J. Bangladesh Agril. Univ. 10(2): 217–222, 2012 ISSN 1810-3030

Starch and flour extraction and nutrient composition of tuber in seven cassava accessions

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Abstract

Cassava (*Manihot esculenta* Crantz) roots (tubers) are used as staple food. Starch extracted from tubers is widely utilized as raw materials in industries. Dry matter (DM) content, starch and flour extraction and proximate composition were investigated in seven cassava accessions (Coc-A_1, Kh-A_2, Cow-A_3, Sa-A_4, Me-A_5, Va-A_6 and Sy-A_8.) in 2010-2011. Leaf DM varied from 20.51% in Me-A_5 to 29.01% in Sy-A_8; that of stem from 27.24% in Va-A_6 to 32.10% (average of Sy-A_8, Me-A_5 and Sa-A_4); and that of tuber from 37.30% in Kh-A_2 to 45.26% in Sy-A_8. Starch was extracted by blending chopped tuber followed by decantation. Tubers were sliced, sun dried and milled into flour. Tuber starch content (fresh wt. basis) varied between 15.04% in Sy-A_8 and 24.97% (average of Coc-A_1 and Me-A_5); that of peel from 4.54% in Va-A_6 to 5.85% in Coc-A_1. Crude protein varied from 1.80% (average of Kh-A_2, Cow-A_3 and Sy-A_8) to 4.53% in Va-A_6. Crude fiber content varied from 1.95% (average of Sa-A_4 and Coc-A_1) to 4.27% in Cow-A_3. Cyanogens present in cassava plant escape as hydrogen cyanide (HCN) during harvesting and processing. Variation for HCN existed and it was 140.95 mg/kg fresh tuber (average of Sy-A_8 and Coc-A_1) to 546.0 mg/kg fresh tuber in Va-A_6. There was no detectable HCN in the extracted flour and starch. It may be concluded that genetic variation for DM, starch, protein and HCN existed in seven cassava accessions, and Coc-A_1 may be a better one due to its lower HCN, higher DM and starch content.

Keywords: Cassava roots, DM, HCN, Proximate composition

Introduction

Cassava (*Manihot esculenta* Crantz) is a perennial, subtropical, woody shrub, grown as annual and is valued for its underground starchy tubers (roots) (Grace, 1977; Purseglove, 1988; Islam *et al*., 2008). Cassava is the important source of energy as staple food for more than 500 millions people in Africa, Latin America and Asia (Hillocks, 2002). Tuber of cassava is also used as raw materials in the garment, bakery, food and Pharmaceutical industries (Bokanga *et al*., 1994; IITA, 2011; Fakir *et al*., 2012). Cassava root can be consumed raw as a snack or just after boiling like sweet potato. Cassava is a mesophyte and can be grown in fallow high land, hill slope, rice field dyke ('ail') and other unutilized high lands. It can be grown in poor soils and produce fairly good yield where other crops almost fails and provide food security (Siritunga *et al*., 2004). In Bangladesh, tribal people of Madhupur, Garo Hill, Natrokona and Chittagong Hill Tract region locally grows and eat cassava. There is a good potentiality of cultivating and introducing this crop to other areas in Bangladesh. Private entrepreneurs like 'Rahman and Chemical Co.' and 'Bharsha group' have also been producing cassava in the country through contact farmers in Comilla, Tangail and Chittagong Hill Tracts and utilising tuber for starch, glucose and glucose syrup production. There is no reliable statistics of areas and production in Bangladesh.

