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Comparison of Taiwan paddy- and upland-cultivated taro (*Colocasia esculenta* L.) cultivars for nutritive values

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Abstract

Taro (*Colocasia esculenta* L.), an important food staple for millions of people, is grown exclusively in the tropical and semitropical regions of the world. It is cultivated mainly in developing countries, rarely on large plantations but on small farms with little technology. The purpose of this study was to investigate the effect of cultivars and field preparations of taro corms on the nutrient content and protein nutritional quality. Three local cultivars of taro corms were grown by paddy and upland cultivation in Taiwan. The results showed that taro contained 63.6%–72.4% moisture, and upland-cultivated taro corms retained a higher moisture content compared to paddy taro. Results revealed that taro corms also contained 21.1%–26.2% starch and 1.75%–2.57% crude protein and provided total energy in the range of 97.1–118.3 kcal/100 g fresh taro. Taro corms had reasonably high contents of potassium and magnesium, whose ranges were 2251–4143 and 118–219 mg/100 g dry matter, respectively. Upland-cultivated taro tended to have higher mineral content than paddy taro. Taro corms are moderately good sources of water-soluble vitamins, such as thiamin, riboflavin and ascorbic acid, compared to other tropical roots. A higher soluble sugar content in upland-cultivated taro corms was found than in paddy taro. The cultivar Mein contained higher soluble fibre levels than two other cultivars. Total oxalate and phytic acid levels of taro corms were in the range of 234–411 and 139–169 mg/100 g dry matter, respectively, which included 60%–75% of water-soluble oxalate. Essential amino acid contents of taro proteins from both paddy and upland cultivation were fairly similar to the FAO reference pattern, except for the contents of sulfur-containing amino acids, tryptophan, and histidine.

Keywords: *Colocasia esculenta*; Taro corms; Paddy and upland cultivation; Nutrient content; Protein nutritional quality

1. Introduction

Taro or cocoyam (*Colocasia esculenta* L. Schott) of the family Aracea is cultivated for its edible corms and is a staple food throughout subtropical and tropical regions of the world. The nutritional value is the main concern when a crop is being considered as a food source. Due to the emphasis placed on the nutritional value of food by consumers, a great need exists for information on the nutritional contents of root crops. The high starch content of most root crops is considered an excellent energy source, but they are marginal to poor sources of protein (Bradbury, 1988; Davidson, Passmore, Brock, & Truswell, 1979). Root crops contain a wide variety of minerals and trace elements, including relatively substantial quantities of iron and calcium, as well as potassium and magnesium (Bhandari, Kasai, & Kawabata, 2003; Englberger et al., 2003; Huang, Titchenal, & Meilleur, 2000). Root crops are usually a good source of vitamins, e.g., yellow cultivars of the sweet potato or giant swamp taro are considered to provide ample β-carotene (Bureau & Bushway, 1986; Englberger, Schierle, Marks, & Fitzgerald, 2003; Picha, 1985; Singh & Bradbury, 1988).

In humid subtropical and tropical areas, water availability is generally considered as the first priority in taro

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production. Two different field preparations of taro, paddy and upland fields, are used, occasionally depending on water availability. It is desirable to have a continuous supply of water for paddy taro production. However, upland taro cultivation is more flexible because upland taro can withstand periods of water shortage. Although several factors have been reported to influence the nutritional compositions of root crops, such as species, climate, and fertilization, fewer data are available on the effects of land preparation on the nutritional values of root crops.

The purposes of this study were to quantify the nutrient compositions and anti-nutritional factors of taro corms, to evaluate the quality of taro protein,and to compare differences in nutritional values of taro corms from paddy and upland field cultivation.

2. Materials and methods

2.1. Sample preparation

2.1.1. Taro cultivation

Three different local varieties (*Colocasia esculenta* L. var. *Mein*, var. *KS1*, and var. *Betelnut*) of taro were grown by paddy and upland cultivation under irrigation at the Kaohsiung Agricultural Improvement Station (Kaohsiung, Taiwan). The paddy taro was cultivated on land which was kept flooded for the initial 6 months and then drained for the remainder of cultivation period. The upland taro was grown on dry land for 9 months. After 9 months of cultivation, all of the taro was harvested and stored at 18 °C for 24 h for proximate analysis. Taro corms were washed, peeled and sealed in zip-lock plastic bags and frozen at −20 °C before analyses.

