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Starch, Proteins and Minerals Content of Papua New Guinea Taro (*Colocasia esculenta*) Corms

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Abstract

The aim of the presented investigation was to study chemical composition variation in starch, protein and minerals found in corms of ten taro cultivars from Papua New Guinea, South Pacific. The chemical analyses were performed on oven dried materials. The starch content ranged from 66 % to 79 %, mean content of crude protein was 3.72 g/100g. Among minerals, K was the most abundant (1.77 %), followed by P (0.43 %), Ca (1230 mg/kg) and Mg (976 mg/kg). The analyzed materials could also be considered as moderate sources of Zn (22.10 mg/kg), Fe (19.63 mg/kg), and Cu (6.87 mg/kg). The content of Mn was rather low (5.12 mg/kg).

Keywords: taro, *Colocasia esculenta*, corms, chemical composition, starch, proteins, minerals

Introduction

Taro [*Colocasia esculenta* (L.) Scott] is an old staple root crop in Papua New Guinea (PNG), and is fourth most important root crop staple after sweet potato, banana and Cassava. It is primarily grown for its edible corm. It is cultivated up to 2200 m a.s.l. As a minor food crop it can be found as high as 2740 m (Okpul et al., 2002). In the past, taro used to be much more important crop in PNG and the Pacific but its production started to decline because of pests and diseases. Taro also has a considerable social and cultural significance in PNG and is associated with rituals and traditional celebrations (Yalu et al., 2009).

Cropping systems used for taro production in PNG are highly variable. Most of the crop is produced under normal rain-fed conditions or irrigated plots in traditional agrosystem. Taro is usually planted as the first crop in a newly-cleared garden in the shifting cultivation system. It may be intercropped with sweet potato, peanuts and various vegetables, or it may be grown as a sole crop. It may also be planted in the spaces between plantation tree crops such as oil palm or coconut (Onwueme, 1999).

Taro is highly polymorphic with at least two main botanical varieties – *Colocasia esculenta* (L.) Schott var. *esculenta* or dasheen and *C. esculenta* (L.) Schott var. *antiquorum* (Schott) Hubbard & Rehder, eddoe. The main difference is in the shape of a central corm and lateral (side) cormels. In dasheen type, the central corm is large and cylindrical with small side cormels. The eddoe type is characterized by a relatively small central corm and several relatively large side cormels (Purseglove, 1972; Lebot and Aradhya, 1991). Our study involved the dasheen type.

The corms of the dasheen types can be up to 30 cm long and 15 cm in diameter, and represents the main edible part of the plant. The corm consists of three main parts: skin, cortex and core. The skin may be smooth, fibrous or covered with scales. The cortex is the region between the skin and the root initials. The cortex and the core consist mainly of parenchymatic tissues (Lebot, 2009). The color of core flesh can be white, yellow, pink, red, purple, or there are combinations of different colours, depending of the cultivar (Onwueme, 1999).

Taro corms are valuable sources of carbohydrates. They contain considerable amounts of starch, about 21-26 % on fresh weight basis (Bradbury and Holloway, 1988; Lebot et al., 2011.) Small size granules offer smooth textured starch gel and enables high level of digestion (Nip, 1997). Corms are also moderately good sources of dietary fibers. The main sugar is sucrose, followed by glucose, fructose, mannose and xylose. In some varieties, maltose and a small amount of raffinose were also detected (Tamate and Bradbury, 1985; Mbfonget al., 2006). The protein content is generally relatively low; about 4.5–7 % on dry weight basis (Maga, 1992; Iwuoha and Kalu, 1995; Tattiyakul et al., 2000; *Olayiwola et al., 2012*). Previous studies of mineral composition of taro corms showed that potassium is dominating (763 –1451 mg/100g on dry weight basis) (Sefa-Dedeh and Agyir-Sackey, 2004). Other

abundant minerals are also magnesium, phosphorus, zinc and sodium. From a nutritional standpoint it is indeed unfortunate that taro is rather low in iron and manganese (Bradbury and Holloway, 1988; Maga 1992; Huang et al., 2007; Lewu et al., 2010). Taros can also be considered as relatively good sources of some vitamins and phenolic compounds. Studies of Huang et al. (2007), and Champagne et al. (2010) showed large amounts of β-carotene, thiamin, riboflavin and ascorbic acid.

