



Asian Journal of **Poultry Science**

ISSN 1819-3609



Academic
Journals Inc.

www.academicjournals.com

Variation in Nutrient Composition of Cassava Pulp and its Effects on *in vitro* Digestibility

¹N. Chauynarong, ¹M.M. Bhuiyan, ²U. Kanto and ¹P.A. Iji

¹Department of Animal Science, Woolshed Building (W49), School of Environmental and Rural Science, University of New England, Armidale NSW 2351, Australia

²Department of Animal Science, Kasetsart University, Kamphaengsaen Campus, Nakhon Pathom, Thailand

Corresponding Author: P.A. Iji, Department of Animal Science, Woolshed Building (W49), School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia

ABSTRACT

The objective of this study was to evaluate the variation in nutrient composition of cassava pulp from four different sources (starch manufacturers) in Thailand. Moisture content varied with drying process, being lowest in the oven-dried product and highest in the sample that was sun-dried. Gross energy content ranged between 16.2 and 16.84 MJ kg⁻¹ while fat, crude protein starch contents were approximately 0.4-0.9, 2.0-4.0 and 37.0-75.0%, respectively. The sun-dried pulp from Chonburi contained the highest concentration of calcium, sodium, magnesium, iron and manganese. Phosphorus and potassium were 0.32-0.63 and 2.28-8.86 mg kg⁻¹, respectively. The amino acid contents in cassava pulp were low, in line with the protein content (1.39-2.45%). Lysine, methionine and isoleucine were 0.82-1.24, 0.06-0.18 and 0.54 -1.40 mg g⁻¹, respectively. Most of the Non-Starch Polysaccharides (NSP) were in insoluble forms (approximately 40-90 g kg⁻¹) whereas soluble NSP was between 13.93 and 16.21 g kg⁻¹. The main sugars in the insoluble NSP were xylose, galactose and mannose.

Key words: Cassava pulp, starch manufacturing, nutritive value, non-starch polysaccharides

INTRODUCTION

Cassava (*Manihotesculenta* Crantz), is one of the most important crops in Thailand, after rice and sugarcane. Cassava starch production is a huge and growing industry in the country, with approximately 10 million tonnes of fresh cassava roots used annually (Chauynarong *et al.*, 2009a). Starch extraction also yields cassava pulp as a by-product, which constitutes approximately 30% of the original weight of roots. Approximately 1.5-2.0 million tonnes of cassava pulp are produced annually from the entire cassava starch industry. Cassava roots and other parts of the plant, especially leaves, are used as animal feed, particularly in Asia and Africa (Chauynarong *et al.*, 2009b).

Fresh cassava pulp, which is delivered at the end of the cassava starch production process contains approximately 60-75% moisture and 50% starch on a dry matter basis due to the inextricable starch trapped inside the cell of cassava roots (Ukita *et al.*, 2006). The fresh cassava pulp is normally sun-dried to a moisture content of 10-13% and commonly used as animal feed. The nutritional quality of cassava pulp is variable, depending on a number of factors including the starch extraction process, cassava cultivars cultivation practices adapted by farmers (Bede, 2010; Chavez *et al.*, 2005).

Starch quantity and quality in cassava is affected by the conditions of the cassava during growing and harvesting (Tonukari, 2004; Chauynarong *et al.*, 2009a). Drought during the early establishment period results in roots with low dry weight and starch content. Onset of rain after an extended dry period results in starch with different characteristics. Moreover, the application of potassium fertilizer is advantageous to root quality, stimulating dry matter and starch accumulation (Sriroth *et al.*, 2000). The nutrients content of cassava pulp produced in Thailand may be variable due to these factors and conditions in various parts of the country. This study was therefore conducted to evaluate the variation in nutrients content and *in vitro* digestibility of dried cassava pulp produced in different areas of Thailand.

MATERIALS AND METHODS

A total of four cassava pulp samples from Northeast and Eastern parts of Thailand were obtained. Two samples, one sun-dried (Chacho-sun) and other, oven-dried (Chacho-oven), were obtained from Chachoengsao province; a sun-dried sample came from Chonburi and a pellet form was from Kalasin (Kalasin). The samples were ground to pass through a 1 mm sieve and subjected to proximate and detailed analyses as described below.

Proximate analyses: Dry matter and crude fat contents were determined according to the AOAC (1984) method. The Gross Energy (GE) was determined for individual samples of cassava pulp using an IKA® bomb calorimeter. The chamber was calibrated for the heat of combustion of 0.6 g benzoic acid (26.53 KJ g⁻¹). Approximately, 0.50 g of sample was used for determination of GE in this system.

