and phloroglucinol (Yariv et al. 1962). A range of arabic gum AG (0; 0.125; 0.2; 0.5; 1 mg/mL) served as standard. 15 μ L of standards or non purified AGP extracts were deposited in each well of the gel and the electrophoretic process carried out for 16 h in a migratory buffer solution (25 mM Tris, 200 mM glycine, pH8.4) at 150 V, 20 mA. In the process of the electrophoresis rocket shaped arc is formed when the AGPs come into contact with the Yariv reagent. The gel was then rinsed in the 2 % NaCl solution before taking its picture. The amount of AGP in our taro samples were determined from a calibration curve (migration distance of the shaped arc in mm vs quantity of gum in mg) of Arabic gum standard and expressed as g/kg of flour.

Purification of crude taro AGPs The AGPs samples were treated for 24 h at 4 °C with 0.1 mg/mL Yariv reagent in 1 % of NaCl to obtain an insoluble complex which was collected after centrifugation at 14 000 g for 1 h. This pellet complex was then washed thrice with 1 % NaCl solution, and twice with methanol, to remove excess Yariv reagent. Following this, the pellet was dried under a hood and dissolved in 0.5 mL of dimethylsulfoxide (DMSO) with the addition of

a pinch of sodium hydrosulfite and some water to obtain a pale yellow color solution. The solution was then dialysed, frozen and freeze-dried. The freeze-dried material was then taken up in 1 mL of 1 % NaCl solution to represent the pure AGPs. The purity of the AGPs was assessed by simple and cross electrophoresis in an agarose gel (1 %) in 1 M glycine-Tris buffer pH8.6 for 2 h at 10 mA after which the gels were developed in 0.1 mg/mL Yariv reagent in 1 % NaCl and washed copiously with water.

Monosaccharide content of taro mucilage and AGPs Samples (1–2 mg) were hydrolysed in 2 mL of 2.5 M trifluoroacetic acid at 100 °C for 2 h in a sealed tube under nitrogen. After hydrolysis the acid was removed on a rotary evaporator, and the hydrolysate was then reduced with sodium borohydride and acetylated (Albersheim et al. 1967). The resulting alditol acetate derivatives were separated on a 1.85 m×4 mm column of 3 % SP2340 on 100/120 Supelcoport, in a Hewlett-Packard model 5710A gas chromatograph. The chromatography was conducted isothermally at 215 °C with an N₂-carrier-gas flow rate of 60 mL/min.

Antioxidant properties of GST mucilages

Total phenolic content The amount of total phenolic compound in extract was determined using Folin–Ciocalteu reagent, according to the method of Singleton and Rossi (1965) with slight modification and using ferulic acid as a standard. Briefly, 750 μ L of extract solution (1 mg/mL) was added to 75 μ L of Folin–Ciocalteu reagent and mixed thoroughly. After 3 min, 750 μ L Na₂CO₃ (20 %) was added. The mixture was allowed to stand for 1 h with intermittent shaking. The absorbance was measured at 760 nm using a visible spectrophotometer. The total phenolic content was determined as mg of ferulic acid equivalent per g of dry mucilage weight, using an equation obtained from the standard ferulic acid calibration graph.

Ferric reducing antioxidant power assay (FRAP) The FRAP procedure described by Benzie and Strain (1996) was followed. Essentially the FRAP reagent containing 1 part of a 10 mmol/L TPTZ (2, 4, 6- tripyridyl- s- triazine) solution in 40 mmol/L HCl plus 1 part of FeCl₃ (20 mmol/L) and 10 part of 0.3 mol/L acetate buffer pH=3.6 was prepared freshly. Aliquots of 75 μ L sample were mixed with 2 mL FRAP reagent and the absorbance of reaction mixture at 593 nm was measured spectrophotometrically after incubation at 37 °C for 12 min. For construction of calibration curve five concentrations of FeSO₄·7H₂O (1,000, 750, 500, 250, 125 μ mol/L) were used and the absorbencies were measured as sample solution. The values were expressed as mmol/L equivalent of Fe^{II} per g of mucilage.

