Isolation and properties of starch from some local cultivars of cassava and taro in Fiji

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ABSTRACT
*Sedimentation method was used for isolating starch from local cassava (*Manihot esculenta*) and two types of taro (*Colocasia esculentum *var.* esculenta*), one having pink corms and the other having white corms. The extracted starches were characterized for pH, moisture content, ash content, paste clarity and gelatinization temperatures. Cassava starch was found to have a higher pH and moisture content compared to taro starches while taro starches had a higher ash content. Optical microscopy revealed that taro starches have smaller granule size than cassava starch. Cassava starch showed higher paste clarity than taro starches. The paste clarity of all the starches was found to be pH dependent.*
***Keywords**: Starch, Moisture content, Ash content, Gelatinization temperature, Paste clarity.*

1 INTRODUCTION

Starch is one of the most abundant substances in nature and is a renewable resource. It is a semi - crystalline carbohydrate synthesized as rough spherical granules in many plant tissues including roots, tubers, rhizomes and seeds. The major botanical sources of starch are wheat, maize, potato, cassava and taro (Tester *et al*. 2004). Starch is a basis of our food and industrial economy. Although it is mainly used as food, it can also be readily converted chemically and biologically into many useful and diverse products such as paper, textiles, adhesives, beverages, confectionery, pharmaceuticals, and plastics.

Cassava and taro are rich sources of starch and are important food and cash crops for most of the South Pacific Islanders (Plunknett, 1970). Cassava is cultivated in large areas of Asia, Africa, North America and South Pacific. In contrast to other food crops, cassava grows well under marginal conditions.

Cassava starch is produced primarily by the wet milling of fresh cassava roots but in some countries such as Thailand it is produced from dry cassava chips as well. Starch is the main constituent of cassava. About 25% starch may be obtained from mature, good quality tubers and about 60% starch may be obtained from dry cassava chips. Cassava starch has many remarkable characteristics, including high paste viscosity (Sajeev *et al.* 2003), high paste clarity (Alves *et al*. 2002), and high paste stability (Moorthy, 2002), which are advantageous to many industries.

Taro starch is used directly in different ways or as a raw material for further processing. It is considered to be easily digestible; hence it is widely used in baby foods and the diets of people allergic to cereals and children sensitive to milk (Benesi *et al*. 2004). Taro starch, in view of its small granule size, has also been used for industrial applications (Wang, 1983). The small size of granules makes it ideal in cosmetic formulations like face powder and in dusting preparations that use aerosol dispensing systems (Griffin and Wang, 1983).

As the environmental impact of plastic wastes is becoming a serious concern, many researchers feel that starch may offer a substitute for petroleum-based plastics (Schwach and Averous, 2004). The conversion of starch into biodegradable plastics is being researched on by many countries. This is being achieved either by chemically modifying the starches (Demirgoz *et al.* 2000) or by blending them with other polymers (Parra *et al.* 2004). In both these techniques, it is important to know the chemical as well as physical characteristics of the starch.

While various attempts have been made to characterize starches derived from cassava (Sriroth *et al.* 1999; Defloor *et al*. 1998) and taro (Moorthy *et al.* 1993) grown elsewhere, no such studies have been reported on cassava and taro starch of Fiji Islands. During the present study, we extracted starch from cassava and two types of taro. The pH, ash content, moisture content, light transmittance and gelatinization temperature of the extracted starches were determined. The characterized starches will be used in our future studies for developing biodegradable materials.

2 MATERIALS AND METHODS

Freshly harvested cassava (*Manihot esculenta*, locally known as Vulatolu) (CV) and taro roots (*Colocasia esculentum var. esculenta*, locally known as Tausala), grown in the same climatic and agronomic conditions, were purchased from the local market. Two different kinds of taro with different corm colours; pink (PT) and white (WT) were used. Analytical grade NaOH and HCl were obtained from Sigma.

