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Proximate composition, mineral contents, hydrogen cyanide and phytic acid of 5 cassava genotypes

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Abstract

Five cassava genotypes Rayong 5, Kaesetsart 50 (KU50), Rayong 2, Hanatee and KMUL 36-YOO2 (YOO2), were used in this study. Investigations showed that cassava contained 9.2–12.3% moisture, 1.2–1.8% crude protein, 0.1–0.8% crude lipid, 1.5–3.5% crude fibre, 1.3–2.8% ash, 80.1–86.3% carbohydrate, 1406–1465 kJ 100 g^{-1} DM and 95–135 mg g^{-1} of phytic acid. Mineral contents were 10.9–39.9, 15.2–32.3 and 9.3–54.1 mg g^{-1} for Ca, Mg and P, respectively, and 221–328, 4.7–25.8, 1.41–4.25, 0.29–1.73 and 1.2–4.44 mg g^{-1} for K, Na, Zn, Mn, Cu, and Fe, respectively. HCN content ranged from 8.33 to 28.8 mg HCN/kg dry weight basis. A linear relationship between Ca and P and carbohydrate and energy existed with correlation coefficients of 0.99 and 0.82, respectively. Phytate: total *p* ranged from 77% to 88% and a linear relationship existed between phytate and total *p* with a correlation coefficient of 0.975.

Keywords: Cassava genotypes; Mineral composition; Mineral; Proximate composition; Cyanidric acid; Phytic

1. Introduction

Cassava (*Manihot esculenta*, Crantz) is emerging as a dominant staple of primary or secondary importance in many developing countries of the humid and sub-humid tropics in Africa and elsewhere. Since it can withstand drought, it is sometimes a nutritionally strategic famine reserve crop in areas of unreliable rainfall. Cassava is a starchy staple whose roots are very rich in carbohydrates, a major source of energy. In fact, the cassava plant is the highest producer of carbohydrates among crop plants with, perhaps, the exception of sugarcane. It has been reported that cassava can produce 250×10^3 cal/ha/day compared to 176×10^3 for rice, 110×10^3 for wheat, 200×10^3 for maize, and 114×10^3 for sorghum (Okigbo, 1980).

Although cassava roots are rich in calories, they are grossly deficient in proteins, fat, and some of the minerals and vitamins. Consequently, cassava is of lower nutritional value than are cereals, legumes, and even some other root and tuber crops, such as yams (Latham, 1969). The cassava root contains carbohydrate, 64–72% of which is made up of starch, mainly in the form of amylose and amylopectin. About 17% sucrose is found in sweet varieties, and small quantities of fructose and dextrose have been reported. The lipid content of cassava is only 0.5%. Cassava is reasonably rich in calcium (16–35 mg/100 g) and vitamin C (15–45 mg/100 g) (Okigbo, 1980; Charles, Chang, Ko, Sriroth, & Huang, 2004) and, although it is poor in proteins (1–2%)

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(Charles et al., 2004), its amino acid profile is remarkably comparable to that of other root tubers in terms of some essential amino acids, particularly lysine and threonine (Buitrago, 1990;Camara & Madruga, 2001; Okigbo, 1980).

Certain varieties of cassava have traditionally been designated as sweet or bitter, purportedly in relation to their cyanogenic glucoside content. The sweet varieties are supposedly much lower in hydrogen cyanogen (HCN) content than the bitter varieties. Nevertheless, reports have shown that age, variety, and environmental conditions influence the occurrence and concentration of HCN in various parts of the cassava plant and at different stages of development, respectively. Foodstuffs prepared from cassava roots had lower cyanogen contents (2–31 mg HCN/kg) than those prepared as cassava root slices or from cassava flour (28–88 mg HCN/kg) (Okigbo, 1980). Coursey and Haynes (1970) and Coursey (1982) reported less than 50 mg HCN/kg of fresh, peeled root as innocuous in cyanide toxicity and this was used as a benchmark in this paper. Another chemical compound of relative importance to the nutritive value of the tuber root is phytate. Phytate is a storage form of phosphorus which is found in plant seeds and in many roots and tubers (Dipak & Mukherjee, 1986). Phytic acid has the potential to bind calcium, zinc, iron and other minerals (Oke, 1990). On the other hand, phytate may play an important role as an antioxidant by complexing iron and thereby reducing free radical generation and the peroxidation of membranes, and may also act as an anticarcinogen, providing protection against colon cancer (Graf, Empson, & Eaton, 1987). Therefore, interest in the assessment and manipulation of phytate contents, mineral and proximate composition in cassava breeding programmes is increasing.