2.2. Analytical methods

2.2.1. Proximate analysis

After 24 h at 18 °C, fresh taro corms were washed and peeled for proximate analysis. The analyses for moisture (Method 934.01), crude protein (Method 984.13), crude fat (Method 954.02), and ash content of the corms were carried out, according to the methods of the AOAC (1990). The conversion factor of total nitrogen to crude protein is 6.25. The starch content of the root was analysed according the official method of the AACC (1995).

2.2.2. Mineral analyses

Minerals, including calcium, sodium, potassium, magnesium, iron, and copper, were analysed after wet-ashing, according to the method of Onwuliri and Anekwe (1992), with an atomic absorption spectrophotometer (Model 2380, Perkin–Elmer Co., Norwalk, CT, USA). Phosphorus was estimated colorimetrically (UV-visible spectrophotometer, Model U2001, Hitachi Co., Tokyo, Japan), using dihydrogen phosphate as the standard solution (AOAC, 1990).

2.2.3. β-Carotene and ascorbic acid analyses

Both β-carotene and ascorbic acid were analysed by high performance liquid chromatograph, (HPLC). Analysis of β-carotene was based on a method described by Singh and Bradbury (1988). Ground taro (2 g) was weighed and saponified in 10% KOH in alcohol–water (50:50, v/v) at 80 °C for 1 h. After filtration, the solution was extracted with hexane. The extract was injected into a HPLC, fusing a 5-μm C-18 column, with a mobile phase of methanol–acetonitrile–water (40:40:20, v/v/v). Absorbance for β-carotene was measured at 452 nm. The method of Bradbury and Singh (1986) was applied for ascorbic acid determination. Ground taro was extracted in aqueous metaphosphoric acid (5%). Separation on the HPLC was achieved using a micro-Bondapak-NH_2 cartridge and a pH 4.6 phosphate buffer was used as the mobile phase. A dual-wavelength UV absorption acid determination (Bradbury & Singh, 1986). The β-carotene and ascorbic acid contents of the taro samples were calculated on a dry-weight basis.

2.2.4. Thiamin and riboflavin analyses

A 5 g ground sample was hydrolyzed by 65 ml 0.1 M hydrochloric acid at 100 °C for 30 min. After cooling, the solution was adjusted to pH 4.5 and incubated with β-amylase and takadiastase at 37 °C for 18 h. The filtrate was obtained and used for chromatographic determination of thiamin and riboflavin (Arella, Lahely, Bourguignon, & Hasselmann, 1996). Separation by reverse-phase (RP)-HPLC was accomplished with an octadecylsilyl stationary phase (4-mm id. × 250 mm) and a mobile phase consisting of methanol:0.05 M sodium acetate (30:70; v/v).

2.2.5. Nicotinic acid analysis

The nicotinic acid (niacin) content of taro corms was analysed according to the method of Bradbury and Singh (1986). Ground taro (2 g) was homogenized and extracted in 40 ml of 0.5 M H_2SO_4 for 3 min. The mixture was heated to 100 °C for 1 h. The pH was adjusted to 4.5 with sodium hydroxide, and the solution was filtered. The addition of ammonium sulfate followed by cyanogen bromide and sulfanilic acid produced a coloured compound for quantification. Colorimetric analysis at 440 nm was used for niacin determination (AOAC, 1990).

2.2.6. Phytic acid and total oxalate

The phytic acid (phytate) content was measured by the methods of Griffiths (1982) and Wang, Chang, and Grafton (1988). A 2 g ground sample was extracted with 40 ml of 0.5 M HNO_3 for 2 h and then filtered. A 1-ml solution was used for the total phosphorus determination (Thompson & Erdman, 1982). Ferric chloride ($FeCl_3$) was added to another 10 ml of solution and heated in boiling water for 75 min. After centrifugation at 12,000*g* for 15 min, the supernatant was used to determine the soluble phosphorus. Total and soluble phosphorus levels were determined colorimetrically using 0.05 M ammonium thiocyanate and were estimated using a phosphorus standard

curve. The difference between total and soluble phosphorus was insoluble phosphorus. The phytic acid content of the taro corms was calculated from the insoluble phosphorus, assuming 1 mol of phytic acid contains 6 mol of insoluble phosphorus. The content of total oxalate of the taro was measured by the method of Holloway, Argall, Jealous, Lee, and Bradbury (1989). Taro corms (2 g) were weighed and 25 ml of aqueous H_2SO_4 (0.25 M) were added. One millilitre of aqueous glutaric acid (10%) was added to the solution as an internal standard, and the mixture was placed in boiling water for 10 min. The extracted solution was filtered, separated by HPLC equipped with an Aminex HPX-87H column (7.8 × 300 mm; Bio-Rad Co., USA) and analysed by a UV-detector at 214 nm.