2.1 DRY MATTER CONTENT

The dry matter contents of the roots were determined using the method described by Benesi *et al.* (2004). Approximately 100g of freshly peeled and shredded undamaged roots were placed in weighed petri dishes (w_1). The samples were dried at 65°C for 72 h, cooled in a desiccator and weighed immediately. The drying and weighing steps were repeated until consecutive constant weights (w_2) were achieved. These steps were carried out within 24 h after harvest to avoid postharvest changes through physiological deterioration or moisture loss of the roots. Dry matter (DM) contents of the roots were calculated using the Equation (1).

10.1071/SP08007

$$\text{DM (\%)} = \frac{w_2}{w_1} \times 100 \qquad (1)$$

2.2 STARCH EXTRACTION

Starch was extracted using the method described by Benesi *et al.* (2004). Fresh roots were washed, peeled, chopped into approximately 1 cm cubes and then pulverized in a high-speed blender for 5 min. The pulp was suspended in ten times its volume of water, stirred for 5 min and filtered using double fold cheesecloth. The filterate was allowed to stand for 2 h for the starch to settle and the top liquid was decanted and discarded. Water was added to the sediment and the mixture was stirred for 5 min. Filtration was carried out using double fold cheesecloth and the starch from the filtrate was allowed to settle. After decanting the top liquid, the starch was dried at 60°C for 12 h and stored for further treatment. The extracted starch content (SC) was determined by Equation (2).

$$\text{SC (\%)} = \frac{w_3}{w_4} \times 100 \qquad (2)$$

Where w_3 is the weight of starch extracted from a known weight (w_4) of the root matter.

2.3 MOISTURE CONTENT OF STARCH

Petri dishes with lids were washed and dried in an oven at 105°C overnight, cooled to ambient temperature in a desiccator. Approximately 5g of starch samples were weighed accurately in petri dishes (w_5). The samples were dried for 24 h at 105°C, cooled in a desiccator and weighed (w_6). Moisture content (MC) was calculated using Equation (3). Average of three trials was taken.

$$\text{MC (\%)} = 100 - \frac{w_6}{w_5} \times 100 \qquad (3)$$

2.4 ASH CONTENT

Ashing crucibles were cleaned, heated for 30 min at 900°C, cooled in a desiccator to ambient temperature. Approximately 5 g of starch sample was weighed accurately in the crucible (w_7). The sample was incinerated on a Bunsen burner until completely carbonized. Then the incineration was completed in a furnace at 900°C for 5 h. The incinerated samples were cooled in a desiccator to ambient temperature and weighed (w_8). Ash content (AC) was calculated using Equation (4). Average of three trials was taken.

$$\text{AC (\%)} = \frac{w_8}{w_7} \times 100 \qquad (4)$$

2.5 pH OF STARCH

The method reported by Benesi *et al*. (2004) was used for pH determination. Approximately 5 g of starch sample was added to 20 ml of distilled water in a beaker. The contents were stirred for 5 min. Starch was allowed to settle and the pH of the water phase was measured using a calibrated pH meter.

2.6 MICROSCOPY

Dry starch samples were viewed under a compound Olympus BX50 microscope at a magnification of 400X. The micrographs were used to compare the morphology of the starch granules. Sizes of the starch granules were determined using the eyepiece and stage micrometer (Graticules). An average of ten reading was taken as size of the granule.

2.7 DIFFERENTIAL SCANNING CALORIMETRY

Gelatinization properties of the starches were studied using a Perkin Elmer Pyris 6 Differential Scanning Calorimeter (DSC) equipped with an intercooler. Starch samples were weighed and slurried with weighed amounts of water to yield a 0.5 mass fraction. The slurries were left at room temperature for 1 h to equilibrate. The slurries were dispensed into empty aluminium pans and sealed. The samples were heated from 20 to 110°C at a heating rate of 10°C/min. An empty aluminium pan was used as a reference. The instrument's software was used to calculate the gelanitization temperatures.