Dry matter (DM) determination in different genotypes of cassava is important since nutrition and energy calculation is based on magnitude and nature of DM content. Higher DM content naturally would provide greater yield once partition of the same is increased to the economic part. Boerboom (1978) and Islam *et al.* (2008) investigated dry weight of plant parts and observed that leaf, stem and tuber contained 30-60% DM. Cassava tuber contains about 70% moisture, 20-30% carbohydrate, 1.0-1.8% crude protein, 1.5-3.5% crude fiber, 0.35-0.45% fat and 8-28 mg HCN/kg of dry mass (Purseglove, 1988; Charles *et al.,* 2005). Cassava plant parts are rich source of vitamins and minerals. Though tuber is the main product of cassava plant, its young branch and leaf is also edible both for human and animal (Fakir *et al*., 2010). Tuber is the main source of starch and minerals; leaf is the rich source of protein, vitamins and minerals. Cassava flour (10-30%) in combination with wheat flour is used in bread industry to reduce pressure on wheat (Grace, 1977). Therefore, cassava flour along with mixture with wheat flour can be used to make nutritious food and food products. Its tuberous root contains (fresh weight basis) 30-40% dry matter (DM) and 25-30% starch. Nutritionally, cassava contains potassium, iron, calcium, vitamin A, folic acid, sodium, vitamin C, vitamin B-6, and protein (Montagnac *et al*., 2009). Nutritional quality especially protein can be added in composite flours (tapioca) in cassava-soya, cassava-peanut bread. The protein content of 'tapioca' is about 10% and the macaroni is nearly twice as nutritious as rice (Grace, 1977). Supplemental use of cassava flour and starch in combination with wheat flour may reduce pressure and thus would enhance food security in Bangladesh.

Cassava flour is used for making bread and other products like Chips, jam, jelly and chutneys. Flour extraction from cassava tuber depends on reduction of moisture. Cassava drying aims at reducing its water content to less than 15%. IITA (2005) cites four factors that influence drying of cassava (chips flour and starch). These are temperature, airflow, humidity and tumbling frequency. Starch from cassava tuber can be extracted in two simple, wet and sun dry, methods. In the wet method, fresh tubers are blended with adequate water and the filtrate is decanted to starch. The starch obtained is then dried in the sun and is ready for use. In wet method fresh tubers are certainly be used for flour production immediately after harvest, within 72 hrs, since fresh roots deteriorates quickly. In sun dry methods, fresh tubers are chopped into small pieces and are sun dried until desirable moisture content is achieved. The dried cubes are ground and milled into flour. The methods of flour extraction, therefore, also influence the degree of detoxification.

All parts of the cassava plants contain cyanogens that are hydrolyzed to hydrocyanic acid (HCN) that escapes into the air during harvesting and processing (Bokanga *et al*., 1994; Fakir *et al*., 2009). At harvest of cassava tubers, the amount of HCN acids varies from harmless to lethal. The lethal dose of HCN is 50mg/kg fresh weight. Hydrolysis of glycoside by the enzyme can be accelerated by soaking the roots in water, by crushing or cutting them or by heating. HCN content of cassava roots could thus be reduced to a great extent by treating in such ways (Fakir *et al*., 2010). Although literatures on botany, physiology, nutrient content and HCN is available at home and abroad (Grace, 1977; Alves, 2002; Anonymous, 2004; Charles *et al.*, 2005; Islam *et al*., 2008; Fakir *et al*., 2009, 2010, 2011), there is scanty information in Bangladesh on methods of flour and starch production and proximate composition of cassava tuber (Jannat, 2011; Fakir *et al.*, 2012). So it was necessary (i) to estimate the dry matter content of plant parts; (ii) to investigate the methods of flour/starch extraction; and (iii) to determine the proximate composition of tuber of seven cassava accessions.

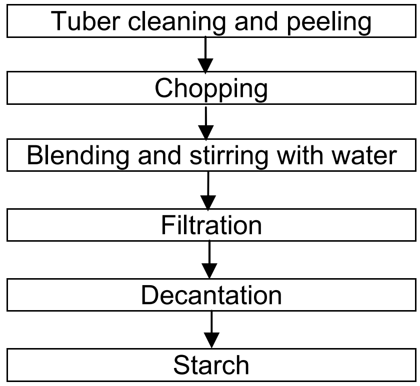
Materials and Methods

Plant establishment: The experiment was conducted at the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh during November, 2010 to October, 2011. Healthy and uniform size (about 15cm with 5 to 6 nodes) 8 months old stem cuttings of seven cassava accessions (Coc-A_1; Kh-A_2; Cow-A_3; Sa-A_4; Me-A_5; Va-A_6 and Sy-A_8) were planted at 1m x 1m spacing in 16 m^2 plots. Stem cuttings were, collected from previous experiment, planted horizontally at 10 to 12 cm soil depth with one cutting per hole. The cuttings were treated for ten minutes with the fungicides ‘Bavistin’ @ 5 g/10 L before planting. Seven treatments (seven accessions) were planted in a randomized complete block design (RCBD) with four replications.