The objectives of the present study were to evaluate the chemical composition of 5 cassava genotypes and to determine variability in mineral and proximate compositions among these genotypes.

2. Materials and methods

2.1. Materials

In this work, tubers of five cassava genotypes were collected from north Thailand; these included Rayong 5, Kasetsart 50 (KU50), Rayong 2, Hanatee, and KMUL 36-YOO2 (YOO2), obtained from the Biotechnology Department, Faculty of Agro Industry, Kaesetsart University, Bangkok, Thailand. Some of these genotypes have been tested for their starch physicochemical properties (Sriroth et al., 1999; Charles et al., 2004), and the effects of processing on their starch properties (Abera & Rakshit, 2003).

2.2. Sample preparation

The tubers were washed, hand-peeled, cut into smaller pieces with a Cuisinart food processor equipped with a 0.1 cm ultrathin blade and dried on perforated trays in a mechanical convection oven (60 °C for 20 h). The dried slices were ground into flour using a Cross-Beater mill (Glen Mill Corp., Maywood, NJ) equipped with a 0.5 mm screen. The flour was then packed and heat-sealed in laminated bags, of about 1 kg each, and stored in a cool place until used.

2.3. Proximate analysis

Moisture content was determined according to the AACC (1980). The crude protein content was calculated by converting the nitrogen content determined by the micro-Kjeldahl method ($N \times 6.25$). Ash content was determined by dry-ashing in a furnace oven at 525 °C for 24 h. Crude lipid, using a Soxhlet apparatus (AOAC, 1975; 14.018), and crude fibre (AOAC, 1975; 7.054) were also determined. Carbohydrate content was calculated by difference (Vadivel & Janardhanan, 2001). The energy content of the tubers was determined by multiplying the percentages of crude protein, crude lipid, and carbohydrates by the factors 16.7, 37.7 and 16.7, respectively (Siddhuraju, Vijayakumri, & Janardhanan, 1992).

To determine phytate, the method of Latta and Eskin (1980) was employed. A 500 mg sample was extracted with 20 ml of 2.4% HCl (0.65 N) for 2 h at room temperature on a rotary shaker. The extract was centrifuged (10,000*g*, 15 min) and the supernatant was decanted and filtered through Whatman number 1 filter paper. A 3 ml aliquot of the filtrate was diluted to 18 ml with distilled water, and the diluted sample was passed through a 200–400 mesh AG1-X8 chloride anion exchange resin, taking care that no more than 3 mg phytate per 1.0 g of resin was applied. Inorganic phosphorus was eluted with 0.07 M NaCl, followed by elution of phytate with 0.7 M NaCl. Phytate was determined colorimetrically, based on the pink colour of the Wade reagent, which is formed upon the reaction of ferric ion and sulfosalicylic acid, and which has an absorbance maximum at 500 nm. In the presence of phytate, the iron is sequestered and unavailable to react with sulfosalicylic acid, resulting in a decrease in pink colour intensity.

2.4. Chemical analysis

A Perkin–Elmer Model 5000 atomic absorption spectrophotometer equipped with both flame and flameless atomization systems was used in the mineral content analyses. The mineral constituents were determined by wet-ashing 10 g each of sample, taken from the treatment groups, with a mixture of nitric acid, perchloric

acid (60%) and sulphuric acid (10:4:1). Lanthanum chloride (1% v/v) was added to acid solutions of the ashes and to the standard solutions to minimize possible interference in the determinations of the minerals.

Flame photometry was used for Na and K and atomic absorption spectrometry for the remainder of the minerals studied. Phosphorus and iron contents were determined colorimetrically (Dickman & Bray, 1940) from the triple acid-digested samples. HCN was analyzed following procedures outlined in O' Brien, Taylor, and Poulter (1991). The results were expressed as mg HCN equivalents/kg dry weight basis (mean ± SD) based on at least three replicate analyses.

2.5. Statistical analysis

Three separate samples from each genotype were taken and analyses on each sample were conducted. Data were assessed by analysis of variance (ANOVA) and Duncan's multiple range test with a probability $p \leqslant 0.05$ performed using a SAS programme (SAS Institute, Cary, NC).