2.8 PASTE CLARITY

Starch samples were suspended in distilled water to yield 1% (w/v) slurries in screwcap tubes. pH of the slurries were adjusted to 2, 4, 6, 8, 10 and 12 by the addition of 0.1M HCl or NaOH as required. The tubes were then heated in a boiling water bath (with occasional shaking) for 30 min. After cooling to ambient temperature, the percentage transmittance (%T) at 650 nm was determined against water as a blank using a Cecil 1021 Spectrophotometer.

3 RESULTS AND DISCUSSION

The average root dry matter contents of CV, PT and WT were 41.2, 39.8 and 33.5% respectively. While the cassava sample had higher root dry matter content than the taro samples, a significant difference was observed between the two taro samples. Benesi *et al*. (2004) have reported the root dry matter of cassava in Malawi to be in the range 38.24 – 46.48 % and found that dry matter content of roots was not as much influenced by environment as by genetic differences.

The average extracted starch contents were 32.1% for CV, 28.3% for PT and 27.0% for WT. While CV had higher starch content than the taro samples, there was not much difference in the starch contents of the two taro samples. The starch content of Thailand cassava was found to be in the range 21.9–24.4% by Sriroth *et al.* (1999). In the Malawi cassava the range was found to be 26.22–43.43% by Benesi *et al*. (2004). They attributed the high degree of variability in starch content of cassava samples to differences in rainfall distribution. They feel that extended dry weather might force the plants to use their food reserves by breaking down some of the starch into sugars for survival.

The optical micrographs of the starches are given in Figures 1- 3.

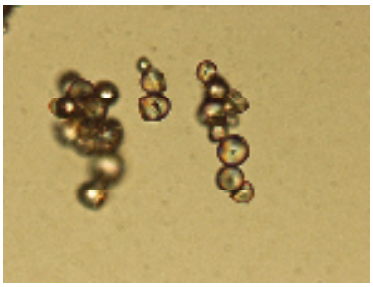

Figure 1 Micrograph of CV starch, 400X

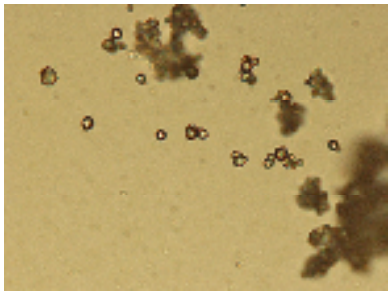

Figure 2 Micrograph of WT starch, 400X

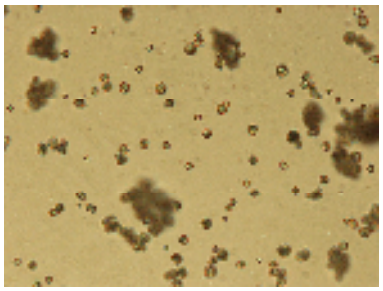

Figure 3 Micrograph of PT starch, 400X

Both the cassava and taro starch granules were generally spherical in shape. CV starch granules were 1.0 – 1.25 μm and the taro starch granules were 0.25 – 0.5 μm in size.

The pH, ash contents and moisture contents of starch obtained form the cassava and taro samples are given in Table 1.

Taro starches had a slightly lower pH compared to CV starch. Ash content of CV starch was found to be lower while moisture content higher than taro starches as can be seen in Table 1. Out of the two taro starches, PT starch had the higher ash content and moisture content. A comparison of these properties has been made with the values reported in literature in Table 1.

When starch is heated in the presence of excess of water, the granules undergo an order – disorder phase transition called gelatinization over a temperature range characteristic of the starch source. The above phase change is associated with diffusion of water into the granules, water uptake by the amorphous background region, hydration and radial swelling of the granules, loss of optical birefringence, uptake of heat, loss of crystalline order, uncoiling and dissociation of double helices (in crystalline regions) and amylase leaching (Hoover, 2001).

The gelatinization temperatures were found to be 66.1°C, 69.5°C and 69.9°C for CV starch, PT starch and WT starch respectively. The taro starches had a slightly higher gelatinization temperature than the CV starch indicating a greater degree of order in the crystalline structure. Sriroth *et al*. (1999) found the gelatinization temperature of cassava starch (from Thailand) to be in the range 69 - 71°C.