The main purpose of the present study was to analyze starch, protein and mineral contents of ten representative PNG taro cultivars. The data about the chemical composition would also help to design programs for nutrient bioavailability breeding.

Materials and Methods

Plant Material and Preparation of Samples

The varieties selected for physio-chemical analyses were planted on 10th July, 2012, at the National Agricultural Research Institute (NARI), Momase Regional Centre (MRC) at Bubia near Lae in Morobe Province, Papua New Guinea. The experimental field is located about 20 m a.s.l., with 2900 mm of average annual rainfall. The trial included 10 representative varieties from the PNG National Taro Germplasm Collection which was maintained at MRC Bubia. Each individual plot (1 × 1 m) consisted of a single row with five plants. Plots were manually weeded on monthly basis, from the trial establishment to harvest. The fertilizer (urea) was applied one month after planting (10 grams per plant). The trial was planned to be harvested about 7-8 months after planting. Due to unfavorable weather conditions (extremely dry weather in December 2012 and January 2013, and extremely wet conditions in May 2013, the harvest took place almost a year after planting - on 4th July, 2013.

A sample of 2-3 corms of each variety was selected and then carefully washed and peeled. The peeled corms were sliced into small, about 5 mm thick slices, and oven-dried for 48-72 hours at 60˚C until they were completely dry. Each sample was labeled with the variety name and sampling dates and sent to Slovenia for physico-chemical analysis.

Chemical Analysis

Starch

Starch content was determined following a Megazyme starch determination procedure (Megazyme International, Ireland Ltd.).All solutions, reagents and buffers were prepared as described in the instructions given by Megazyme. One hundred mg of sample was accurately weighed into 50 mL centrifuge tube treated with thermo stable α-amylase, capped and boiled for 6 min with vortexing at 2 min interval. The sample was then cooled to 50 ºC, 0.1 mL amyloglucosidase was added and the tube was incubated in a water bath at

50 ºC for 30 min. At the end of incubation the content of the tube was quantitatively transferred into 100 ml flask and diluted to volume with high purity Milli-Q water. An aliquot of the solution was transferred into 1.5mL eppendorf tube and centrifuged at 11000 rpm for 10 min. Then 0.1 mL of sample was transferred into individual tube and 3.0 mL of GOPOD reagent was added to each tube (including the D-glucose control and reagent blank) and incubated in for 20 minutes at 50 ºC. The absorbance was read for each sample and the D-glucose control at 510 nm against the reagent blank. The analyses were performed in triplicate.

Protein

For the determination of total nitrogen 1.0000±0.0010 g of lyophilized sample was weighed into digestion tube, then two catalyst tables and 20 mL of 98% sulfuric acid were added. The tube was placed in the block digester heated at 60 °C for 20 min and then digested at 360 °C for 3 hours. The samples were allowed to cool down. Before distillation was conducted, 20 ml of water was added then letting it cool down after followed by adding 32% NaOH solution filling the tube to 100mL to neutralize all acid. The developed ammonia was trapped into known amount of H_2SO_4 and the excess acid was titrated with 0.1M NaOH. Reagent blank and phenylalanine were included in analyses to check the correctness of the procedure. The protein content was calculated from the percentage of nitrogen multiplied by 6.25 (N(%) × 6.25).

Minerals

The dried corm samples from PNG, were milled into fine flour using a titanium mill, and then digested in a microwave oven according to the previously published protocol (Kristl, Veber, Slekovec, 2002). The prepared solutions were then diluted to 25 mL with Milli-Q water. The blank solutions were prepared in the same manner as the samples. The concentrations of Ca, Mg, and Zn were determined by flame absorption spectrometry (AAS), whereas the contents of K were determined by flame emission spectrometry (AES). For the determination of Fe, Mn, Cu, electrothermal atomic absorption spectrometry (ETAAS) was used. P was determined by a vanadate-molybdate method. The color developed was measured at 406 nm. Four commercial reference materials (NIST 1515, NIST 1547, NIST 1575 and NIST 8433) were used as quality-control samples. The accuracy was adequate for all of the studied mineral elements (data not presented). Samples were analyzed in duplicates, and the results were expressed as mg/kg of dry weight (DW).

