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Physicochemical and Functional Properties of Some Cultivars of Irish Potato and Cassava Starches

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Abstract: In this study, starches were extracted from two cultivars of local Irish potatos (*Solanum tuberosum*) and tree cultivars of local Cassava (*Manihot esculanta*). These starches and a commercial Irish Potato Starch (IPS), where characterized with respect to their physico-chemical and functional properties. Significant differences ($p<0.05$) were observed among starches as far as their proximate composition were concerned. The commercial starch showed the highest phosphorus content. The amylose content was observed to be significantly lower ($p<0.05$) in the cassava starches than in the local Irish potato starches. The highest ($p<0.05$) gelatinisation parameters were those of 2425 starch cultivar. Potato starch granules exhibited the largest granule size at 10, 50 and 90% diameter compared to those of cassava starches. Potato starches had wider particle size distribution compared to cassava starches. There were apparent differences, between species (Cassava and potatoes) with respect to granule morphology and size. No significant colour difference ($p>0.05$) was observed between the Sipiera starch cultivars and the Irish potatoes commercial starch.

Key words: Cassava starches, potatoes starches, physico-chemical properties, functional properties

INTRODUCTION

A number of starchy food plants from the tropical zone produce tubers, roots and fruits are of primordial importance for the local populations since they constitute the basic foods for their nutrition. Many different forms and scales of starchy food processing and derived products are usually encountered. These included micro-scale household level processing where the products are often destined for home consumption (Agbor Egbe *et al*., 1995). Starch, the principal constituents of these plants is a polysaccharide often used in certain food products mainly for their thickening and gelling properties. The presence of small amounts of this material can bind large quantities of water, bringing about a desirable change in the texture of a food product. Starch from cereals, tubers and roots are widely used in the food industry as stabilizers or texture modifiers. Starches are attractive food ingredients for texture modification because they are both natural and safe (Sangeetha Mishra and Rai, 2006). Because of the enormous potential benefits that can be derived from these tropical plants, they are of great interest not only in human and animal nutrition but also for industrial application (FAO, 2006). However, the use of starch produced from these crops remain essentially limited to the preparation of traditional foods. This aspect is not surprising due to the fact that the starches of tropical plants have been less studied compared to the conventional starches. The rational use of starch requires a prior knowledge of its properties. This is in line with a study of the department of agriculture of the FAO (1986) which reported that, if the agronomic and phenotypic properties of starchy and other plant sources of tropical raw materials, have been the object of detailed research, starches have not received adequate attention on the research of its added value which can render them competitive on an international scale. For some years now, research has been carried out on some of these plants in West and Central Africa. In Cameroon, works have been centred on starchy crops not on starch. These included among others, the study of the physico-chemical properties of some improved varieties of Adamawa cassava (Mohamadou *et al*., 1999) the detoxification of cassava and the study of physico-chemical characteristic

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of two local starchy crops, cocoyam and cassava (Klan, 2002). In order to generate data that can promote new uses, physico-chemical, morphological and functional properties of starched extracted from some local crops were studied.

MATERIALS AND METHODS

Cassava starches were obtained from three cultivars of cassava (*Manihot esculanta* Crutz), 2425, 4115 and *Seedling* obtained from experimental fields of the IRAD (Agricultural Institute for Research and development of Ngaoundere, Cameroon). Potatoes starches were extracted from two cultivars of Irish potatoes (*Solanum tuberosum*), *Telefou* and *Sipiéra.* These two tubers were used at their commercial maturity, 6 months for potatoes and 12 months for cassava. A commercial Irish potato starch (Leader price™) was purchased from a local supermarket.

Native starch extraction: Starch extraction was carried out using the method described by Hermann and Cecil (1992) with a slight modification. A total of 10 kg tubers and roots were used in this study. All impurities and damaged tubers and roots were discarded. The remaining intact tubers and roots were first peeled, washed, cut into small sizes and then milled using a cutter (Manurhin, 03300 Cusset, n°426, France). The resulting product mixed with distilled water and Fibre was separated by sieving through a 170-mesh screen (90 mm). After washing several times, starch was oven dried at 45°C.