2.2.7. Amino acid analysis

The ground up sample was hydrolyzed with 6 N HCl in a sealed tube at 150 °C for 1.5 h. A Beckman amino acid analyser (Model 6300, Beckman Co., USA) was used for separating the amino acids, using sodium citrate buffers. Concertrations of amino acids are presented as mg/g taro protein. The reference pattern of amino acids was taken from the FAO/WHO (1985). The essential amino acid (EAA) score was calculated following the method of Siddhuraju, Becker and Makkar (2000), as follows:

$$\text{EAA score} = (\text{g of EAA in16 g N of test samples}/\text{g of EAA in16 g N of FAO}/\text{WHO reference pattern}) \times 100$$

2.2.8. Statistical analysis

All determinations were carried out using six replicates for each nutrient analysis of taro corms and in triplicate for the amino acid composition of taro protein. For all analyses, the data of treatments were subjected to analysis of variance (ANOVA); where *F*-values were significant, the means of each nutrient were compared using the least significant differences (LSD) procedures of the Statistical Analysis System (SAS, 1990).

3. Results and discussion

3.1. Proximate compositions

The proximate compositions of taro under different cultivation methods available in Taiwan are presented in Table 1. *Mein* taro exhibited the highest moisture content, compared with the other cultivars. In a comparison of moisture content of taro corms, the data indicated that upland fields produced higher moisture than paddy field cultivation. It could be that corms of upland taro reserved more water to resist water shortages during growth.

The starch and protein contents of taro ranged from 21.1% to 26.2% and 1.75% to 2.57% on a fresh-weight basis, respectively. The starch and protein contents of taro corms from both paddy and upland field cultivation were similar to reported values for tropical taro species from the Pacific Islands and Africa (Bradbury & Holloway, 1988). Significant differences ($p < 0.05$) in starch contents were observed among taro cultivars and field preparations. Paddy-cultivated taro corms had higher starch contents than upland taro, except for the *Mein* taro corms. Upland *KS1* taro exhibited the highest protein content, which indicated its nutritional superiority. Upland-cultivated taro corms possessed slightly higher protein contents than paddy taro.

The crude lipid and crude fibre contents among cultivars and field preparations were remarkably similar, within ranges of 0.09%–0.15% and 0.39%–0.61% fresh weight, respectively. These values are lower than those of other root and tuber crops, such as yam (Bhandari et al., 2003; Wanasundera & Ravindran, 1994) and sweet potato (Zhang, Wheatley, & Corke, 2002). The ash content of taro corms was between 0.90% and 1.37% of the fresh weight. The ash contents in this study were higher than values reported for other cultivated taro species (Mega, 1992). Differences in the ash contents of taro corms might have been related to their species origin, fertility, geographical sources, or planting periods (Bradbury & Holloway, 1988).

Table 1
Proximate compositions of three paddy- and upland-cultivated taro corms

Parameters[1] (mg/100 g fresh weight)	Paddy-cultivated taro			Upland-cultivated taro		
	Mein	KS1	Betelnut	Mein	KS1	Betelnut
Moisture	72.4^{a}	63.6^{d}	64.8^{d}	71.7^{ab}	69.4^{c}	70.5^{bc}
Starch	21.1^{b}	26.1^{a}	25.3^{a}	22.3^{b}	22.2^{b}	21.6^{b}
Crude protein	1.82^{c}	2.04^{b}	1.80^{c}	1.75^{c}	2.57^{a}	2.09^{b}
Crude lipid	0.14^{a}	0.11^{bc}	0.12^{b}	0.15^{a}	0.09^{d}	0.10^{cd}
Ash	1.28^{b}	1.03^{cd}	1.10^{c}	1.37^{a}	0.90^{e}	0.96^{de}
Soluble sugar	0.75^{b}	0.76^{b}	0.71^{b}	1.02^{a}	0.67^{b}	0.71^{b}
Soluble fibre	0.54^{b}	0.46^{c}	0.46^{c}	0.61^{a}	0.39^{d}	0.42^{cd}
Energy (kcal/100 g)[2]	97^{b}	118^{a}	114^{a}	103^{b}	104^{b}	100^{b}

$^{a–e}$ Means with different letters within the same row differed significantly ($p < 0.05$).