Data Analysis

The data were tested for normal distribution using Shapiro-Wilk test. As the data were normally distributed, we applied the parametric statistics analysis: the analysis of variance (ANOVA) and the Duncan ‘post-hoc’ test in order to determine significant differences between means of different studied groups ($P \leq 0.05$). For determine the correlation among starch, proteins and mineral, Pearson's correlation matrix was applied. The statistical analysis was

done using Statistical Package for Social Science SPSS (IBM Statistics 21 Software).

Results and Discussion

The mean values of the starch, proteins and minerals of the analyzed taro cultivars are presented in Tables 1 and 2.

The starch content ranged from 66% to 79% with the mean value of 72%. The highest content was detected in 'C5 353' and 'BC 737', and the lowest in 'Lae Yellow'. Taro corms are generally characterized by a relatively low content of proteins (Bradbury and Holloway 1988). The highest values of crude proteins (CP) were obtained in 'NT 02', followed by 'NT 01'. The overall mean was 3.72 g/100g and can be compared with the values obtained for cassava (Ceballos et al., 2006) and yam (Wanasundera and Ravindran, 1994).

Table 1. *Mean Values of Starch, Proteins and Minerals Contents of Corms of Ten Taro Cultivars from Papua New Guinea.*

Cultivar	Starch (%)	Protein (g/100g)	K (%)	P (%)	Ca (mg/kg)	Mg (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)
'NT 01'	73	6.44^{b}	2.16^{b}	0.43^{a}	1291^{bc}	1080^{b}	29.4^{a}	11.3^{fg}	8.20^{b}	5.26^{d}
'NT 02'	72	6.91^{a}	1.96^{c}	0.32^{bc}	1352^{b}	1054^{b}	20.1^{c}	7.20^{h}	8.78^{a}	4.74^{ef}
'NT 03'	67	2.13^{h}	1.69^{f}	0.26^{de}	1103^{de}	797^{de}	23.1^{b}	11.6^{f}	7.32^{c}	5.00^{de}
'NT 04'	74	2.19^{gh}	1.69^{f}	0.28^{cd}	1241^{bcd}	750^{e}	16.4^{d}	12.0^{f}	7.27^{c}	2.79^{g}
'C5 353'	79	3.75^{e}	1.78^{e}	0.32^{bc}	1161^{cde}	824^{cd}	16.7^{d}	10.5^{h}	7.21^{c}	5.44^{cd}
'BC 737'	79	3.34^{g}	1.12^{h}	0.19^{f}	1322^{b}	1336^{a}	22.9^{b}	42.1^{b}	8.42^{ab}	5.98^{b}
'KPOK 35A'	68	3.34^{f}	2.28^{a}	0.30^{cd}	1265^{bc}	853^{cd}	15.4^{d}	13.9^{e}	5.34^{d}	5.00^{de}
'Lae Geen'	72	4.47^{c}	1.29^{g}	0.25^{e}	771^{f}	1358^{a}	19.8^{c}	39.6^{c}	8.58^{ab}	4.46^{f}
'Lae Yellow'	66	1.78^{i}	1.90^{d}	0.29^{cd}	1047^{e}	883^{c}	16.4^{d}	17.8^{d}	4.09^{e}	6.71^{a}
'Numkowe'	73	3.91^{d}	1.87^{d}	0.35^{b}	1748^{a}	835^{cd}	16.2^{d}	59.1^{a}	3.52^{f}	5.82^{bc}

Means with Different Letter in the Same Column Differed Significantly

The most abundant mineral was K. Root crops are valuable sources of carbohydrates and therefore have a relatively high requirement for K (Marschner, 1995). Its content ranged from 1.12 % to 2.28 %, with the mean value of 1.77 %. The highest content of K was determined in 'KPOK 35A', followed by 'NT 01'and 'NT 02', whereas the lowest in 'BC737'. There were significant differences among cultivars regarding the content of this mineral. The highest content of P was determined in 'NT 01' (0.43%), followed by 'Numkowe' and 'NT 02'. The lowest value was obtained for 'BC 737', followed by 'Lae Green' and 'NT 03'. Considering all analyzed PNG cultivars, the mean value of P content was 2.29%. The contents of Ca ranged between 771 mg/kg and 1748 mg/kg DW, with the mean value of 1230 mg/kg. The highest contents were determined in 'Numkowe', followed by 'NT 02' and 'BC 737', whereas the lowest content was determined in 'Lae Green'.