Proximate analysis: Fat, ash and moisture content were determined according to the AOAC (1990) official procedure (methods 920.39, 923.03 and 925.09, respectively). Starch, amylopectine and damaged starch content of the native starch, were analysed using the method described by AFNOR (1982), Chrastyl (1986) and AACC 76-30A (1992), respectively. Crude protein was analysed by micro Kjeldahl method (AFNOR, 1984).

Amylose content: Amylose was determined according to the iodine binding method of Chrastyl (1986). The amylopectin content was calculated by subtracting the amylose content from the total starch content of the native starch.

pH determination: The pH of the starch samples was determined by a pH-meter (Eutech Cyberscan 1000, Singapore), following the procedure described by Larsonneur (1993).

Phosphorus analysis: Phosphorus content was determined using the standard AOAC methods (AOAC, 1990).

Colour analysis: A Colorimeter Lovibond RT Colour measurement Kit V2.28 was used for colour determination. Prior to colour measurement, the instrument was calibrated. Colour measurements were made at least in 5 fold on samples placed in a clear Petri dish. The colour was measured in a CIE 1976 L*, a*, b* colour space. L* is the measure of the brightness from black (0) to white (100). Parameter a* describes red-green colour with positive a*-values indicating redness and negative a*-values indicating greenness. Parameter b* describes yellow-blue colour, with positive b*-values indicating yellowness and negative b*-values indicating blueness (Good, 2002).

Light transmittance (Paste clarity): Paste clarity was studied using the method of Bhandari and Singhal (2002) with modifications. Fifty milligrams (on dry weight basis) of native starches were suspended in 5 mL of distilled water, using 10 mL test tubes. The test tubes were then heated in a boiling water bath (with occasional shaking) for 30 min. After cooling to ambient temperature, the percentage transmittance (%) was determined at 650 nm against a water blank using a spectrophotometer (Hewlett-Packard spectrophotometer).

Particle size distribution: The particle sizes of the isolated starches were measured using a Malvern Master Sizer (Malvern Instrument, Ltd, UK) laser diffraction analyzer in, at least, triplicate replicates at room temperature (Tecante and Doublier, 1999). The isolated starches were dispersed in ethanol. The instrument output had a volume distribution as the fundamental measurement, with medians of D[V, 0.1], D[V, 0.5], D[V,0.9] diameters and Span. The output data D[V, 0.1], D[V, 0.5], D[V, 0.9] mean, the diameter of the granules for which 10, 50 and 90% of the starch volume was made up of granules that were smaller. These derived output data are numerical transformations of diffracted light angles according to Mie's theory (Malvern Instruments Ltd., UK, 1990).

Scanning electron microscopy: Scanning electron microscopy was performed using the modified method described by Gunarata and Hoover (2002). Dried starch samples were prepared for observation by scanning electron microscopy by sprinkling the starch on double-sided adhesive tape attached to a circular specimen stub and coating with gold using a Baltzers SCD 004 sputter coater. The samples were viewed and photographed using a Hitachi S2500 scanning electron microscope.

Thermal properties: Thermal properties of potato and cassava starches were analyzed using a differential scanning calorimeter Perkin-Elmer, model Pyris 1

(Perkin-Elmer Corp., Norwalk, USA) by the modified method described earlier by Paton (1987). The gelatinization temperature parameters: onset Temperature (To); peak Temperature (Tp); enthalpy of gelatinization (ΔH) and completion Temperature range (Tc) were calculated.

Swelling power: Swelling power and solubility determinations were carried out in the temperature range of 60-90°C, using the modified method of Leach *et al.*, (1959). 0.2 g of starch samples were accurately weighed and quantitatively transferred into a clear dried test tube and weighed (w1). Twenty five milliliter of distilled water was added to the test tube and the mixture was mixed thoroughly with a Variwhirl mixer for 30 sec. The resultant slurries were heated at temperatures varied between 60 and 90°C for 30 min in a water bath (using temperature regulated water bath). The mixture was cooled to room temperature and centrifuged (4500/mn, 30 min). The residue obtained from the above experiment (after centrifugation) with the water it retained and the test tube was Weighed (W2).