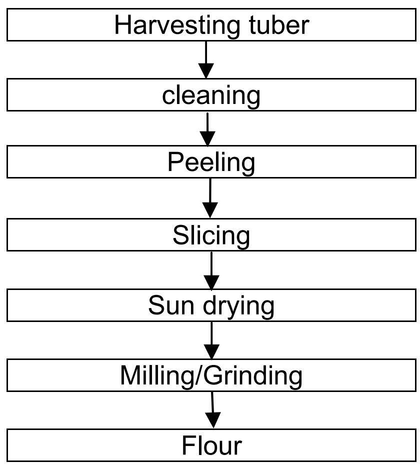
Crop sampling and harvesting: After 10 months, four plants excluding border ones were randomly selected from each plot and harvested, cleaned and brought to the laboratory for further observations.

Peeling and dry matter content: After harvest, tubers were peeled and cut into small cubes (2 cm long and 0.5 cm wide) for dry matter content. The dry matter contents of the different plant parts of cassava were determined by Benesi *et al.* (2004). The samples were sun dried following oven drying (65°C for 72 h) until constant weight and cooled in desiccators and weighed immediately. The drying and weighing steps were repeated until consecutive constant weights were achieved.

Starch extraction: Starch was extracted using the wet method described by Benesi *et al.* (2004). Fresh tubers were washed, peeled, chopped into approximately 1 cm cubes and then pulverized in a high-speed blender (Model KING, Osaka, Japan) for 5 min. The pulp was suspended in ten times its volume of water, stirred for 5 minutes and filtered using double fold cotton cloth. The filtrate 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 again for 5 minutes. Filtration was repeated as before and the starch from the filtrate was allowed to settle. After decanting the top liquid, the sediment (starch) was sun dried for 24 h and stored. The starch of peel was also extracted by the same procedure. Following is flow diagram of starch extraction.



Dry matter (DM) content of starch, pulp and flour: DM content of starch was determined by the same procedure described earlier. The pulp (broken tissue plus fibers in moistened condition) after filtration was also sun dried and kept at 10-12% moisture for making flour. Flour was obtained after grinding dried pulp followed by sieving. Following is the flow diagram for flour production:



Tubers proximate composition: Crude protein (CP), crude fiber (CF), crude fat (EE), total carbohydrate (NFE) and ash were determined by AOAC (1990) and hydrogen cyanide (HCN) by Grace (1977).

Data collection and analysis: The data were compiled and analyzed to find out the statistical significance. The means for all the collected data were calculated and the mean differences were evaluated by Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

Dry matter (DM) content of plant parts

Peel*:* The dry matter content of peel varied significantly ($P \leq 0.05$) among the seven cassava accessions and it was greater in Coc-A_1, Kh-A_2 and Me-A_5 (average of 24.58%) than in the Sa-A_4 and Cow-A_3 (average of 21.72%), Va-A_6 (18.99%) and Sy-A_8 (16.62%) (Table 1). **Tuber:** The tuber DM content varied significantly ($P \leq 0.05$) from 37.30% in Kh-A_2 to 45.26% in Sy-A_8 (Table 1). It was greater in Sy-A_8 (45.26%) than Va-A_6 (43.79%), Cow-A_3, Coc-A_1, Sa-A_4 and Me-A_5 (average of 41.08%) and Rh-A_2. (37.30%). On an average, tuber contained 41.53% DM i.e. 58.47% water in the current research. **Stem:** Stem DM content was greater in Sa-A_4, Sy-A_8 and Me-A_5 (average of 32.10%) than Coc-A_1 (29.97%) Cow-A_3 (28.72%) and Va-A_6 (27.24%) (Table 1). **Petiole:** The DM content of petiole varied significantly ($P \leq 0.05$) with greater magnitude in Cow-A_3 (31.91%) than in Va-A_6 (29.32%), Kh-A_2 (28.02%), Me-A_5 and Coc-A_1 (average of 26.42%) and Sa-A_4 (21.66%) (Table 1). **Leaf lobe:** Leaf lobe DM varied from 20.51% in Me-A_5 to 29.01% in Sy-A_8. The dry matter content of Leaf lobe was significantly greater in Sy-A_8 (29.01%) than Coc-A_1 and Cow-A_3 (average of 26.97%), Va-A_6 (24.36%), Kh-A_2 and Sa-A_4 (average of 22.50%) and Me-A_5 (20.51%) (Table 1).