The paste clarity of various starches at different pH values is presented in Figure 4.

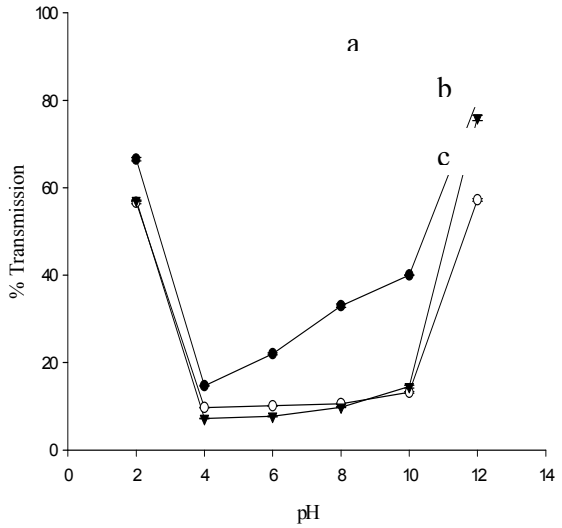

Figure 4 Paste clarity of a) CV starch b) WT starch and c) PT starch

CV starch had a higher paste clarity compared to the taro starches at all pH values. The paste clarity of all starches was found to be high at pH 2 which decreased sharply up to pH 4. In very acidic solutions, negatively charged phosphate groups are neutralized, and the ionization of hydroxyl groups is suppressed. Therefore, lysophospholipid complexed amylose chains contain only electropositive nitrogens. Coulombic repulsion between these positive nitrogens on adjacent amylose chains decrease the compactness of the amorphous region, thus increasing the transmission (Hoover and Vasanthan, 1992).

The paste clarity decreased from pH 2 to pH 4. However, the light transmission increased gradually from pH 4 to pH 9 and a significant increase was observed after pH 10. This can be explained in terms of granular swelling, resulting from repulsion between adjacent negative charges centered on the hydroxyl groups of complexed lysophospholipid molecules. CV starch showed better paste clarity than taro starches. This may be due to higher amylose content of taro starches. According to Wang *et al*. (1993), starches containing high amylose show relatively lower light transmission.

Table 1 Properties of CV, PT and WT starches and comparison with Malawi and Thailand cassava.

Properties	CV	PT	WT	Malawi cassava (Benesi *et al*. 2004)	Thailand cassava (Sriroth *et al*. 1999)
Storage root dry matter content (%)	41.2 ± 1.5	39.8 ± 1.5	33.5 ±1.5	38.24 – 46.48	-
Starch content (%)	32.1± 1.0	28.3 ± 1.0	27.0 ±1.0	26.22 – 43.43	21.9 –24.4
pH	5.26 ± 0.05	5.12 ± 0.05	5.04 ± 0.05	4.7 – 5.8	-
Ash content in starch (%)	0.08 ± 0.01	0.20 ± 0.02	0.15 ± 0.02	0.10 – 0.20	0.08 – 0.15
Moisture content in starch (%)	10.00 ± 0.04	9.62 ± 0.04	9.23 ± 0.04	12.05 – 13.65	-
Gelatinization temperature (°C)	66.1± 1.0	69.5 ± 1.0	69.9 ± 1.0	-	69 - 71

4 CONCLUSION

Starch was extracted from local cassava (*Manihot esculenta*) and two cultivars of taro (*Colocasia esculentum var. esculenta*. The pH, moisture content, ash content, paste clarity and gelatinization temperatures of the extracted starches were derermined. Cassava starch was found to have a higher pH and moisture content compared to taro starches while taro starches had a higher ash content. Cassava starch showed higher paste clarity than taro starches. The paste clarity of all the starches was found to be pH dependent. Research is in progress to utilize these starches for the preparation of biodegradable materials.

5 ACKNOWLEDGEMENT

The authors wish to thank the Fiji Institute of Technology Research Committee for the financial support towards this project.

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