Swelling of starch = W2-W1/Weight of starch Aliquots

Oil and water absorption capacity: The method of Beuchat (1977) was used to determine oil and water absorption capacity of the starch. Ten milliliter of distilled water or oil (sun flower oil) was added to 1 g of sample. The mixture was mixed thoroughly with a Variwhirl mixer for 30 sec and allowed to stand for 30 min. Then the volume of the supernatant was recorded. The mass of oil or water absorbed was expressed as g/g starch on a dry weight basis.

Statistical analyses: All determinations were replicated three times and mean values and standard deviation reported. Analysis of Variance (ANOVA) were performed and the mean separation were done by multiple comparison test of Duncan, using Statgraphics plus version 5.0.

RESULTS AND DISCUSSION

The proximate composition of the starches is presented in Table 1. The moisture content plays a significant role in the flow and other mechanical properties of starches (Shieldneck and Smith, 1971). The moisture contents of the different starch cultivars were significantly different from each other and varied from 8.58±0.12 to 18.33±0.15% for the cultivar 2425 and commercial starch (IPS), respectively. The moisture content of these starches was in moisture ranges generally accepted for dry products in order to obtain a desirable shelf life and other conventional starches (Swinkels, 1985; Brown, 1995; Thomas and Atwell, 1999; INN, 1999; Sriroth *et al.*, 2000). The protein contents of the starches cultivars varied from 0.15±0.04 to 0.24±0.05 for IPS and 2425, respectively. These results were comparable to those reported for *Xanthosoma sagittifolium*, *Colocasia esculenta* and *Manihot esculenta* (Elevina *et al.*, 2005). The lipid content was in the range reported for most tubers and root starches (0.1-1.14%) (Hoover, 2001). Lipid, protein and ash contents of different starch cultivars showed statistically significant differences ($p<0.05$) among cultivars. Phosphorous content is an important parameter used to define the functional properties of starches. As shown in Table 1, significant difference ($p<0.05$) was observed in phosphorous content of the different starches as far as their botanical origin and condition of extraction were concerned. The phosphorus contents of the starches studied were higher than those found by Chen *et al.* (2003) in potato starch. Theses variations in phosphorus contents could be attributed to the nature of the soil.

The purities of isolated starches varied from 73.89±3.85 to 84.88±2.28 for *Seedling* and *Tselefou*, respectively (Table 2). The low purities of the native starches may be principally due to their fibre content, slowing down the sedimentation and co-settling with the starch to give a light loose deposit. The purity of *Tselefou* starch was significantly higher ($p>0.05$) than that of the other starch cultivars. The amylose content in starches has an important effect on their functional properties. Therefore, it is quite important that the amylose content be quantified for food processing and quality (Elevina *et al.*, 2005). The amylose contents ranged from 14.09±1.36 to 38.40±1.20 and were closed to those reported in the literature (Elevina *et al.*, 2005). Water activity, is a critical factor affecting the shelf life of a product (Yang and Paulson, 2000). Degradation mechanisms can generally be inhibited by low water activity (a_w) content (Mathlouthi, 2001). Starch cultivars presented a_w contents between 0.546±0.009 and 0.747±0.003 for *Tselefou* and IPS, respectively. Thus being considered as intermediate moisture products, are susceptible to microorganism growth and chemical reactions (Belitz and Grosch, 1999). The pH and a_w of the starches were observed to vary ($p>0.05$) independently of their botanical origin. These variations could be due to the influence of the nature of the soil on the composition of the starch. Presence of impurities in the starches also influenced their pH (Sangeetha and Rai, 2006).