[1] Proximate compositions of taro corms were calculated on the basis of fresh taro corm (g/100 g fresh weight).

[2] Total energy (kcal/100 g fresh weight) = $(17B + 38C + 17E + 16F)/4.186$, where B = % crude protein, C = % crude lipid, E = % starch, F = % soluble sugars.

The soluble sugar levels of taro corms (0.67%–1.02%) were generally higher than those reported for other tropical roots, including yam, cassava, and potato (Bradbury & Holloway, 1988; Wanasundera & Ravindran, 1994), but lower than those of sweet potato (Zhang et al., 2002). These higher soluble sugar contents of taro corms highlight their superiority in taste as a staple food. Although the different field preparations did not produce a significant difference ($p < 0.05$) in soluble sugar contents, upland-cultivated *Mein* taro had slightly higher soluble sugar contents (1.02% fresh weight) than the other cultivars. *Mein* taro possessed a higher soluble fibre level than the other two cultivars. Taro corms are moderately good sources of soluble fibre, compared with other root and tuber crops, such as sweet potato (Bradbury & Holloway, 1988). The higher soluble fibre contents of taro corms highlight their superiority with regard to protection against health problems, such as diabetes. The total energy values (97.1–118.3 kcal/100 g fresh weight) recorded in this study are similar to those of root and tuber crops (Charles, Sriroth, & Huang, 2005; Huang et al., 2000; Wanasundera & Ravindran, 1994). Due to the slightly higher starch and lower moisture contents, *KS1* and *Betelnut* paddy-cultivated taro corms exhibited higher energy values than upland taro.

3.2. Nutrient contents

The results of nutrient contents analyses, including minerals, vitamins, and soluble sugars are presented in Table 2. The nutrient contents of the taro corms were calculated on a dry-weight basis (g/100 g dry matter). The results indicated that potassium was the most abundant mineral and ranged from 2251 to 4143 mg/100 g dry matter. These levels are higher than other reported values for taro species (Charles et al., 2005; Huang et al., 2000; Wanasundera & Ravindran, 1994). The high potassium and phosphorus contents in taro corms can possibly be attributed to the high-potassium and phosphorus chemical fertilizers used in Taiwan. From a nutrients supply point of view, taro corms may be considered as a good source of carbohydrates and magnesium. A serving of 100 g fresh taro corms provides 100 kcal and 100–200 mg of magnesium, which is almost one-third of the recommended daily allowance of magnesium for adults. Comparing mineral elements for paddy- and upland-cultivated taro, upland-cultivated taro corms contained significantly higher ($p < 0.05$) sodium, potassium, calcium, and phosphorus levels than paddy-cultivated taro; we thus concluded that upland cultivation retained higher levels of mineral elements.

According to the vitamin analyses in Table 2, the β-carotene contents ranged from 74.4 to 93.6 μg/100 g dry matter. However, the content of β-carotene in taro corms was much lower than the recommended quantity. The β-carotene contents of taro corms from both paddy and upland cultivation were lower than values for yellow sweet potato, yam, taro and giant swamp taro (Englberger et al., 2003; Picha, 1985; Singh & Bradbury, 1988) but were similar to reported values for tropical taro species from the Pacific Islands (Singh & Bradbury, 1988). Due to the small amounts of provitamin A in root crops, a sufficient supplement of carotenes in the diet from other plant sources is necessary.