Reducing power The reducing power was determined according to the method of Duh and Yen (1997). Each powder sample (0.025–5 mg/mL, 2.5 mL), contained in desionised water, was mixed with 2.5 mL of 200 mM sodium phosphate buffer (pH6.6) and 2.5 mL of potassium ferricyanide (Sigma), and the lot incubated at 50 °C, for 20 min. After 2.5 mL of 10 % trichloroacetic acid (w/v, Sigma) were added, the mixture was centrifuged at 3,000 g for 10 min. Five mL of the supernatant was mixed with 2.5 mL of desionised water and 1 mL of ferric chloride (Sigma) and the absorbance was measured at 700 nm against a blank. A higher absorbance indicates a higher reducing power. The EC₅₀ value (mg powder/mL) was taken as the effective concentration at which the absorbance was 0.5 for the reducing power. It was obtained by interpolation from linear regression analysis of the curve of absorbance versus concentration. Ascorbic acid and α -tocopherol were used for comparison.

Chelating ability on ferrous ions Chelating ability was determined using the method of Decker and Welch (1990). By this method, each sample powder taken up in distilled water (0.025–5 mg/mL, 1 mL) was mixed with 3.7 mL of solvent (desionised water) and 0.1 mL of 2 mM ferrous chloride (Sigma) followed by the addition of 0.2 mL ferrozine 5 mM (Sigma). After 10 min at room temperature, the absorbance of the mixture was determined at 562 nm against a blank. A lower absorbance indicates a higher chelating power. The EC₅₀ value (mg extract/mL) is the effective concentration at which ferrous ions were chelated by 50 %. Ethylenediaminetetraacetic acid (EDTA, Sigma) and citric acid were used for comparison.

Statistical analysis All analyses were carried out in triplicate and data expressed as means $\pm$ standard deviation. Analysis of variance was performed to calculate significant differences in treatment means, and Duncan multiple range test was used to separate means using the Statgraphics XV.I statistical software.

Results and discussion

Proximate composition of giant swamp taro (GST) flours Table 1 shows the proximate composition of the different parts of GST expressed on a dry weight basis. Moisture (expressed on fresh weight basis) content was generally high and ranged from 85.4 % for the yellow part to 85.9 % in the white section of tuber. The observation of high moisture content is a known characteristic feature of root and tubers crops. These values are comparable to those of *Colocasia* (70.40–86.50 % fresh weight basis) but fairly higher than those of *Xanthosoma* (60.40–71.60 % fresh

Table 1 Proximate composition of yellow (YP) and white (WP) sections of giant swamp taro tuber

Characteristics	Samples	
	YP	WP
Moisture of fresh tuber (%)	85.4 $\pm$ 1.10 ^a	85.8 $\pm$ 0.84 ^a
Moisture of flour (%)	11.6 $\pm$ 0.41 ^a	10.9 $\pm$ 1.32 ^a
Ash (%)	3.5 $\pm$ 0.07 ^a	3.7 $\pm$ 0.01 ^a
Total fat (%)	2.1 $\pm$ 0.12 ^b	1.5 $\pm$ 0.02 ^a
Total Proteins (%)	9.0 $\pm$ 0.30 ^b	8.1 $\pm$ 0.19 ^a
Dietary fiber (%)	3.6 $\pm$ 0.12 ^b	2.2 $\pm$ 0.07 ^a
Total starch (%)	72.6 $\pm$ 1.90 ^a	77.8 $\pm$ 1.84 ^b

Means $\pm$ SD; $n=3$; values with different letters within the same row differ significantly ($p<0.05$) as determined by Duncan's Multiple Range Test. YP-Yellow section of giant taro; WP-white section of giant taro

weight basis) reported by Agbor-Egbe and Rickard (1990). The crude protein values obtained varied significantly ($p<0.05$) from 8.14 % for the white part to 9.0 % in the yellow part. These values are much higher to the range 1–5.5 %) reported (Aboubakar et al. 2008; Kaur et al. 2011; Himeda et al. 2012) for some varieties of *Colocasia*. This different information emphasizes the possible genetic differences that exist in the protein content of these tubers. As would be expected the total fat levels of the taro flours were low and ranged between 1.50 and 2.11 %. On the other hand *C. merkusii* contains high levels of starch (72.58–77.79 %), as such are a good source of energy. The mean ash content of 3.60 % was comparable to that reported earlier (Aboubakar et al. 2008; Agbor-Egbe and Rickard 1990) for other tubers but higher than 1.2 reported for Indian taro corms (Kaur et al. 2011). Crude fibers varied significantly from 2.24 % (white part) to 3.60 % (yellow part) and are higher than that recorded for 32 *Colocasia* cultivars in Cameroon (Agbor-Egbe and Rickard 1990). On the whole the yellow part was particularly higher in lipids and crude fibers while the peripheral part was higher in total starch.