Table 1: Proximate composition of the starches and phosphorus content

Starch	Moisture (%)	Protein (%)	Lipid (%)	Ash (%)	Phosphorus (mg)
IPS	18.33±0.15^{e}	0.15±0.04^{a}	0.25±0.02^{bc}	0.33±0.02^{d}	0.43±0.03^{d}
Sipiera	10.85±0.04^{d}	0.17±0.02^{a}	0.91±0.09^{d}	0.17±0.03^{bC}	0.18±0.00^{a}
Tselefou	10.29±0.12^{c}	0.24±0.05^{ab}	0.02±0.00^{a}	0.30±0.02^{d}	0.38±0.01^{c}
2425	8.58±0.12^{a}	0.34±0.05^{b}	0.16±0.04^{b}	0.11±0.01^{ab}	0.42±0.00^{d}
4115	10.18±0.03^{c}	0.19±0.02^{a}	0.28±0.06^{c}	0.11±0.03^{a}	0.29±0.00^{b}
Seedling	8.79±0.07^{b}	0.15±0.07^{a}	0.16±0.02^{b}	0.23±0.03^{c}	0.48±0.01^{e}

All values are means of triplicate determinations±standard deviation. Means within columns with different letters are significantly different (p<0:05). IPS: Commercial Irish potatoes starch; *Sipiera:* Local Irish potatoes cultivar starch; *Tselefou:* Local Irish potatoes cultivar starch; 2425: Local cassava cultivar starch; 4115: Local cassava cultivar starch; *Seedling*: Local cassava cultivar starch

Table 2: Starch, amylose, water activities and pH of the native starches

Starch	Starch (%)	Amylose (%)	a_w	pH
IPS	76.83±2.37^{a}	23.49±3.02^{b}	0.747±0.003^{e}	6.96±0.04^{c}
Sipiera	77.19±2.98^{a}	32.14±3.43^{c}	0.610±0.006^{c}	5.49±0.18^{a}
Tselefou	84.88±2.28^{b}	38.40±1.20^{d}	0.546±0.009^{a}	7.11±0.21^{c}
2425	72.91±1.99^{a}	24.31±2.89^{b}	0.744±0.002^{e}	5.55±0.01^{a}
4115	77.11±3.37^{a}	16.33±2.50^{a}	0.637±0.010^{d}	6.56±0.16^{b}
Seedling	73.89±3.85^{a}	14.09±1.36^{a}	0.593±0.018^{b}	5.43±0.05^{a}

All values are means of triplicate determinations±standard deviation. Means within columns with different letters are significantly different (p<0:05)

Table 3: Gelatinisation parameters of different starches as determined by Differential Scanning Calorimetry

Starch	T_o	T_p	T_c	ΔH
IPS	57.69±0.31^{a}	61.31±2.07^{ab}	64.48±2.95^{ab}	10.26±0.13^{a}
Sipiera	55.22±0.97^{a}	62.54±4.72^{ab}	65.01±2.89^{ab}	11.49±0.01^{a}
Tselefou	60.40±1.95^{a}	66.82±0.00^{b}	68.02±0.00^{b}	14.24±0.07^{b}
2425	82.70±7.29^{b}	87.35±4.01^{c}	90.86±4.60^{c}	14.34±0.00^{b}
4115	56.40±1.70^{a}	61.06±0.30^{ab}	64.78±0.21^{ab}	16.75±0.98^{c}
Seedling	55.92±0.32^{a}	58.99±0.00^{a}	61.20±0.06^{a}	13.99±090^{b}

All values are means of triplicate determinations±standard deviation; Means within columns with different letters are significantly different (p<0:05)

Differential Scanning Calorimetry (DSC) was used to study the thermal properties of the starches. The gelatinization temperature obtained from thermograms was defined as the onset Temperature (T_0), peak Temperature (T_p) and completion Temperature (T_c) (Table 3). From the results of the DSC, it was observed that for some of the starches parameters analyzed To, Tp and Tc, recorded for the cultivar 2425 were higher (p<0.05) than those of the cultivars IPS, *Sipiera*, *Tselefou*, 4115 and *Seedling*. Such differences suggested that genetic variation and environmental conditions may have an impact on structure and thermal properties of the starches. High gelatinization temperature is an indication of more perfect crystals (Sasaki and Matsuki, 1998; Van Soest *et al*., 1995) or a higher co-operative unit. The starch cultivars showed significant difference (p<0.05) in ΔH and ranged from 10.26±0.13 to 16.75±0.98. Variability in thermal and functional attributes are a function of amylose content, granule size distribution and, possibly, differences in the structural makeup of amylose and amylopectin (Buléon *et al*., 1998).