The thiamin and riboflavin contents of taro corms tended to differ between field preparations, with values

Table 2
Minerals, vitamins, and soluble sugars content of three paddy- and upland-cultivated taro corms

Nutrients[1] (mg/100 g dry matter)	Paddy-cultivated taro			Upland-cultivated taro		
	Mein	KS1	Betelnut	Mein	KS1	Betelnut
Minerals						
Sodium	82^{e}	87^{d}	88^{d}	96^{c}	113^{a}	109^{b}
Potassium	3222^{b}	2251^{e}	2485^{d}	4143^{a}	2411^{d}	2707^{c}
Calcium	42^{b}	31^{d}	34^{c}	47^{a}	34^{c}	36^{c}
Magnesium	118^{d}	216^{a}	178^{c}	212^{a}	190^{b}	219^{a}
Iron	9.7^{b}	8.6^{c}	8.7^{c}	10.8^{a}	8.1^{c}	8.5^{c}
Phosphorus	195^{c}	158^{c}	174^{d}	340^{a}	196^{c}	215^{b}
Vitamins						
β-Carotene	93.6^{a}	86.4^{bc}	90.0^{ab}	74.4^{d}	88.2^{b}	83.4^{c}
Thiamin	0.85^{a}	0.73^{b}	0.74^{b}	0.67^{c}	0.60^{d}	0.69^{bc}
Riboflavin	0.28^{a}	0.21^{b}	0.23^{b}	0.26^{a}	0.17^{c}	0.21^{b}
Ascorbic acid	13.3^{b}	9.4^{d}	10.5^{c}	16.1^{a}	11.0^{c}	10.5^{c}
Niacin	2.7^{a}	2.5^{ab}	2.4^{ab}	2.2^{b}	2.4^{ab}	2.2^{b}
Soluble sugars						
Sucrose	1207^{b}	782^{e}	813^{d}	1526^{a}	816^{d}	825^{c}
Glucose	130^{c}	148^{b}	133^{c}	212^{a}	133^{c}	147^{b}
Fructose	1126^{b}	903^{e}	986^{d}	1302^{a}	1031^{c}	1079^{c}
Mannose	82^{e}	98^{d}	102^{c}	157^{a}	95^{d}	111^{b}
Xylose	100^{b}	84^{d}	80^{d}	121^{a}	94^{c}	81^{d}

[a–e] Means with different letters within the same row differed significantly ($p < 0.05$).
[1] Nutrients content of taro corms were calculated on the basis of dry matter (mg/100 g dry matter).

ranging from 0.60 to 0.85 and 0.17 to 0.28 mg/100 g dry matter. Thiamin contents of paddy-cultivated taro corms were higher than those of upland taro. Taro corms provided larger amounts of thiamin and riboflavin than other root crops, such as yam and cassava (Bradbury & Singh, 1986).

The ascorbic acid contents of taro corms were determined to be in the range of 9.4–16.1 mg/100 g dry matter, which is higher than values reported for other tropical root crops (Wanasundera & Ravindran, 1994). Upland cultivation produced higher ascorbic acid levels than did paddy cultivation. The difference in ascorbic acid was quite large between paddy- and upland-cultivated *Mein* taro, compared with the other taro varieties.

The niacin content of taro corms ranged from 2.2 to 2.7 mg/100 g dry matter. No significant difference in niacin was observed between field preparations of taro corms ($p < 0.05$).

More meaningful values in Table 2 are achieved by calculating the amount of root and tuber crops that would be needed to supply the recommended daily allowance (RDA) of thiamin (1.3–1.5 mg), riboflavin (1.5–1.8 mg), ascorbic acid (50–60 mg), and niacin (15–20 mg NE) (NRC, 1989). It is evident that taro corms are a better source of thiamin than other tropical roots. Riboflavin and niacin levels are relatively low with regard to fulfilling RDA requirements. To meet the requirements of RDA for these water-soluble vitamins, the amount of fresh taro required was within the range of 1–3 kg/day. Clearly, these vitamins would need to be supplied from sources other than taro.