Detailed analyses: Quantitative amino acid analysis of the cassava pulp samples was done at the Australian Proteome Analysis Facility Ltd, Macquarie University. The cassava pulp samples underwent a 24 h liquid hydrolysis in 6 M HCl at 110°C. After hydrolysis all amino acids were analyzed using the Water Acc QTag Ultra chemistry. The samples were analyzed in duplicate and results were expressed as average.

Total starch and resistant starch in the cassava pulp samples were determined by the “Megazyme” total starch assay, using the enzyme procedure adapted from McCleary *et al.* (1994). Resistant starch was calculated from the equation:

$$\text{Resistant starch (\%)} = \text{Total starch (\%)} - \text{Enzyme digestible starch (\%)}$$

Amylose/amylopectin ratio was determined following the Megazyme amylose/amylopectin assay (Megazyme International Ireland, Bray Business Park, Bray, Ireland) using the selective quantitative precipitation reaction of con-canavalin A (Con A) with amylopectin (Gibson *et al.*, 1997) and by the colorimetric method of iodine binding with amylose (Chrastil, 1987). The mineral contents of the samples were determined, using the microwave digestion technique. The sample was dried and subjected to acid digestion in closed vessel rotor using temperature-controlled microwave heating in a one-step process. Subsequent metal determination was carried out using an Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). The soluble and insoluble NSP in the cassava pulp samples were measured as described by Englyst and Hudson (1993) and Theander and Westerlund (1993).

Determination of *in vitro* nutrient digestibility: *In vitro* digestibility was carried out according to the method described by Babinsky *et al.* (1990), with slight modifications. The ground cassava pulp samples, around 1 g each were digested in triplicate in 12.5 mL of pepsin/HCl solution (4 g of pepsin in 0.1 M HCl, pH 1) and the sample was incubated at 40°C for 1.5 h. Then the sample was dissolved in 2 mL of NaHCO₃ and 12.5 mL of potassium phosphate buffer (pH 6.8) containing 4 g of pancreatin and 4 mL of amylase per litre. The mixture was incubated at 40°C for 3 h. The resultant mixture was dissolved in 2.5 mL of NaCO₃, centrifuged at 9500× g for 30 min and freeze-dried. Protein content was measured using the Kjeldahl method. Digestibility of dry matter, starch and protein was calculated as follows:

$$\text{Digestibility (\%)} = \frac{A - B \times 100}{A}$$

where, A = total weight or percentage of starch or crude protein of sample, B = weight of dry matter, starch or crude protein.

Determination of cyanide content: Determination of HCN content in the cassava pulp samples was done by the Central Laboratory (Thailand) Co., Ltd. The samples were dried, ground and subjected to HCN analysis by the colorimetric digestion method using pyridine and barbituric acid, according to the standard methods for the examination of water and wastewater (APHA, AWWA and WPCF., 2005).

RESULTS AND DISCUSSION

Proximate composition of cassava pulps: The nutrient composition of the samples, including Dry Matter (DM), Gross Energy (GE), ether extract, Crude Protein (CP) and Crude Fibre (CF), is shown in Table 1. The DM, GE, fat, CP and crude fibre contents were 868.7-892.2 g kg⁻¹, 16.42-17.18 MJ kg⁻¹, 1.2-4.8 g kg⁻¹, 13.9-24.5 g kg⁻¹ and 104.0-186.4 g kg⁻¹, respectively. Chacho-oven had the lowest CP content while Kalasin was the highest. Kalasin also had the highest fibre content, 186.4 g kg⁻¹, followed by Chonburi, 144.3, Chacho-oven, 119.1 and Chacho-sun, 104.0 g kg⁻¹, respectively. Chacho-oven was higher in GE than the other samples.

The DM content of cassava can differ depending on age of plant, season and location, with temperature factor related to location as an important (Kawano *et al.*, 1987). Dzisi and Wirth (1994) have reported that artificial dryers (deep-bed crop dryer) take 34 h to dry cassava chips from 645.7-108.3 g kg⁻¹ moisture content while sun drying takes about 150 h to dry chips from 596.3-108.3 g kg⁻¹ moisture content. Cassava pulp would require shorter drying times, being lighter and fluffier than chips. The gross energy content was 16.4-17.2 MJ kg⁻¹, which is similar to the value presented in a previous report by Nitipot *et al.* (2009).