3. Results and discussion

3.1. The proximate composition and starch content

Table 1 gives the proximate analysis values of the genotypes studied. The moisture content of the genotypes varied from 9.2 (Hanatee) to 12.3% (Rayong 2), placing the technological classification of this product as a moderately hygroscopic product, with values between 9% and 15% moisture. The crude protein content of the five genotypes investigated ranged from 1.2% to 1.8%, with significant differences between the lowest values 1.2% (KU50) and 1.3% (Rayong 2), and the highest value 1.8%, Hanatee. Rayong 5 and YOO2 had similar protein contents (1.5%). These protein values are higher than those of other cassava genotype, from 0.15% to 0.30%, w/w in four cassava genotype starches in Sriroth et al. (1999) and 0.53% (Okigbo, 1980) to 1.1% (Buitrago, 1990), in root tubers. Abera and Rakshit (2003) reported lower protein values for similar cassava genotype starches subjected to different treatments and processing conditions. According to published data, the lipid content was 0.47% (Buitrago, 1990) to 0.53% in root tubers, (Okigbo, 1980). All genotypes had lower lipid contents except for Rayong 5 with the highest, 0.4%. However, the values were higher than those of other cassava genotype starches (nil to 0.01%) reported by Sriroth et al. (1999) and 0.03–0.15% by Abera and Rakshit (2003). Means were significantly different ($p \leqslant 0.05$) from one another except for Hanatee and YOO2 genotypes. Crude fibre ranged between the minimum value of 1.5% for KU50 genotype and the maximum values of 3.5% for Rayong 2 and YOO2 genotypes. These values were higher than the range 1.10% (Buitrago, 1990) to 1.4% (Bradbury & Holloway, 1988) for root tubers, but lower than sweet cassava (10.31%) and comparable with bitter cassava (3.09%) (Okigbo, 1980). Ash content ranged from 1.3% (for KU50) to 2.8% (for Rayong 2). Values obtained (except Rayong 2) were lower than those of peeled bitter cassava (2.41% dry weight basis), and sweet cassava (4.44% dry weight basis) (Okigbo, 1980), but higher than those of root tubers (0.84%) reported by Bradbury and Holloway (1988). Carbohydrate values ranged from 80.1% (for Rayong 2) to 86.3% (for KU50). There is a significant ($p \leqslant 0.05$) variation in the carbohydrate content among the genotypes. These carbohydrate content values presented here were higher than those of when compared with fresh cassava (34.7%, edible portion; Okigbo, 1980). Dry matter ranged from 1406 (for YOO2) to 1468 (for KU50). The results are higher than the value (35% in root tubers) reported by Okigbo (1980).

3.2. HCN, phytic acid and phosphorus content

The results presented in Table 2 show low variability of HCN content in cassava flours (mean value 17.0; SD

Table 1
Proximate composition of five genotypes of *Manihot esculenta*[a] (g 100 g^{-1} flour)

Genotype[b,c]	Moisture	Crude protein	Crude lipid	Crude fibre	Ash	CHO[d]	kJ 100 g^{-1}DM
Rayong 5^{B}	9.6 ± 0.2c	1.5 ± 0.2b	0.4 ± 0.8a	1.8 ± 0.3c	1.4 ± 0.5d	85.4 ± 0.5b	1465
$KU50^{B}$	9.6 ± 0.4c	1.2 ± 0.3d	0.3 ± 0.6b	1.5 ± 0.2d	1.3 ± 0.2de	86.3 ± 0.4a	1468
Rayong 2^{S}	12.3 ± 0.2a	1.3 ± 0.5c	0.2 ± 0.2c	3.5 ± 0.5a	2.8 ± 0.4a	80.1 ± 0.3e	1361
$Hanatee^{S}$	9.2 ± 0.3cd	1.8 ± 0.6a	0.2 ± 0.3c	2.5 ± 0.3b	1.7 ± 0.2c	84.6 ± 0.4c	1449
$YOO2^{S}$	10.6 ± 0.6b	1.5 ± 0.6b	0.1 ± 0.7d	3.5 ± 0.5a	1.9 ± 0.3b	82.4 ± 0.2d	1406
Range	9.2–12.3	1.2–1.8	0.1–0.8	1.5–3.5	1.3–2.8	80.1–86.3	1406–1465
Mean	10.3	1.5	0.2	2.5	1.8	83.8	1430
SD	1.3	0.2	0.1	0.9	0.6	2.5	45.8

[a] Results are the averages of three determinations expressed on dry weight basis. ±, standard error.
[b] B, bitter variety; S, sweet variety.
[c] In the same column, values followed by a common letter are not significantly different at $p < 0.05$.
[d] Carbohydrate = 100 − (MS + protein + fat + fibre + ash).