The particle size measurement of the different starches was carried out using laser diffraction analyzer. The laser diffraction results were expressed at 10, 50 and 90% diameter for starch size. The granular size distributions of the five isolated starches and the commercial starch were summarized in Table 4. Potato starch granules exhibited the largest granule size at 10, 50 and 90% diameter compared to those of cassava starches. Cassava starches cultivars had wider particle size distribution compared to Irish potatoes starches. Significant difference (p<0.05) was observed between the means diameters of the granule of the different starches cultivars. These results confirmed the observations of the scanning micrographs where it was found that cassava starches granules were smallest in sizes than those of Irish potato.

Results from Fig. 1 showed that the cultivar IPS held slightly less (p<0.05) water than other starch cultivars. From these results it was also observed that there was not significant difference in Water Retention Capacity (WRC) within the cultivars. Cassava starch cultivars presented the highest (p<0.05) Oil Retention Capacities (ORC). The variation in WRC and ORC of these starches cultivars could be due to the difference in the degree of engagement of hydroxyl groups to form hydrogen and covalent bonds between starch chains (Hoover and Sosulski, 1986). Further differences in the degree of availability of water binding sites among the starches could have played an important role in the variation of water binding capacity (Wotton and Bamunuarachchi, 1978).

When starch is heated in enough water, hydrogen bonds stabilizing the structure of the double helices in crystallites are broken and hydrogen bonds are replaced with water (Tester and Karkalas, 1996), the starch granule swells and its volume increases. The swelling volume of potatoes and cassava starches increased from 60-90°C (Table 5). At temperatures 60-65 and 80-85°C for IPS; 80-85°C for *Sipiera*; 70-75°C for 4115 and 75-80°C for 2425, the swelling was about 10 times as high as that at the precedent temperature. Similar relationships between swelling behaviour and gelatinization temperature were found for chickpea and yellow pea starches (Huang *et al*., 2006). A two-stage swelling pattern has been reported by Agunbiade and Longe (1999) for cowpea starch and Gujska *et al.* (1994) for field pea starch.

Table 4: Particle size distribution parameters

Starch	D(v,0.10)[a] µm	D(v,0.50)[b] µm	D(v,0.90)[c] µm	D[4.3][d] µm	D[3.2][e] µm	Span[f]
IPS	22.11±0.04[f]	43.58±0.08[f]	68.47±0.32[e]	44.16±0.13[f]	21.29±0.04[e]	1.06±0.01[c]
Sipiera	17.92±0.02[e]	32.26±0.02[e]	50.68±0.36[d]	32.99±0.15[e]	15.76±1.19[d]	1.02±0.01[a]
Tselefou	17.13±0.03[d]	32.05±0.03[d]	50.91±0.02[d]	32.75±0.02[d]	14.13±0.03[c]	1.05±0.00[b]
2425	7.10±0.02[a]	15.35±0.02[b]	27.91±0.18[b]	16.53±0.08[b]	6.21±0.03[a]	1.36±0.01[f]
4115	8.12±0.08[c]	16.54±0.02[c]	28.59±0.13[c]	17.41±0.09[c]	6.98±0.09[b]	1.24±0.00[e]
Seedling	7.67±0.01[b]	14.92±0.00[a]	23.98±0.01[a]	15.27±0.00[a]	6.26±0.01[a]	1.09±0.00[d]