Table 1: Nutrient composition of cassava pulp from four different sources

Sources (g kg ⁻¹)	Dry matter	GE (MJ kg ⁻¹)	Fat	CP	CF
Chacho-sun	881.0	16.63	4.8	19.5	104.0
Chacho-oven	868.7	17.18	3.7	13.9	119.1
Chonburi	892.2	16.61	3.6	17.0	144.3
Kalasin	884.6	16.42	1.2	24.5	186.4

DM: Dry matter, GE: Gross energy, CP: Crude protein, CF: Crude fibre

Table 2: Total starch, amylose and amylopectin contents in cassava pulp samples

Samples source (g kg ⁻¹)	Total starch content		Amylose content		Amylopectin content	
	Fresh basis	DM basis	Fresh basis	DM basis	Fresh basis	DM basis
Chacho-sun	353.0	421.0	122.3	156.0	252.9	265.0
Chacho-oven	434.3	645.0	166.8	221.4	394.5	423.6
Chonburi	407.2	539.3	152.8	191.2	331.4	348.1
Kalasin	380.2	403.3	104.6	133.8	254.5	296.5

Starch concentration and composition: The starch contents were 353.0, 434.3, 407.2 and 380.2 g kg⁻¹ in Chacho-sun, Chacho-oven, Chonburi and Kalasin samples, respectively (Table 2). Amylose content on fresh basis was highest in the Chacho-oven sample, with 166.8 g kg⁻¹, while the lowest was 104.6 g kg⁻¹ from the Kalasin sample. Amylopectin content was 252.9-394.5 g kg⁻¹ (on fresh basis) and 265.0-423.6 g kg⁻¹ (on DM basis). Chacho-oven had higher resistant starch than Chonburi (a difference of 77.8 g kg⁻¹), whereas Chonburi sample had higher resistant starch than Chacho-sun (97.6 g kg⁻¹ difference).

Although, the cassava pulp sample from Chachoengsao (oven-dried) contained a high level of starch (43.4%), the *in vitro* starch digestibility was low at only 47.8% due to a high content of resistant starch. The lowest resistant starch was found in Chacho-sun, with 25.3%. Resistant starch has been defined as the sum of starch and products of starch degradation that are not absorbed in the small intestine of animals (Asp, 1992). Starch with high amylose content is often considered to be less digestible (Oates, 1997). In this study, the average concentration of amylose and amylopectin from the four different sources of cassava pulp was 30 and 70%, respectively. Difference in plant species and origin can cause variation in concentration of amylose and amylopectin. Generally, cereal starch is approximately 28% amylose and 72% amylopectin, while cassava root starch has approximately 20% amylose and 80% amylopectin (Aberle *et al.*, 1994; Hoover, 2001). However, the proportion of amylose to amylopectin and structure of amylose and amylopectin in cassava starch can be different depending on the harvest period and varieties of cassava, which can affect gelatinization temperature and final viscosity (Asaoka *et al.*, 1992). In this study cassava pulp was found to have less amylopectin when compared with cassava root. These results can be due to the process of starch extraction solubilises amylopectin more easily, so less is still in the pulp.

Non-starch polysaccharides: Total soluble NSP ranged from 0.78 g kg⁻¹ in the Chacho-oven to 30.14 g kg⁻¹ in the Kalasin samples (Table 3). Galactans, arabans and glucans were the predominant NSP, as evident from the nature of the sugars observed. There was a large variability in concentrations of the different sugars in the NSP, with a CV of 65.5% for arabinose to 84.6% for mannose. Xylans, galactans and glucans were the predominant types in the insoluble NSP fraction (Table 4). Total insoluble NSP was between 67.2 g kg⁻¹ in Chacho-sun to 84.3 g kg⁻¹ in Chacho-oven. The insoluble NSP concentration was less variable than the soluble NSP fraction; the latter showing a CV of only 11.0-36.9%.

Water-insoluble NSP are mostly indigestible by poultry while soluble NSP have the potential to be digested in birds' intestine, however, soluble NSP are found to increase gut viscosity which can affect the growth and performance of birds (Austin *et al.*, 1999; Naqvi and Nadeem, 2004). Water-soluble NSP in maize and soybean meal are approximately 8.4 and 9.8%, respectively (Meng and Slominski, 2005). Cassava pulp might create minimal problems of gut viscosity due to low level of water-soluble NSP, as shown in the present study, most of the NSP being insoluble. Sriroth (1977) suggested that to shorten the time of the starch hydrolyzation, mixed enzymes of

Table 3: Soluble NSP content of the cassava pulp samples from various sources

Sources (g kg ⁻¹)	Chacho-sun	Chacho-oven	Chonburi	Kalasin	Mean±SD	CV (%)
Rhamnose	2.83	0.08	1.55	3.19	1.91±1.41	73.7
Fructose	0.08	0.00	0.06	0.07	0.05±0.04	67.5
Arabinose	3.23	0.23	2.69	4.22	2.59±1.70	65.5
Xylose	0.35	0.00	0.15	0.30	0.20±0.16	79.1
Mannose	1.15	0.16	1.06	1.76	0.95±0.80	84.6
Galactose	16.53	0.63	10.76	18.14	11.51±7.92	68.8
Glucose	3.04	0.14	2.73	5.94	2.96±2.37	80.1
Total soluble NSP	24.39	0.78	17.00	30.14	18.08±12.72	70.4