Table 1. Dry matter (DM) content of plant parts of seven cassava accessions

Accessions	Dry Matter content (%)				
	Peel	Tuber	Stem	Petiole	Leaf lobe
Coc-A_1	24.79 a	41.38 c	29.97 b	26.81d	27.28 b
Kh-A_2	24.20 a	37.30 d	29.10 bc	28.02 c	22.79 d
Cow-A_3	21.85 b	40.88 c	28.72 c	31.91 a	26.67 b
Sa-A_4	21.59 b	40.58 c	32.64 a	21.66 e	22.22 d
Me-A_5	24.75 a	41.49 c	31.80 a	26.04 d	20.51 e
Va-A_6	18.99 c	43.79 b	27.24 d	29.32 b	24.36 c
Sy-A_8	16.62 d	45.26 a	31.88 a	29.12 bc	29.01 a
Mean	21.83	41.53	30.19	27.55	24.69

In a column, numbers followed by different letters differ significantly at $P \leq 0.05$ by DMRT

Genetic variations for DM content of plant parts existed in the current research. Howeler and Cadavid (1983), Boerboom (1978) and Islam *et al.* (2008) also noted genetic variation for DM in different cassava accessions. Mean DM content was greater in tuber (41.53%) than stem (30.19%), petiole (27.55%), leaf lobe (24.69%) and peel (21.83%) (Table 1). Boerboom (1978) and Islam *et al.* (2008) also observed similar results in fewer accessions. Howeler and Cadavid (1983), however, observed higher DM of tuber (50-60%). This difference could be due to variation in genotype and locations between the experiments.

Dry matter (DM) content of starch, pulp and flour

Starch: The DM content of starch of cassava varied significantly ($P \leq 0.05$) among the seven accessions and it was greater in Sa-A_4 (88.11%) than in Kh-A_2 and Me-A_5 (average of 86.90%), Cow-A_3 (84.97%), Coc-A_1 (83.12%) (Table 2). **Pulp:** The DM content of pulp varied significantly ($P \leq 0.05$) among the seven cassava accessions and it was greater in Coc-A_1, Cow-A_3 and Kh-A_2 (average of 90.76%) than in Sa-A_4 and Me-A_5 (average of 86.2%), Va-A_6 (85.16%) and Sy-A_8 (81.72%) (Table 2). **Flour:** The DM of flour varied from 80.38% in Va-A_6 to 89.35% Kh-A_2 (Table 2). It was greater in Kh-A_2 (89.35%) than in Coc-A_1 (88.08%), Cow-A_3 and Me-A_5 (average of 85.88%) and Sa-A_4 (84.77%) (Table 2).

Table 2. Dry matter content of tuber, starch, pulp and flour in seven cassava accessions

Accessions	Dry matter content (%)		
	Starch	Pulp	Flour
Coc-A_1	83.12 d	92.41 a	88.08 b
Kh-A_2	86.73 b	90.95 a	89.35 a
Cow-A_3	84.97 c	90.93 a	85.97 c
Sa-A_4	88.11 a	85.35 bc	84.77 d
Me-A_5	87.08 ab	87.05 b	85.80 c
Va-A_6	82.35 de	85.16 c	80.38 e
Sy-A_8	81.92 e	81.72 d	80.48 e
Mean	84.90	87.65	84.98

In a column, numbers followed by different letters differ significantly at $P \leq 0.05$ by DMRT

Preparation of cassava products such as flour, pulp, starch, chips, pellets etc. depends on DM content. Therefore, DM determination of starch, pulp and flour is important. Generally, 10-12% moisture i.e. 88-90% DM is good for flour production (IITA, 2005). However, in the current research flour moisture content varied from 10-20%. It could be due to improper drying in the sun. For short term storage flour must be dried within the stipulated range.