Table 2
Hydrogen cyanide (HCN) and the relationship between phosphorus and total phytic acid in cassava[a]

Genotype[b,c]	HCN (mg HCN equivalent/kg)	Phosphorus (mg/100 g)	Phytic acid (mg/100 g)	Percentage of phytate/total *p*
Rayong 5[B]	26.9 ± 1.73	135 ± 0.1bc	105 ± 1.40c	77.8
KU50[B]	28.8 ± 1.29	121 ± 0.2e	95 ± 1.46de	78.5
Rayong 2[S]	12.5 ± 3.54	137 ± 0.2b	111 ± 1.82b	81.0
Hanatee[S]	8.33 ± 2.79	124 ± 0.2d	96 ± 2.83d	77.4
YOO2[S]	8.90 ± 2.35	153 ± 0.3a	136 ± 2.23a	88.9
Range	8.33–28.8	121–153	95–136	
Mean	17.1	134.1	108.6	
SD	10.0	12.7	16.7	

[a] Results are the average of three determinations expressed on dry weight basis. ±, standard error.
[b] B, bitter variety; S, sweet variety.
[c] In the same column, values followed by a common letter are not significantly different at $p < 0.05$.

10), in agreement with reports on the homogeneity of HCN content observed in cassava flours (Yeoh & Egan, 1997). HCN content ranged from 8.33 mg HCN equivalent/kg (for YOO2) to 28.8 mg HCN equivalent/kg (for KU50 genotype). As expected, the sweet genotypes had lower cyanide contents; however, according to the benchmark adopted in this paper, the genotype flour samples were all below the limits, indicating some degree of efficiency of oven-drying in rendering these genotype flours safe for use. Yeoh and Sun (2001) reported 15–61 mg HCN/kg in various food products containing cassava flours.

Phosphorus investigations showed a minimum value of 121 mg g^{-1} (KU50) and a maximum value of 153 mg g^{-1}(YOO2) (Table 1). Buitrago (1990) reported phosphorus contents of 0.15 mg/100 g (fresh weight basis).As shown in Table 2, phytic acid level ranged from 95 to 135 mg g^{-1},thus showing a large variability (16.7) for this trait. Genotype YOO2 had the highest phytic acid content, while Hanatee and KU50 had the lowest contents. Oke (1990) reported that cassava, fresh and unprocessed, to contain 624 mg/100 g phytic content. In their report on the effects of fermentation processes on phytic content in cassava flours, mean values ranged from 70 to 116 mg/100 g. Comparatively, our results demonstrated a linear relationship between phytic acid and total P (correlation coefficient of 0.975). Factors that affect the total P content, such as available soil P and fertilizers, can influence the phytic acid concentration (Maga, 1980).

3.3. Mineral contents

The mineral contents of the 5 genotypes are shown in Table 3. The data indicate that K, P and Ca (Tables 2 and 3) were the major mineral constituents in the flours. Calcium content ranged from 136 to 369 mg g^{-1}; it was highest in Rayong 5 and lower in KU50. All genotypes showed significant ($p \leqslant 0.05$) variability in Ca (SD = 100.3). Values obtained in this study were considerably higher than those reported by Buitrago (1990), (10 mg/100 g fresh weight basis), Okigbo (1980) (33 mg/100 g fresh weight basis) and Bradbury and Holloway (1988) (20 mg/100 g fresh weight basis).

Sodium ranged from 36 to 50 mg g^{1}. Although the genotypes differed significantly ($p \leqslant 0.05$), a low variability (SD = 5.8) was observed among the genotypes. Buitrago (1990) reported 7.6 mg g^{-1} (fresh weight basis) of Na content. Magnesium ranged from 31 to 43 mg g^{-1}. KU50 and Rayong 2 were higher in Mg; however, all genotypes were significantly different in their Mg contents. Bradbury and Holloway (1988) and

Table 3
Mineral profiles of processed flour from 5 cassava cultivars[a] (mg 100 g^{1} oven-dried flour)