Mean±SD: Mean±Standard Deviation, CV: Coefficient of variation, NSP: Non-starch polysaccharides

Table 4: Insoluble NSP content of the cassava pulp samples from various sources

Sugars (g kg ⁻¹)	Chacho-sun	Chacho-oven	Chonburi	Kalasin	Mean±SD	CV (%)
Rhamnose	2.04	2.57	2.16	2.49	2.32±0.25	11.0
Fructose	2.21	1.73	1.77	2.56	2.07±0.39	19.1
Arabinose	8.37	13.31	9.75	9.80	10.31±2.11	20.5
Xylose	29.11	17.21	21.34	26.73	23.60±5.36	22.7
Mannose	4.02	2.75	3.61	3.94	3.58±0.58	16.2
Galactose	18.41	43.88	28.74	25.43	29.12±10.75	36.9
Glucose	11.48	13.65	19.71	22.00	16.71±4.96	29.7
Total insoluble NSP	67.18	84.83	77.62	82.78	78.10±7.89	10.1

Mean±SD: Mean±Standard Deviation, CV: Coefficient of variation, NSP: Non-starch polysaccharides

α -amylase and glucoamylase are needed. The most common sugars found in cassava pulp were galactose and xylose. Thus, digestibility of cassava pulp in poultry would benefit from supplementation with microbial enzymes targeting galactans and xylans.

Minerals: The cassava pulp from Chonburi province was highest in calcium, sodium and magnesium concentrations. The lowest calcium was found in Chacho-oven, at 3.15 mg kg⁻¹ (Fig. 1). Phosphorus contents in Chacho-sun, Chacho-oven, Chonburi and Kalasin were 0.32, 0.27, 0.53 and 0.63 mg kg⁻¹, respectively. The sodium content in Chacho-oven was 0.60 g kg⁻¹, which was three times higher than the value in Chacho-sun. The highest sodium content was 1.20 g kg⁻¹, in the Chonburi sample. The average content of potassium was 3.02 mg kg⁻¹, with individual values ranging from 2.28-8.86 mg kg⁻¹. The concentrations of magnesium were similar in the Chacho-oven and Kalasin samples while the lowest level was found in Chacho-sun, with 0.83 mg kg⁻¹.

Iron and manganese were highest in the sample from Chonburi, followed by Kalasin while the lowest levels were found in Chacho-sun and Chacho-oven, which gave similar values (Fig. 2). The highest content of iron, 0.84 g kg⁻¹, was observed in the sample from Chonburi, while the lowest value, 0.17 g kg⁻¹, was in the Chacho-sun. Manganese contents in Chacho-sun, Chacho-oven, Chonburi and Kalasin were 23.49, 23.71, 49.99 and 44.79 mg kg⁻¹, respectively. Copper content in the cassava pulps ranged from 6.17-1.38 mg kg⁻¹. The highest copper level was found in Kalasin sample, four times higher than in Chacho-sun sample. The sample from Chonburi also had the highest level of molybdenum and zinc while Chacho-oven had the lowest values of both minerals, 0.43 and 8.4 mg kg⁻¹, respectively for molybdenum and zinc.

The macro mineral found in greatest concentration in the cassava pulp samples was sodium, while other macro minerals were low. In terms of micro minerals, the main one was iron and this was highest in the Chonburi sample and lowest in Chacho-sun. Soil conditions in different parts of Thailand and varieties of cassava can alter the mineral composition of cassava. In a study on five varieties of cassava, Charles *et al.* (2005) reported higher values of Ca, Mg, P, K, Na, Zn, Mn, Cu