All values are means of triplicate determinations ± standard deviation; Means within columns with different letters are significantly different (p<0.05). a D (V, 0.1): median of 10% granule diameter (µm). b D (V, 0.5): medin of 50% grnule dimeter (µm). c D (V, 0.9): medin of 90% grnule dimeter (µm). d D [4, 3]: gmule dimeter derived from the volume distribution. e D [3, 2]: rtio of volume of prticles to the totl surfce re. f Spn: wide of the distribution

Table 5: Wter Retention cpcity (g/g)

	Tempertures						
Starches	60°C	65°C	70°C	75°C	80°C	85°C	90°C
IPS	7.82±0.22	16.91±0.38[d]	20.61±0.43[d]	25.64±0.35[c]	31.12±0.46[c]	39.18±0.52[c]	44.19±0.68[c]
Sipier	13.08±0.45[c]	15.49±0.95[bc]	18.13±0.05[b]	23.85±0.19[b]	28.60±0.21[b]	39.76±0.78[c]	45.72±0.14[d]
Tselefou	8.21±0.64	14.39±0.08[b]	19.37±0.09[c]	27.38±0.76[d]	32.00±0.18[c]	40.10±0.70[c]	45.06±0.28[cd]
2425	10.56±0.52[b]	14.12±0.18	16.36±0.37	17.58±0.60	26.06±0.43	31.65±0.42	36.80±0.21
4115	10.74±0.32[b]	15.94±0.60[cd]	17.99±0.62[b]	25.52±0.89[c]	28.64±0.43[b]	33.90±0.29[b]	37.25±0.44
Seedling	12.37±0.26[c]	17.03±0.33[d]	17.82±0.13[b]	23.56±0.54[b]	27.44±0.90[b]	33.09±0.57[b]	40.77±0.42[b]

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Table 6: Colour parameters and starches clarities

	IPS	*Sipiera*	*Tséléfou*	2425	4115	*Seedling*
L*	94.18±0.80[b]	93.31±0.19[b]	91.92±0.46[a]	98.51±0.13[c]	99.53±0.86[cd]	99.92±0.59[d]
a*	-0.15±0.02[c]	-0.13±0.02[c]	0.04±0.00[d]	-0.65±0.02[b]	-0.61±0.01[b]	-0.84±0.08[a]
b*	1.10±0.34[a]	1.50±0.26[a]	2.13±0.21[b]	2.70±0.17b[c]	3.28±0.47[c]	2.73±0.02b[c]
Starch clarity (%)**	48.40±0.14[d]	29.15±1.34[b]	31.95±0.35[c]	8.30±0.28[a]	8.40±0.42[a]	32.5±0.14

[c]: All values are means of triplicate determinations±standard deviation means. Within line with different letters are significantly different (p<0:05). **: % of light transmitance

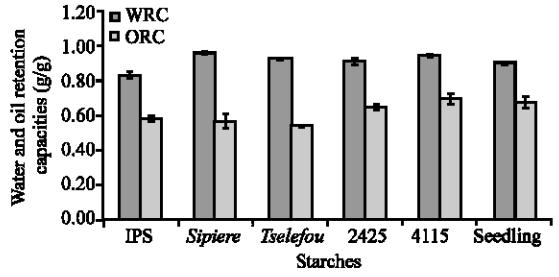

Fig. 1: Water and oil retention capacity of starches studies

Electron micrographs suggested that granules were considerably irregular in shape with wide size distribution ranging from 5-100 µm (Fig. 2). There were apparent difference (p<0.05), between species (Cassava and potato) with respect to granule morphology and size. Cassava granules were round, small and truncated while potatoes ones had irregularly shaped with elongated and spheroid forms. Similar observations have been made on cassava and potatoes starches granule by Gunaratme and Hoover (2002) and Jarunee (2006). These observations confirmed the result of the granule size distribution (Table 4). The presence of small particles of damaged starch granules in cassava starches indicated that the technique of starch preparation caused damage to the cassava starch granules. Small particles of impurities were also observed in cassava and potatoes starches. This confirmed the fact that it is difficult to obtain pure starches from roots and tuber crops, due to their high fibre and other constituents content (Kuakoon *et al*., 2002). There were no apparent differences, within the species with respect to granule morphology.