3.3. Oxalate and phytate contents

Levels of oxalates and phytate are of interest because of their alleged adverse effects on mineral bioavailability (Libert & Franceschi, 1987). Oxalic acid concentrations (Table 3) in the three varieties were high, with values ranging from 163 to 267 and 234 to 411 mg/100 g dry matter for water-soluble oxalate and total oxalate, respectively. The total oxalate contents of our samples were comparable to those reported for yam (Wanasundera & Ravindran, 1994), sweet potato, and taro (Bradbury, 1988; Holloway et al., 1989; Iwuoha & Kalu, 1995), but lower than those reported for other vegetable leaves, such as sweet potato leaves (Almazan, 1995), silverbeet leaves (Savage, Vanhanen, Mason, & Ross, 2000), and spinach (Watanabe, Uchiyama, & Yoshida, 1994). Upland-cultivated taro corms contained higher amounts of water-soluble oxalate and calcium oxalate than did paddy taro. These oxalate levels do not pose a hazard, especially since 60%–75% of the oxalates are present in water-soluble forms. Water-soluble oxalate is known to leach out during cooking in water (Libert & Franceschi, 1987). The phytic acid contents were similar across the three varieties in both paddy and upland fields with values ranging from 139 to 148 and 142 to 169 mg/100 g dry matter, respectively, although levels in upland taro were slightly higher than paddy-cultivated taro corms. Comparatively, the phytic acid contents in our samples are similar to those of other tropical root crops, including yam (Wanasundera & Ravindran, 1994) and cassava (Oke, 1990; Charles et al., 2005). In general, the values of taro corms from both paddy and upland fields were much lower than those reported for cereals, grain and legumes (Reddy, Sathe, & Salumkhe, 1982; Wang et al., 1988), and sweet potato leaves (Almazan, 1995).

3.4. Amino acid compositions

Results of the amino acid compositions of taro corms are presented in Table 4. Among the amino acids, the contents of aspartic acid (146.8–193.7 mg/g protein) and glutamic acid (85.2–117.6 mg/g protein) predominated in taro corms, where the highest quantity was found in upland-cultivated *KS1* taro. Several amino acids were at higher levels in upland-cultivated taro corms than paddy taro corms. The amino acid composition of upland-cultivated *Mein* taro corms was superior to the other varieties in both field preparations. All taro varieties contained fairly high amounts of essential amino acids (EAA), similar to the FAO reference pattern (FAO/WHO, 1985), except for the sulfur-containing amino acids, tryptophan and histidine (Table 5). Levels of essential amino acids were similar to those reported for other tropical roots, such as yam (Bhandari et al., 2003). The lowest EAA score for the different taro varieties was found in upland-cultivated *KS1* taro corms. Although the sulfur-containing amino acids (Met + Cys), tryptophan, and histidine were the most limited in all varieties with EAA scores ranging from 38 to 46,

Table 3
Oxalate and phytic acid contents of three paddy- and upland-cultivated taro corms

Oxalates and phytate[1] (mg/100 g dry matter)	Paddy-cultivated taro			Upland-cultivated taro		
	Mein	KS1	Betelnut	Mein	KS1	Betelnut
Water-soluble oxalate	201[b]	163[d]	182[c]	267[a]	164[d]	198[b]
Calcium oxalate	113[b]	71[d]	96[c]	144[a]	92[c]	95[c]
Total oxalate[2]	314	234	278	411	256	293
Phytic acid	146[b]	148[b]	139[c]	169[a]	163[a]	142[bc]

[a–d] Means with different letters within the same row differed significantly ($p < 0.05$).
[1] Oxalates and phytic acid contents of taro were calculated on the basis of dry matter (mg/100 g dry matter).
[2] Total oxalate = water-soluble oxalate + calcium oxalate.

Table 4
Amino acids of taro protein of three paddy- and upland-cultivated taro corms[1]