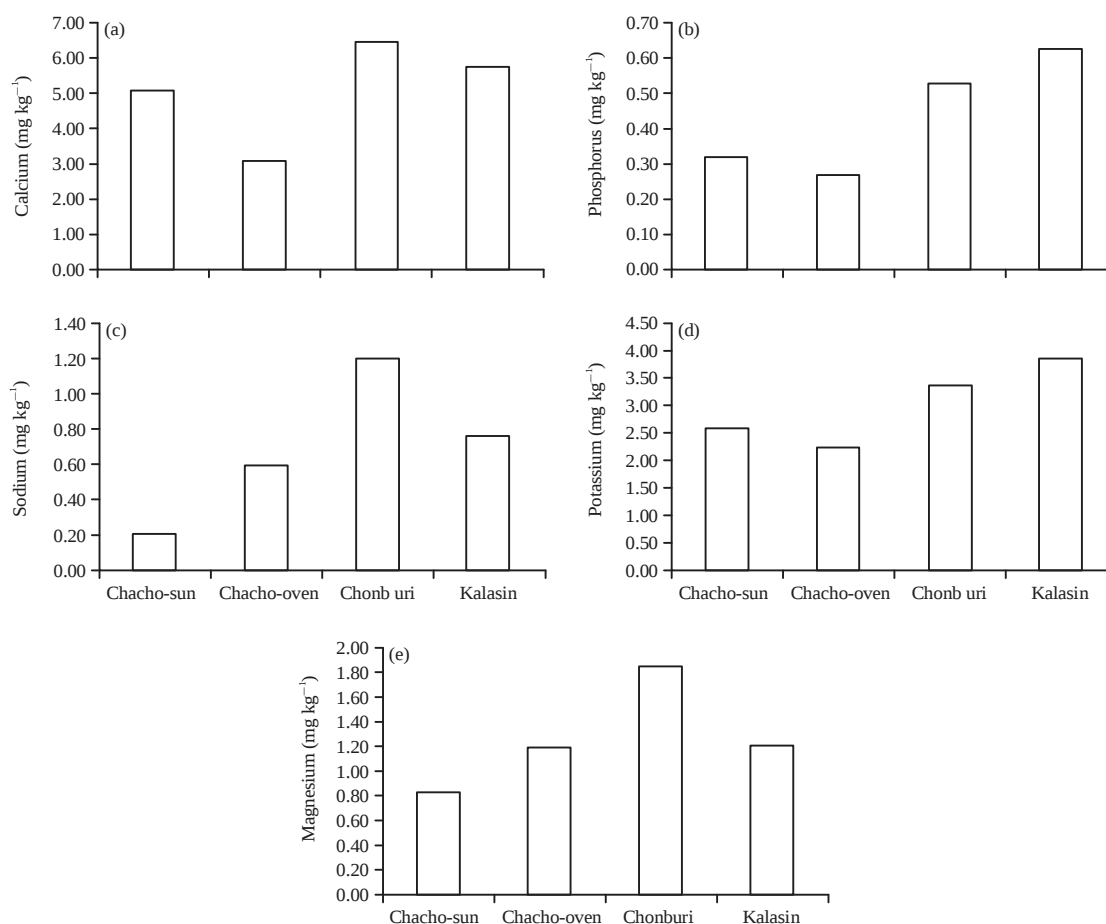


Fig. 1(a-e): Macro minerals in cassava pulp from four different sources of Thailand, (a) Calcium, (b) Phosphorus, (c) Sodium, (d) Potassium and (e) Magnesium

and Fe in whole cassava roots. However, after starch extraction, the mineral content tends to decrease, as reported by Khempaka *et al.* (2009) and supported by results from the current research.

Amino acids: The amino acid contents of the four samples are shown in Table 5. The major amino acids of importance were valine, histidine and arginine. The coefficient of variation varied from 18.10-87.43%. Lysine contents were 0.93, 0.82, 1.24 and 0.96 g kg⁻¹ in Chacho-sun, Chacho-oven, Chonburi and Kalasin, respectively. Methionine content ranged from 0.06 g kg⁻¹ in Chacho-oven, to 0.18 g kg⁻¹ in the sample from Chonburi province.

Amino acid contents in the cassava pulp were low due to the low protein content of the pulp. The values obtained in this study are similar to those of Khempaka *et al.* (2009). However, the variation in amino acid contents between the sources of cassava pulp was high and the CV ranged between 18 and 87%. The essential amino acids needed by poultry, such as lysine and methionine, were low, with values of 0.93-1.24 and 0.06-0.98 mg g⁻¹, respectively. Thus the use of cassava pulp at high level in poultry diet should be minimal and would require amino acid supplementation.