The contents of Mg ranged between 750 and 1358 mg/kg DW, with mean value of 976 mg/kg. The highest content of this mineral was determined in 'Lae Green' and 'BC 737'. The concentration of Fe (the mean value was 19.63 mg/kg) was relatively high when compared with the data published by Bradbury and Holloway (1988) and Maga (1992). The highest content was determined in 'NT 01'. The cultivars 'KPOK 35A', 'NT 04', 'BC 373' and 'Numkowe' exhibited lower values, however, there were no significant differences between the analyzed cultivars. The concentrations of Cu and Mn ranged between 3.52 and 8.78 mg/kg, and 2.79 and 6.71 mg/kg respectively.

Table 2. *Mean Values and Variation of Starch, Proteins and Minerals Content Determined in Corms of Ten Papua New Guinea Taro Cultivars.*

	N	Minimum	Maximum	Mean	St. Dev.	CV (%)
Starch (%)	10	66	79	72	4.30	5.9
Protein (g/100g)	10	1.77	6.89	3.72	1.79	48.8
K (%)	10	1.12	2.28	1.77	0.342	19.4
P (%)	10	0.19	0.43	0.29	0.06	20.6
Ca (mg/kg)	10	771	1748	1230	247	20.8
Mg (mg/kg)	10	750	1358	976	216	22.1
Zn (mg/kg)	10	7.20	59.1	22.50	17.3	76.8
Fe (mg/kg)	10	15.4	29.4	19.63	5.72	29.1
Cu (mg/kg)	10	3.52	8.78	6.87	1.85	26.9
Mn (mg/kg)	10	2.79	6.71	5.12	1.16	22.6

The correlation matrix (Table 3) revealed positive and highly significant ($p \leq 0.01$) correlation between P and K, Mg, Mn. There is also an interesting and significant negative correlation between Mg and K, and starch and K. Relatively strong and significant correlation among some of the analyzed minerals and starch may serve as guidelines for breeders in order to improve the quality of future cultivars.

Table 3. *Pearson's Correlation Matrix for Eight Analyzed Minerals, Starch and Proteins of Corms of Ten Papua New Guinea Taro Cultivars*

	Starch	CP	K	P	Ca	Mg	Fe	Cu	Mn	Zn
Starch	0.000	-0.458*	-0.109	0.229	0.324	0.090	0.425	-0.083	0.243	
CP			-0.075	0.068	-0.007	-0.274	-0.011	-0.121	-0.006	
K				0.311	-0.588**	-0.052	-0.397	0.035	-0.505*	
P			0.782**		0.346	-0.341	0.233	-0.188	0.046	-0.261
Ca						-0.310	-0.072	-0.389	0.142	0.320
Mg							0.355	0.576**	0.133	0.385
Fe								0.453*	0.344	-0.097
Cu									-0.383	-0.307
Mn										0.269
Zn										

** Significant at 0.01
* Significant at 0.05

Conclusion

The presented study provides useful information about some of the crucial parameters of the chemical composition of typical taro cultivars from Papua New Guinea. The study suggests that corms of the sampled taro cultivars can be considered as valuable sources of starch and minerals, especially potassium, calcium, phosphorus and magnesium in the human diet. They are also a relatively good source of zinc, iron, and copper. The most valuable source of Fe were corms of the cultivar 'NT 01', and the cultivar 'Numkowe' was the richest source of Zn. Corms of all analyzed taro cultivars were rather low in Mn. The values of crude proteins were relatively low suggesting that taro as a food commodity should be combined with other food sources which are richer in proteins. We also have to consider the prolonged vegetation period (taros were harvested almost a year after planting) which probably had a significant impact on the chemical composition as well as on the nutrient value. The results can be helpful in breeding programs aimed at improving the quality of future cultivars.

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