Peeling ratio, starch and flour yield, and HCN content of tuber

Peeling ratio: Weight of the peel to tuber i.e. peeling ratio of cassava tuber varied significantly ($P \leq 0.05$) among the seven cassava accessions and it was greater in Coc-A_1 and Sa-A_4 (average of 19.62%) than in Me-A_5 (17.79%), Kh-A_2 (16.42%), Sy-A_8 (14.40%) and Va-A_6 (12.91%) (Table 3). **Starch content:** Tuber starch content varied from 15.04% in Sy-A_8 to 25.05% in Coc-A_1. It was significantly greater in Coc-A_1 and Me-A_5 (average of 24.97%) than Kh-A_2 and Cow-A_3 (average of 21.73%), Sa-A_4 and Va-A_6 (average of 17.19%) and Sy-A_8 (15.04%) (Table 3). **Peel starch content:** The Starch content of peel of cassava and it was greater in Coc-A_1 (5.85%) than in Cow-A_3, Sa-A_4 and Me-A_5 (average of 5.32%), Kh-A_2 (5.19%), Sy-A_8 (4.85%) and Va-A_6 (4.54%) (Table 3). **Flour Yield:** Flour content varied from 101.89 g/kg (average of Kh-A_2, Cow-A_3 and Va-A_6) to 201.86 g/kg (in Sy-A_8). It was significantly greater in Sy-A_8 (201.86 g/kg) than Coc-A_1, Sa-A_4 and Me-A_5 (average of 162.44 g/kg) and Kh-A_2, Cow-A_3 and Va-A_6 (average of 101.89 g/kg) (Table 3).

Tuber HCN content: The HCN content of fresh tuber varied significantly ($P \leq 0.05$) among the seven cassava accessions (Table 3). It was greater in Va-A_6 (546.0 mg/kg fresh weight) than in Sa-A_4 (324.0 mg/kg fresh weight), Cow-A_3 (244.4 mg/kg fresh weight), Kh-A_2 and Me-A_5 (average of 215.6 mg/kg fresh weight) and Sy-A_8 and Coc-A_1 (average of 140.95 mg/kg fresh weight) (Table 3).

Table 3. Peeling ratio, starch and flour yield, and hydrogen cyanide (HCN) contents (fresh wt. basis) in seven cassava accessions

Accessions	Peeling ratio (peel to tuber)	Starch % (fresh wt.)		Flour yield (g/kg)	Tuber HCN (mg/kg)
		Tuber	Peel		
Coc-A_1	19.89 a	25.05 a	5.85 a	162.03 b (16.20)$^+$	137.20 e
Kh-A_2	16.42 c	21.56 b	5.19 c	107.59 c (10.76)	217.01 d
Cow-A_3	17.35 bc	21.91 b	5.30 b	098.14 c (09.81)	244.42 c
Sa-A_4	19.35 a	17.61 c	5.27 b	166.35 b (16.63)	324.06 b
Me-A_5	17.79 b	24.90 a	5.54 b	158.94 b (15.89)	214.28 d
Va-A_6	12.91 e	16.78 c	4.54 e	99.94 c (09.99)	546.01 a
Sy-A_8	14.40 d	15.04 d	4.85 d	201.86 a (20.18)	144.70 e
Mean	16.87	20.41	5.22	142.12 (14.20)	261.04

In a column, numbers followed by different letters differ significantly at $P \leq 0.05$ by DMRT, +: Figures within parenthesis indicate percentage flour yield