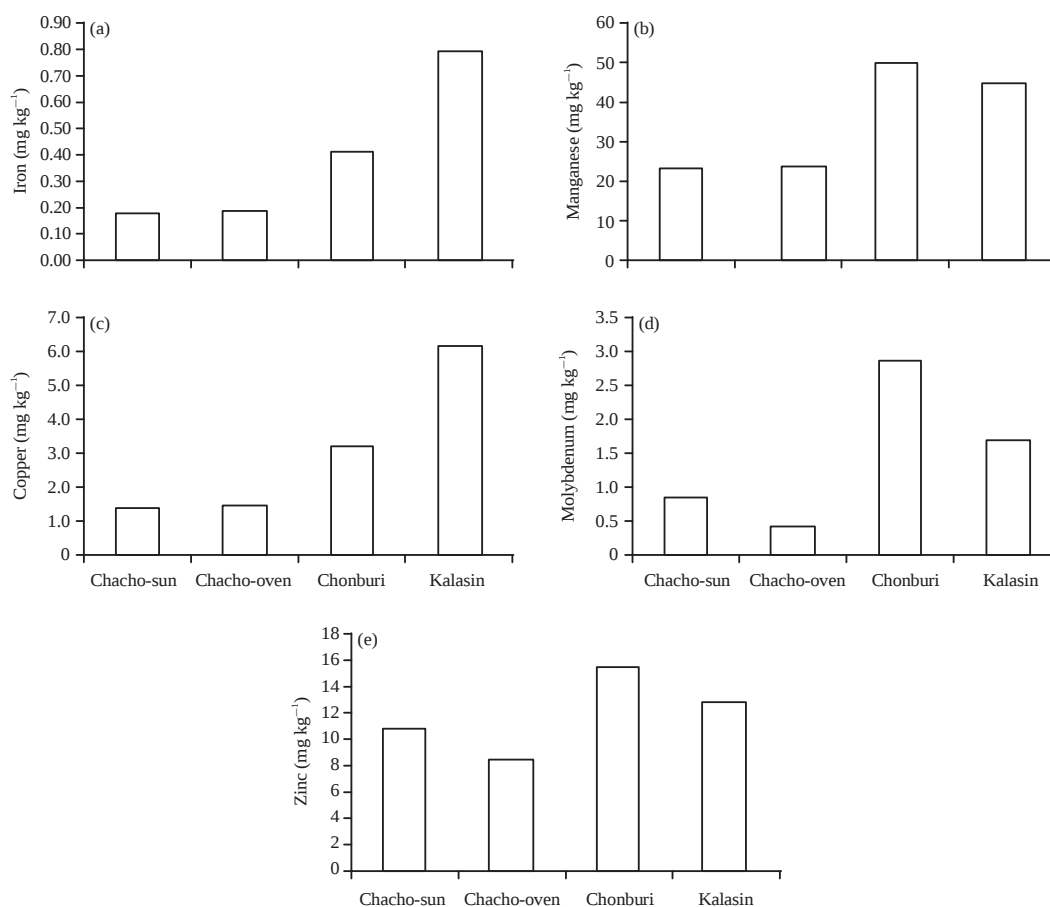


Fig. 2(a-e): Micro minerals (mg kg⁻¹) in cassava pulp from four different sources of Thailand, (a) Iron, (b) Manganese, (c) Copper, (d) Molybdenum and (e) Zinc

Table 5: Amino acid profiles of cassava pulp from four various sources in Thailand

Source of sample (g kg ⁻¹ DM)	Chacho-sun	Chacho-oven	Chonburi	Kalasin	Mean±SD	CV (%)
Histidine	0.67	2.75	0.79	0.56	1.19±1.04	87.43
Serine	0.62	0.97	1.26	0.77	0.91±0.28	30.58
Arginine	0.71	1.66	1.13	0.84	1.09±0.42	38.86
Glycine	0.68	0.71	1.47	0.94	0.95±0.37	38.48
Aspartic acid	1.22	1.38	2.59	1.85	1.76±0.61	34.92
Glutamic acid	1.39	1.68	3.09	2.26	2.11±0.75	35.61
Threonine	0.81	0.54	1.40	0.87	0.91±0.36	39.76
Alanine	0.83	0.48	1.70	1.08	1.02±0.51	50.30
Proline	0.55	0.53	1.43	0.79	0.83±0.42	50.94
Lysine	0.93	0.82	1.24	0.96	0.99±0.18	18.10
Tyrosine	0.17	0.17	0.50	0.24	0.27±0.16	58.09
Methionine	0.09	0.06	0.18	0.14	0.12±0.05	45.23
Valine	1.04	0.78	1.96	1.29	1.27±0.51	39.96
Isoleucine	0.68	0.54	1.40	0.97	0.90±0.38	42.32
Leucine	0.97	0.77	2.12	1.39	1.31±0.60	45.50
Phenylalanine	0.56	0.49	1.34	0.85	0.81±0.39	47.68

Mean±SD: Mean±Standard Deviation, CV: Coefficient of variation

Cyanide content: The lowest cyanide content was found in the sample from Chonburi, 0.86 mg kg⁻¹, followed by Chacho-oven, Chacho-sun and Kalasin with 2.90, 7.17 and 8.02 mg kg⁻¹, respectively (Fig. 3). The concentrations were generally lower than 50 ppm, the point that is

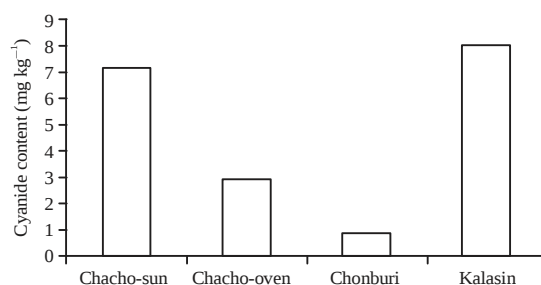


Fig. 3: Cyanide content in cassava pulp from four different sources of Thailand

considered to be harmful to animals (CFIA., 2005). Similar values were reported by Kemdirim *et al.* (1995) who stated that cassava products can be detoxified by fermentation process or sun drying. They reported that fermentation of cassava pulp for 96 h during cassava processing for grain, a by-product of cassava root, can reduce the cyanide content by 22 ppm (52.4%). Moreover, soaking of the sliced cassava tissue for 24 hours during cassava flour production prior to sun drying resulted in about 15-16 ppm (38%) reduction in HCN and about 5-6 ppm (14%) was lost during sun drying. Thus, the residual cyanide in gari was 10-12 ppm.