Characteristics of isolated GST mucilage The crude fibers content above-mentioned represented the portion of food material resistant to combine actions of α -amylase, protease and amyloglucosidase. Mucilages are resistant to α -amylase and amyloglucosidase actions, but not to protease. In this respect mucilage, recognized by its high water solubility may be part of the fibers. Table 2 summarizes the extraction yield and composition of taro mucilage. The results showed considerable differences between the two samples tested. Crude water-soluble mucilage varied significantly from 40.0 g/Kg (YP) to 51.5 g/kg (WP) and is lower than that recorded for 12 *Colocasia* varieties (75.7–137.0 g/kg) in Hong Kong (Jiang and Ramsden 1999). When compared

Table 2 Yield and monosaccharide composition of mucilage and arabinogalactan-proteins (AGPs) from giant swamp taro tuber

Parameters	Mucilage		AGPs	
	YP	WP	YP	WP
Yield (g/kg)	40.0±1.40 ^a	51.5±2.10 ^b	/	/
Sugar (%)	69.1±0.90 ^a	71.4±0.50 ^b	/	/
Protein (%)	30.9±0.90 ^b	28.6±0.50 ^a	/	/
Ara (%)	2.4±0.21 ^a	5.2±0.14 ^b	26.6±0.63 ^c	33.2±0.77 ^d
Rha (%)	1.6±0.21 ^a	2.4±0.14 ^b	10.7±0.20 ^d	7.4±0.02 ^c
Fuc (%)	0.3±0.07 ^a	2.2±0.14 ^d	1.5±0.07 ^c	1.1±0.14 ^b
Xyl (%)	0.9±0.14 ^a	2.3±0.21 ^b	7.0±0.14 ^c	7.3±0.28 ^c
GalA (%)	1.5±0.07 ^b	1.1±0.14 ^a	2.4±0.14 ^c	0.9±0.07 ^a
GluA (%)	1.6±0.14 ^a	5.6±0.21 ^b	6.9±0.14 ^c	8.1±0.21 ^d
Man (%)	3.2±0.14 ^a	10.4±0.35 ^c	5.1±0.07 ^b	5.1±0.21 ^b
Gal (%)	0.7±0.14 ^a	25.3±0.77 ^b	32.0±0.28 ^c	34.0±0.21 ^c
Glc (%)	78.8±1.06 ^b	44.9±0.35 ^a	/	/
Ara/Gal	/	/	0.80±0.02 ^a	0.97±0.01 ^b

Means ± SD; $n=3$; values with different letters within the same row differ significantly ($p<0.05$) as determined by Duncan's Multiple Range Test; YP-Yellow section of giant taro; WP-white section of giant taro

to the variation in fibers content of the flour affected by portion of the tubers, the yield of the mucilage was not only higher, but a different trend was observed. This could be attributed to the protein moiety of the mucilage which levels has been demonstrated to negatively correlate with the mucilage yield (Njintang et al. 2012). The proportion of carbohydrate and protein in the mucilage was variable independently of the yield. Mucilage content was significantly ($p<0.05$) high in WP, while protein content was significantly ($p<0.05$) high in YP fraction. According to Jiang and Ramsden (1999), this difference may reflect variation in length and number of carbohydrate side chains along the Arabinogalactan-protein (AGP) protein core.

The sugar composition of mucilages indicated that glucose (45.0–78.9 %) was the major sugar component in both YP and WP taro tuber mucilage studied. Glucose, galactose, mannose and arabinose were identified as the major neutral sugar residues of the hydrolysates. Charles et al. (2007) also reported high levels of glucose (36.3–40.5 %) in cassava mucilage and argued that it may be associated with sugar alteration during maturation or may due to the presence of starch components in the gum after purification. Studies by Jiang and Ramsden (1999) revealed that for water extractions performed at different temperature the quantity of starch extracted increased with increasing temperature, indicating that the least contamination of water-soluble taro mucilage would occur with extraction at the lowest temperature. In this study we used a low temperature water extraction (4 °C), nevertheless some starch was still present as indicated by the high level of glucose observed in the mucilage after combined hydrolysis with α -amylase and pullulanase. The ratio of arabinose to galactose observed in the purified mucilage was 1:3 similar to that reported by Jiang and Ramsden (1999) for some varieties of taro, and

within the range reported for acacia mucilage (gum arabic). The presence of arabinose and galactose associated to the relatively high percentage of protein strongly suggested that this mucilage contained an AGP. Indeed an AGP consists of a hydroxyproline-rich core protein which is decorated by arabinose and galactose-rich polysaccharide units (Yariv et al. 1962).