Genetic variation for tuber mean starch content (15.04-25.05 %) was observed in the current study (Table 3). This supports the results of Sajeev *et al.* (2003) who also observed variations in starch (20-25 %) in fresh tuber. Of the 100 g fresh tuber, there were 20.41 g starch, 14.20 g flour and the rest, 65.39 g water on mean weight basis (Table 3). On fresh weight basis, current cassava starch yield was greater (7.25 t/ha, mean of seven accessions, data not shown) than potato and sweet potato (6 t/ha), rice (3.2 t/ha), corn (2.5 t/ha) and wheat (2.4 t/ha) (Jannat, 2011). Variation also existed for HCN content in tuber. Lethal dose of HCN is 50 mg/kg fresh weight. But HCN could almost be removed by proper processing. HCN produced during harvesting, chopping, boiling, drying, blending and other postharvest operations are almost removed (Bokanga *et al*., 1994; Fakir *et al.*, 2009, 2010). The flour and starch thus produced was free of toxicity since HCN was not detected there.

Tuber proximate composition

Crude protein: The crude protein was greater in Va-A_6 (4.53%) than in Coc-A_1 and Sa-A_4 (average of 2.92%), Kh-A_2, Cow-A_3 and Sy-A_8 (average of 1.80%) (Table 4). **Crude fiber:** Crude fiber content significantly varied from 1.95% in Coc-A_1 and Sa-A_4 to 4.27% in Cow-A_3 (Table 4). It was significantly greater in Cow-A_3 (4.27%) than Coc-A_1 and Sa-A_4 (average of 1.95%). **Crude fat (**Etheral extract, EE**):** EE content of cassava varied significantly ($P \leq 0.05$) and it was greater in Va-A_6 (1.87%) than Sa-A_4 (0.80%) (Table 4). **Ash:** The ash or mineral content of cassava varied significantly ($P \leq 0.05$) among the seven accessions and it was greater in Me-A_5 and Va-A_6 (average of 5.53%) than Cow-A_3 and Kh-A_2 (average of 3.65%) (Table 4). ***Total Carbohydrate*** **(**Nitrogen free extract, NFE**):** The NFE content of cassava tuber varied significantly ($P \leq 0.05$) among the seven accessions (Table 4). It was greater in Kh-A_2 (91.10%) than in Me-A_5 (87.92%) and Va-A_6 (84.35%) (Table 4).

Cassava tuber is used as staple food, feed and vegetables (Grace, 1977; Charles *et al.*, 2005; Fakir *et al*., 2010). Proximate composition such as crude protein, crude fiber, crude fat, ash and NFE of tuber is important. (Hang *et al*., 2007). Genetic variation for proximate composition in seven accessions was observed and therefore, selection for genotype with good nutrients is possible. High protein (4.53%) in Va-A_6 may not be useful since it also contained high HCN (546 mg/kg fresh wt.). However, nature and duration of processing like chopping, threshing, boiling etc. reduces as much as 95% HCN (Montagnac *et al*., 2009; Fakir *et al*., 2009, 2010). Therefore, processing is important in this case. Genetic variations for DM content of plant parts; and flour, starch and HCN content of tuber existed. There is, therefore, opportunity for selection of improved genotype(s) for higher DM, flour and starch yield. Further, selected genotypes could be used as parent(s) to develop high yielding varieties. It appears that the Coc-A_1 would be a better accession based on DM and nutrients contents.

Table 4. Proximate composition of tuber of seven cassava accessions

Accessions	Proximate composition of tuber (%)				
	Crude protein	Crude fiber	Crude fat	Ash	NFE[†]
Coc-A_1	2.83b	1.66c	1.52ab	4.55ab	89.42bc
Kh-A_2	1.92c	2.45bc	1.18abc	3.84b	91.18a
Cow-A_3	1.68c	4.27a	1.44abc	3.47b	89.12bc
Sa-A_4	3.01b	2.24c	0.80d	4.04ab	89.90ab
Me-A_5	2.56bc	2.88bc	1.33abcd	5.47a	87.92c
Va-A_6	4.53a	3.60ab	1.87a	5.60a	84.35d
Sy-A_8	1.81c	2.65bc	0.86cd	4.41ab	90.26ab
Mean	2.62	2.82	1.29	4.48	88.88

In a column, numbers followed by different letters differ significantly at $P \leq 0.05$ by DMRT, [†]**:** Nitrogen free extract

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