***In vitro* digestibility of dry matter, starch and protein:** The digestibility of DM was between 39.0 and 44.6%. Starch digestibility was 65.3, 54.8, 49.5 and 47.8% in the Chacho-sun, Chonburi, Kalasin and Chacho-oven sample, respectively. The *in vitro* digestibility of protein was highest in Chacho-sun, which was 89.9% while the lowest was 87.4% in the Chacho-oven sample.

Potato and legume starches display lower digestibility than cereal starches and cassava while sorghum has a lower starch digestion values compared with the other cereal grains due to higher content of amylose (Aarathi *et al.*, 2003). However, earlier studies have illustrated that decreasing sorghum particle size can improve both starch and protein digestibility (Luce *et al.*, 1970). The *in vitro* digestibility of starch in cassava, wheat, maize and sorghum has been shown to be 92.1, 84.1, 74.6 and 69.4%, respectively (Weurding *et al.*, 2001).

CONCLUSION

The quality of cassava pulp depends on varieties of cassava, starch manufacturing and dehydration processes. Contamination with impurities of fibre, sand or soil can further affect the nutritional quality. Like other by-products, cassava pulp has a relatively low content of certain essential amino acids, fat and high insoluble NSP. The starch content in cassava pulp can be up to 500 g kg⁻¹, depending on the process. However, the availability of this starch depends on other factors present in the product, particularly NSP. The feeding value of the material is examined in follow-up research to this preliminary assessment.

REFERENCES

- AOAC., 1984. Official Methods of Analysis. 14th Edn., George Banton Co. Ltd., Washington, DC., pp: 1018.
- APHA, AWWA and WPCF., 2005. Standard Methods for the Examination of Water and Wastewater. 21st Edn., American Public Health Association, Washington, DC., USA., ISBN-13: 978-0875530475.

- Aarathi, A., A. Urooj and S. Puttaraj, 2003. *In vitro* starch digestibility and nutritionally important starch fractions in cereals and their mixtures. *Starch-Starke*, 55: 94-99.
- Aberle, T., W. Burchard, W. Vorwerg and S. Radosta, 1994. Conformational contributions of amylose and amylopectin to the structural properties of starches from various sources. *Starch-Starke*, 46: 329-335.
- Asaoka, M., J.M.V. Blanshard and J.E. Rickard, 1992. Effects of cultivar and growth season on the gelatinisation properties of cassava (*Manihot esculenta*) starch. *J. Sci. Food Agric.*, 59: 53-58.
- Asp, N.G., 1992. Resistant starch. Proceedings for the 2nd plenary meeting of EURESTA: European FLAIR Concerted Action No. 11 on physiological implications of the consumption of resistant starch in man. Crete, 29 May-2 June 1991. *Eur. J. Clin. Nutr.*, 46: S1-S148.
- Austin, S.C., J. Wiseman and A. Chesson, 1999. Influence of non-starch polysaccharides structure on the metabolisable energy of U.K. wheat fed to poultry. *J. Cereal Sci.*, 29: 77-88.
- Babinsky, L., J.M. van der Meer, H. Boer and L.A. der Hartog, 1990. An *in-vitro* method for prediction of the digestible crude protein content in pig feeds. *J. Sci. Food Agric.*, 50: 173-178.
- Bede, N.O., 2010. Nutritional implications of projects giving high priority to the production of staples of low nutritive quality: The case for cassava (*Manihot esculenta*, Crantz) in the humid tropics of West Africa. The International Institute of Tropical Agriculture, Ibadan, Nigeria.
- CFIA., 2005. Natural toxins in fresh fruit and vegetables. Canadian food Inspection Agency (CFIA), Canada.
- Charles, A.L., K. Sriroth and T.C. Huang, 2005. Proximate composition, mineral contents, hydrogen cyanide and phytic acid of 5 cassava genotypes. *Food Chem.*, 92: 615-620.
- Chauynarong, N., A.V. Elangovan and P.A. Iji, 2009a. The potential of cassava products in diets for poultry. *World's Poult. Sci. J.*, 65: 23-36.
- Chauynarong, N., P.A. Iji and U. Kanto, 2009b. Variation in nutrient composition of cassava pulp from Thailand. Proceedings of the Recent Advances in Animal Nutrition, Volume 17, July 12-15, 2009, Australia, pp: 183-183.
- Chavez, A.L., T. Sanchez, G. Jaramillo, J.M. Bedoya and J. Echeverry *et al.*, 2005. Variation of quality traits in cassava roots evaluated in landraces and improved clones. *Euphytica*, 143: 125-133.
- Chrastil, J., 1987. Improved colorimetric determination of amylose in starches or flours. *Carbohydr. Res.*, 159: 154-158.
- Dzisi, A.K. and J. Wirth, 1994. Cassava drying in a wood-fired deep-bed crop dryer. *Acta Horticulturae*, 380: 283-286.
- Englyst, H.N. and G.J. Hudson, 1993. Dietary Fiber and Starch: Classification and Measurement. In: *Dietary Fiber and Human Nutrition*, Spiller, G.A. (Ed.). 2nd Edn., CRC Press, Boca Raton, Florida, pp: 53-71.
- Gibson, T.S., V.A. Solah and B.V. McCleary, 1997. A procedure to measure amylose in cereal starches and flours with concanavalin A. *J. Cereal Sci.*, 25: 111-119.
- Hoover, R., 2001. Composition, molecular structure and physicochemical properties of tuber and root starches: A review. *Carbohydr. Polym.*, 45: 253-267.
- Kawano, K., W.M.G. Fukuda and U. Cempukdee, 1987. Genetic and environmental effects on dry matter content of cassava root. *Crop Sci.*, 27: 69-74.
- Kemdirim, O.C., O.A. Chukwu and S.C. Achinewhu, 1995. Effect of traditional processing of cassava on the cyanide content of gari and cassava flour. *Plant Foods Hum. Nutr.*, 48: 335-339.