The colour parameters of the starches are shown in Table 6. The L* values for cassava starches were higher (p<0.05) than those observed with potatoes and commercial starches. Slight difference (p<0.05) was also observed within cassava and potatoes starches as far as the L* values were concerned but the differences were most obvious between potato and cassava species. The b* values, indicating the yellowness were also higher for cassava starches than for potatoes starches. These differences in colour between starches could be explained by difference in their physico-chemical composition that may be influenced by their botanical origin (Sun *et al*., 2006).

Significant difference (p<0.05) was found between and within the starches extracted from potato and cassava species with respect to the paste clarity (Table 6). These observations lead to the fact that past clarity did not directly depend on botanical origin but is influenced by water penetration and absorption on the starch granules, which ultimately lead to more swelling of starch and resulting in more transmittance of light (Craig *et al*., 1989).

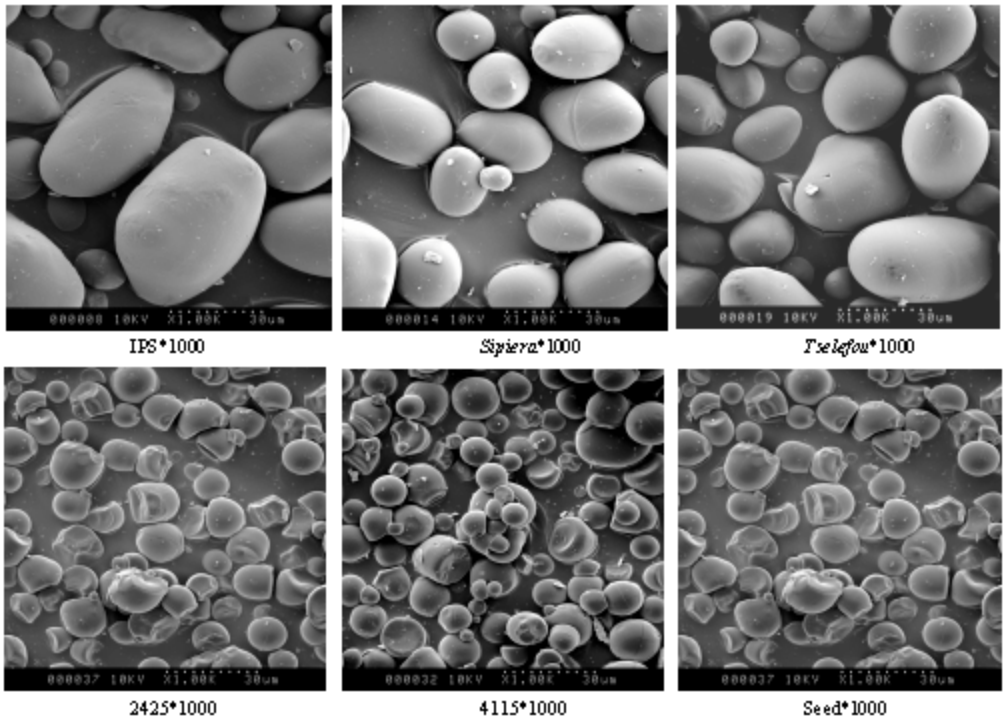

Fig. 2: Granular appearance of potatoes (*IPS, Sipiera* and *Tselefou*) and cassava (2425, 4115, *Seedling*) starches under scanning electronic microscope

CONCLUSION

The physico-chemical, functional and morphological characteristics of the starches analysed varied from one cultivar to another. A significant difference was observed in some physico-chemical and morphological properties of the different starches obtained locally, as well as between those of the starches obtained locally and the commercial sample. However, some functional characteristics showed that there was no significant differences ($p>0.05$) observed between some local starches and the commercial sample. These observations suggested that some of the local starches studied can be used to substitute the commercial starch in some food preparations.

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