Analysis of the isolated GST AGPs AGPs are a family of highly glycosylated hydroxyproline-rich glycoproteins analogous to animal proteoglycans. AGPs are operationally defined by their ability to react with a synthetic chemical reagent, a phenylazoglycoside dye called Yariv reagent. The presence of AGPs in our mucilage samples was confirmed by the binding of the β -glucosyl Yariv reagent. Results from the Rocket electrophoresis (Fig. 1) showed that the YP sample contained 5.3 g AGPs /kg of flour and WP sample

Fig. 1 Rocket electrophoresis of YP and WP AGPs of giant swamp taro tubers. YP-Yellow section of giant taro; WP-white section of giant taro; standard is Arabic gum. Values on top of the shaped arc are the weight of AGP in 15 µL of extract deposited in each well of the gel

Fig. 2 Simple (a) and cross (b) electrophoresis of YP and WP AGPs of giant swamp taro tubers. YP-Yellow section of giant taro; WP-white section of giant taro; GA-arabic gum. Simple migration of the gel was first done in direction (1) followed by a second migration (cross) in direction (2)

contained 8.83 g AGPs /kg of flour. The composition of purified AGPs from YP and WP samples was also analysed and the results are summarized in Table 2. The arabinose/galactose ratio varied from 0.80 for YP to 0.97 in the WP samples but the level of galactose (32.90 % and 34.05 % respectively for YP and WP) in AGPs was closely similar, but could be substituted to a varying degree. Levels of rhamnose, xylose, mannose and glucuronic acids showed a larger range but it remains to be determined if these are components of the AGPs or derived from separate polysaccharides present in the mucilage.

Agarose gel electrophoresis of purified taro AGPs extracts (Fig. 2a) gave an undersized band after staining with β -glucosyl Yariv reagent compared with huge band observed with acacia AGP. Taro AGPs did not migrate as far as acacia AGP indicating either a lower charge or a greater molecular size. Furthermore, cross electrophoresis (Fig. 2b) showed only one peak for giant swamp taro AGPs compared with two peaks observed with acacia AGP. A similar compartment for *Colocasia* AGP electrophoresis had earlier been documented by Jiang and Ramsden (1999). The present results are suggestive of the high purity of YP and WP AGPs samples, but this need to be confirmed.

AGP content of flour is a key specification in flour application studies. For current applications, AGPs content varies according to the food product type to achieve the desired eating quality. For industrial applications, the ability of plant gum (generally gum arabic) to suspend flavorings and colorings, and to do so with low viscosity, makes it an extremely valuable additive in the food industry (Serpe and Nothnagel 1999). Since, gum arabic is used in the candy industry to slow the hardening process in the manufacture of hard candy and as an adhesive in the stamp industry, it is reasonable to infer that similar applications could be found for giant swamp taro AGPs in traditional as well as industrial food processing. The begging question to be answered in this respect, however, is the extent to which AGPs in plant gums are directly responsible for these remarkable properties.

Separation of water-soluble mucilage from starch increases the cost of starch processing and commercial taro starch is usually contaminated with AGPs (Moorthy et al. 1993). However, Arabinogalactan-proteins from acacia are valued as a food additive for their excellent emulsifying properties. If similar properties are found for giant swamp taro AGPs this could represent a potentially useful by-product of starch production from this taro type.

Total phenolic content and antioxidant activity The mucilages obtained from the two parts possessed different but important phenolic content. The total phenol content in the yellow part (35.4 ± 0.3 mg ferulic acid equivalent/g) was higher than that in the white part (28.0 ± 0.7 mg ferulic acid equivalent/g) (Fig. 3). The importance of natural phenolic compounds from plants materials is raising interest among scientists, food manufacturers, and consumers due to functional food with specific health effects. For instance they retard oxidative degradation of lipids and thereby improve the quality and nutritional value of food (Kähkönen et al. 1999). The antioxidant activity of phenolic compounds is mainly due to their redox properties, which allow them to act as reducing agents, hydrogen donors, and singlet oxygen quenchers. In addition, they have a metal chelating potential (Rice-Evans et al. 1995). All these reactions mechanism allow phenolic compounds to act as preventive or chain breaking antioxidants.

FRAP measures the ferric reducing ability of the antioxidant molecule at low pH. The reducing capacity of a compound may serve as a significant indicator of its potential antioxidant activity. In this respect Kosanić et al. (2011) reported that ferric reducing properties are generally associated with the presence of reductone, which the action is based on the breaking of free radical chain by donating a hydrogen bond. As shown in Fig. 3, the mucilages from YP and WP contained a considerable amount of antioxidant effect, with respective Ferric reducing antioxidant power of 346.7 ± 9.4 and 366.7 ± 9.4 mM ferric reducing antioxidant power (FRAP).