- Khempaka, S., W. Molee and M. Guillaume, 2009. Dried cassava pulp as an alternative feedstuff for broilers: Effect on growth performance, carcass traits, digestive organs and nutrient digestibility. *J. Applied Poult. Res.*, 18: 487-493.
- Luce, W.G., L.T. Omtvedt and D.G. Stephens, 1970. Grinding and dry-rolling of milo and wheat for growing-finishing swine. Oklahoma Agricultural Experiment Station. *Animal Science Research*, 1970, pp: 60-64. http://beefextension.com/research_reports/research_56_94/rr70/rr70_10.pdf.
- McCleary, B.V., V. Solah and T.S. Gibson, 1994. Quantitative measurement of total starch in cereal flours and products. *J. Cereal Sci.*, 20: 51-58.
- Meng, X. and B.A. Slominski, 2005. Nutritive values of corn, soybean meal, canola meal and peas for broiler chickens as affected by a multicarbohydrase preparation of cell wall degrading enzymes. *Poult. Sci.*, 84: 1242-1251.
- Naqvi, L.U. and A. Nadeem, 2004. Bioavailability of metabolizable energy through kemzyme supplementation in broiler rations. *Pak. Vet. J.*, 24: 98-100.
- Nitipot, P., T. Nishida, R. Chaithiang, V. Pattarajinda and K. Sommart, 2009. Metabolizable energy evaluation of Pangola grass hay, cassava chip, cassava pulp and brewery waste in Thai native cattle. *Proceedings of the Annual Seminar on Agricultural Tea*, May, 23-25, 2009, Khon Kaen, Thailand, pp: 55-57.
- Oates, C.G., 1997. Towards an understanding of starch granule structure and hydrolysis. *Trends Food Sci. Technol.*, 8: 375-382.
- Sriroth, K., 1977. Development of cassava product for Industries. *Food Sci.*, 10 : 26-36.
- Sriroth, K., K. Piyachomkwan, S. Wanlapatit and C.G. Oates, 2000. Cassava starch technology: The Thai experience. *Starch*, 52: 439-449.
- Theander, O. and E. Westerlund, 1993. Determination of Individual Components of Dietary Fiber. In: *Dietary Fiber and Human Nutrition*, Spiller, G.A. (Ed.). 2nd Edn., CRC Press, Boca Raton, Florida, pp: 77-98.
- Tonukari, N.J., 2004. Cassava and the future of starch. *Electron. J. Biotechnol.*, 7: 5-8.
- Ukita, M., T. Imai and Y. Hung, 2006. Food Waste Treatment. In: *Waste Treatment in the Feed Processing Industry*, Wang, L.K., Y. Hung, H.H. Lo and C. Yapijakis (Eds.). Taylor and Francis, Boca Raton, Florida, pp: 291-321.
- Weurding, R.E., A. Veldman, W.A. Veen, P.J. van der Aar and M.W. Verstegen, 2001. Starch digestion rate in the small intestine of broiler chickens differs among feedstuffs. *J. Nut.*, 131: 2329-2335.