Amino acids	Paddy-cultivated taro			Upland-cultivated taro		
	Mein	KS1	Betelnut	Mein	KS1	Betelnut
Asp	156.8[c]	149.7[d]	146.8[d]	193.7[a]	160.7[b]	158.3[bc]
Glu	110.9[b]	85.2[d]	86.3[d]	117.6[a]	92.6[c]	94.1[c]
Pro	85.2[b]	74.4[c]	75.7[c]	90.0[a]	71.7[d]	72.2[d]
Leu	87.2[a]	67.7[e]	72.1[d]	87.5[a]	75.9[b]	74.1[c]
Phe	58.4[b]	51.9[d]	52.3[d]	69.3[a]	56.0[c]	57.5[b]
Val	54.0[a]	44.0[b]	43.6[b]	55.8[a]	44.7[b]	45.5[b]
Lys	50.5[b]	45.3[d]	46.3[c]	52.2[a]	45.0[d]	46.9[c]
Ala	47.0[b]	41.9[c]	42.3[c]	50.7[a]	40.5[d]	41.7[c]
Thr	47.6[a]	40.5[b]	41.6[b]	48.0[a]	40.7[b]	41.2[b]
Ser	46.5[a]	45.3[a]	45.9[a]	45.3[a]	43.8[b]	43.1[b]
Ile	41.1[a]	30.6[d]	32.8[c]	42.2[a]	33.5[bc]	34.2[b]
Tyr	32.1[b]	21.8[e]	23.2[d]	34.8[a]	28.4[c]	28.8[c]
Gly	23.0[b]	20.4[c]	20.1[c]	24.9[a]	22.2[b]	22.6[c]
His	11.9[b]	11.1[b]	11.9[b]	13.7[a]	11.6[b]	13.9[a]
Arg	2.7[d]	12.9[a]	10.5[b]	13.5[a]	2.7[d]	4.3[c]
Trp	6.2[b]	9.8[a]	9.6[a]	5.1[c]	3.8[d]	3.4[d]
Met	6.9[b]	8.0[a]	7.6[a]	6.9[b]	8.3[a]	8.0[a]
Half-Cys	3.6[a]	2.3[b]	2.6[b]	3.5[a]	3.5[a]	3.46[a]

[a–e] Means with different letters within the same row differed significantly ($p < 0.05$).
[1] Amino acid contents (mg/g protein) of protein were calculated on the basis of taro protein.

Table 5
Essential amino acid (EAA) compositions of three paddy- and upland-cultivated taro corms compared to the FAO/WHO reference protein (g amino acid per 100 g protein)

Essential amino acids[1]	FAO/WHO reference protein[2]	Paddy-cultivated taro			Upland-cultivated taro		
		Mein	KS1	Betelnut	Mein	KS1	Betelnut
Val	3.5	5.4	4.4	4.4	5.6	4.5	4.6
Leu	6.6	8.7	6.8	7.2	8.8	7.6	7.4
Ile	2.8	4.1	3.1	3.3	4.2	3.4	3.4
Lys	5.7	5.1	4.5	4.6	5.2	4.5	4.7
Met + Cys	2.6	1.1	1.0	1.0	1.0	1.2	1.1
Phe + Tyr	6.2	9.1	7.4	7.4	10.4	8.4	8.3
Thr	3.3	4.8	4.1	4.2	4.8	4.1	4.1
Trp	1.1	0.6	1.0	0.9	0.5	0.4	0.5
His	1.9	1.2	1.1	1.2	1.4	1.2	1.4

[1] EAA is presented as g amino acid per 100 g protein.
[2] WHO technical report series No. 724, 1985 (Energy and protein requirements report of a joint FAO/WHO/UNU expert consultation).

36 to 91, and 58 to 74, respectively, our values for EAA scores are similar to those reported for wild yam tubers (Bhandari et al., 2003). In general, most essential amino acids in taro corms exhibited a high EAA score, which implies that taro corms are more desirable than other tropical roots as a staple food (Table 6).

Table 6
Essential amino acids scores of three paddy- and upland-cultivated taro corms[1]

Essential amino acids	Paddy-cultivated taro			Upland-cultivated taro		
	Mein	KS1	Betelnut	Mein	KS1	Betelnut
Val	154	126	126	160	129	131
Leu	132	103	109	133	115	112
Ile	146	111	118	150	121	121
Lys	89	79	81	91	79	82
Met + Cys	42	38	38	38	46	42
Phe + Tyr	147	119	119	168	135	134
Thr	145	124	127	145	124	124
Trp	55	91	82	45	36	45
His	63	58	63	74	63	74

[1] Essential amino acid scores = (g of EAA in 16 g N of test sample/g of EAA in 16 g N of FAO/WHO reference patern) × 100.

4. Conclusions

This study provides evidence that taro is as an important staple food in several regions of developing countries because it contains high amounts of carbohydrates and is an excellent energy supplier. Paddy and upland cultivation of taro, which are cultivation methods chosen depending on water availability, showed significant differences in the proximate compositions, nutrient contents and anti-nutritional factors. The variation in levels of nutrients and anti-nutritional factors observed among the varieties and field preparations may offer some meaningful information for taro cultivation and for further processing operations.

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