Reducing power of both mucilages increased with increased concentrations (Fig. 4a). At 5 mg/mL, YP showed reducing power of 1.1 ± 0.4 ; the value of WP sample was $1.1 \pm$

Fig. 3 Total phenolic content (expressed in mg ferulic acid per g of mucilage) and FRAP (expressed in mM equivalent FeII per g of mucilage) of YP (yellow part) and WP (white part) of giant swamp taro tuber ($n=3$). Error bars represent standard deviation; bars means $\pm$ SD for each parameter with different superscripts differ significantly at $P<0.05$

Fig. 4 Reducing power and Chelating ability of WP and YP mucilages from Giant swamp taro at different concentration ($n=3$). Each value is expressed as mean $\pm$ standard deviation. YP-Yellow section of giant taro; WP-white section of giant taro; Vit C and Vit E are vitamins C and E standards respectively

0.2. However, the range value of Vitamin C was lower than reducing powers of YP sample. α -tocopherol showed a reducing power of 1.3 at 5 mg/mL. YP reducing powers of 0.8–1.1 were almost the same to those of WP (0.8–1.1). EC_{50} , the effective concentration of mucilage at which the reducing power (absorbance) is 0.5, was found to be lower than 0.025 mg/mL, either for the mucilages or the positive controls ascorbic acid and α tocopherol. The comparative activity of mucilage to ascorbic acid and α tocopherol suggests the potential antioxidant activity of the mucilages.

WP and YP chelated ferrous ions by 20–76 % and 16–71 % respectively (Fig. 4b). However, EDTA showed an excellent chelating ability of 95 % at 1 mg/mL whereas chelating ability of citric acid was less, 83 % at 5 mg/mL. Already, at 2.5 mg/mL WP and YP chelated 76 % and 71 % of ferrous ions, showing they are good chelating agents for ferrous ions. Since ferrous ions are the most effective pro-oxidants in the food

system (Yamaguchi et al. 1988), the high ferrous ions chelating abilities of the two samples would be somewhat beneficial. The effective concentration (EC_{50}) at which ferrous ions are chelated by 50 % was significantly higher for WP ($1.42 \pm 0.04 \text{ mg.mL}^{-1}$) compared to YP mucilage ($1.28 \pm 0.05 \text{ mg.mL}^{-1}$) with values. These values were systematically higher compared to positive control EDTA ($0.55 \pm 0.01 \text{ mg.mL}^{-1}$), but lower compared to citric acid ($1.58 \pm 0.04 \text{ mg.mL}^{-1}$). Express in equivalent EDTA, the chelating ability of the mucilages were 0.39–0.43 EDTA equivalent, values which are comparable to 0.48–0.68 EDTA equivalent reported for *Vigna aconitifolia* seed (Siddhuraju 2006).

In the results mentioned above, the YP mucilage performed better than WP in total phenolic content and reducing power tests while in FRAP and chelated ferrous ions effect, the opposite was found. Generally, extracts that contain a high amount of phenolic compounds also exhibit high antioxidant activity. The mucilages have an antioxidant activity which could be granted to phenolic compounds. Huang et al. (2006) demonstrated that, in mucilage of sweet potato roots extracted with isopropanol, it might exist isoflavonoids, anthocyanins, phenolic compounds and some proteins that enhance crude mucilage significant antioxidant activities. Some authors showed a linear positive relationship between the antioxidant activity and the total phenolic content; but in our case, they were not correlated. In this extent, Kähkönen et al. (1999) showed that extract with high total phenolic content are not the one with the better antioxidant activity. In our mucilages, antioxidant effect seems to be involved by compound other than phenolic compounds.

Conclusion

This study has shown that giant swamp taro contains appreciable amount of mucilage, much more than the ash, lipids and dietary fibers content. The mucilage consisted of a sugars moiety representing about 70 %, and a protein moiety representing 30 %, irrespective of the section part of the tuber. In addition glucose is far the most important sugar in the mucilage, followed by galactose (less than half of the glucose level) and mannose. The Arabinogalactan-protein (AGP) in the tuber represents 0.5 % (yellow section) to 0.8 % (white section) with galactose and arabinose being respectively the most representative sugars with a ara/gal ratio varying from 0.80 (yellow section) to 0.97 (white section). Moreover, the mucilage acts as potent and suitable antioxidant with an effective chelating concentration of 0.39–0.43 equivalent EDTA, higher than that of citric acid.

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