Genotype[b,c]	Sodium	Calcium	Potassium	Magnesium	Iron	Copper	Zinc	Manganese
Rayong5[B]	50.0 ± 0.4a	369 ± 0.2a	514 ± 0.2b	37 ± 0.6c	29 ± 0.06e	0.037 ± 0.02e	13 ± 0.06d	1.58 ± 0.01c
KU50[B]	36 ± 0.1e	136 ± 0.2e	554 ± 0.1a	43 ± 0.2a	32.7 ± 0.07c	0.053 ± 0.00b	15 ± 0.05c	0.31 ± 0.02e
Rayong 2[S]	40 ± 0.2c	254 ± 0.6c	343 ± 0.2d	38 ± 0.1b	32.5 ± 0.02dc	0.046 ± 0.00c	17 ± 0.02b	1.93 ± 0.02b
Hanatee[S]	38 ± 0.1d	309 ± 0.3b	385 ± 0.3c	31 ± 0.2d	40 ± 0.09a	0.057 ± 0.0a	19 ± 0.01a	0.76 ± 0.00d
YOO2[S]	46 ± 0.1b	152 ± 0.1e	324 ± 0.1e	28 ± 0.2e	39 ± 0.06b	0.042 ± 0.00cd	13 ± 0.06d	3.54 ± 0.02a
Range	36–50	136–369	324–554	31–43	29–40	0.037–0.057	13–19	0.31–3.54
Mean	42.0	243.8	424.1	35.5	34.77	0.15	15.40	1.62
SD	5.8	100.3	103.7	6.0	4.51	0.20	2.31	1.16

[a] Results are the averages of three determinations expressed on dry weight basis, ± standard error.
[b] B, bitter variety; S, sweet variety.
[c] In the same column, values followed by a common letter are not significantly different at $p < 0.05$.

Buitrago (1990) reported 30 mg/100 g fresh weight basis of Mg content.

K ranged from 324 to 554 mg g^{-1}. The data indicated that all genotypes were significantly different and demonstrated high variability (SD = 103.7) among the genotypes. Results obtained in these genotypes are generally higher than the reported ranges 250 mg Buitrago (1990) to 302 mg fresh weight basis, (Bradbury & Holloway, 1988).

The iron content ranged from 29 to 40 mg g^{-1}, which was markedly higher than the values reported on a fresh weight basis by Bradbury and Holloway (1988) (0.23 mg g^{-1}), and 0.7 mg g^{-1} (Okigbo, 1980) and 1.7mg g^{-1} Buitrago (1990). Copper content ranged from 0.037 to 0.057 mg g^{-1}. The copper content of Hanatee (0.057 mg g^{-1}) was significantly higher than those of all other genotypes whereas the Cu content of Rayong 5 (0.037 mg g^{-1}) was significantly lower than those of the other genotypes, while mean contents for Rayong 2 and YOO2 were not significantly different. The values obtained in this study were lower than copper values (0.2 mg g^{-1}) reported by Buitrago (1990).

Zinc content ranged from 13 to 19 mg g^{-1}. All genotypes showed variability in zinc content and were significantly different ($p \leqslant 0.05$). However, genotypes Rayong 5 and YOO2 had the same Zn contents (13 mg g^{-1}) and were significantly different from the remaining genotypes. Buitrago (1990) reported 1.4 mg g^{-1} (fresh weight basis) for Zn in cassava root tubers.

Manganese was found to range from 0.31 to 3.54 mg g^{-1}. All genotypes showed significant differences ($p = 0.05$), with low standard deviations, indicating low variability among the genotypes. Buitrago (1990) reported 0.3 mg g^{-1} for Mn content of cassava root tubers.

4. Conclusions

Cassava has an important amount of carbohydrate, because of its physiological role as a reserve. The genotypes studied represent new breeding cassava lines which are characterized by variability in protein, carbohydrates, energy, calcium and potassium. This can be advantageously utilized in breeding programmes designed to improve the nutritional quality of cassava. Dried flours of the genotypes provided lower HCN contents and phytate concentrations than those of composite values and mineral contents of similar genotypes and other cassava root tubers reported in the literature. This research has demonstrated the possibility of producing better nutritional products from cassava, which may adequately supply some of the nutrients in composite meals, rather than by using fresh bulky roots, which make processing operations inflexible and often logistically precarious. The significant variability observed among the genotypes and apparent differences from to those found in the literature, demands further studies of the effects of treatments on the nutritional composition and value of cassava products.

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