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Physicochemical and Functional Properties of Fermented Starch from Four Cassava Varieties

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ABSTRACT
The weaknesses of cassava starch as the raw materials in food industries are low protein content, the ununiform of viscosity and gel forming ability, not resistant to high temperature of heating, acidic conditions and mechanical processes and prone to be syneresis. The purpose of this research was to modify cassava starch by fermentation to produce high nutritional value of starch and better physical and chemical characteristics than those of the native one. Cassava varieties used in this research were the Adira 1, Malaysia, Tahunan and Gunting Saga that are widely grown by farmers in North Sumatera. Starch modification process was done through several methods of fermentation i.e., natural fermentation by soaking in tap water for 16 days, soaking in distilled water for 16 h at 30°C, soaking in 1% lactic acid solution for 16 h at 30°C. After that the fermented starch was dried under the sun or by oven at 50°C. The results showed that different methods of fermentation and drying produced cassava starch of different physicochemical and functional characteristics. The process that produced the good physicochemical and functional characteristics of starch was the natural fermentation by soaking in water for 16 days and dried under the sun based on the color, paste clarity, water and oil absorption of the starch. Starch from Malaysia and Gunting Saga varities had better physicochemical and functional properties if used in making bread or noodles compared to those produced from Adira1 and Tahunan.

Key words: Cassava varieties, modified starch, fermentation, starch properties

INTRODUCTION
Cassava (*Manihot esculenta* Crantz) is an important root crop and staple food in Indonesia and contributes to food security. The advantages of this plant is its ability to grow in dry and less fertile land, as well as its relative highly resistance to disease. Most people in the tropics use the tubers as sources of carbohydrate (Blagbrough *et al.*, 2010).

Cassava starch is equitable to other tuber and cereal starches on top of being easily extracted (FAO, 2000). Conventionally, it can be obtained by steeping and wet milling of the root. This is a finer product as the sieving stage ensures that coarse particles are removed. Cassava starch can be used as raw materials for many kinds of industries, both for food or non food. These industries may include sugar syrup, noodle, cake, biscuits, paper, textile or sorbitol. But as raw material for food industries, it has limitations in some of its quality characteristics such as the lower of protein, lipid and fiber content (Charles *et al.*, 2004), ununiform of viscosity and gel forming ability, not resistant to high temperature of heating, acidic conditions and mechanical processes and prone to be syneresis (Benesi, 2005). Therefore, it is necessary to repair its physical and chemical properties by means of modification its starch. Modification intended here is a change in the molecular structure that can be done chemically, physically or enzymatically.

Modification of cassava starch using natural fermentation followed by sun-drying resulted in sour starch with higher expansion (Demiate *et al.*, 1999). The starch, known as *Polvilho azedo* or sour cassava starch, is used for production of specific gluten-free breads and biscuits in some countries in South America. Besides that the natural fermentation in tanks which normally take approximately 30 days, soaking in 1% (w/w) lactic acid solution for 15-30 min was also studied (Vatanasuchart *et al.*, 2005, 2003; Demiate *et al.*, 2000). The oxidative modification of cassava starch with lactic acid together with either sun dried or artificial UV source proved to obtain baking characteristics of an increase in specific volume of tested biscuits.

The present study was undertaken to obtain more information on the effect of modification on the physicochemical properties of starch isolated from 4 varieties of cassava. Fermentation is an alternative in the process of modification of starch, because during the fermentation process dominant microbes will produce enzymes that will give the desired product of modified starch. The process conducted in this study will examine the influence of different fermentation and drying methods on the quality characteristics, the physico-chemical and functional properties, that are very important in the further utilization of cassava.

MATERIALS AND METHODS

Materials: Four varieties of cassava were used in this study i.e., Adira1, Malaysia, Tahunan and Gunting Saga obtained from farmers in Medan Tuntungan, North Sumatera Province. The roots were harvested at 9 months after planting. DL-Lactic acid was purchased from Sigma Chemical Co. Other chemicals agents used in this study were of analytical grade from Merck (Germany).

Starch extraction: Freshly harvested roots of cassava were washed, peeled and ground with water (1:3 w/v). The mash was then sieved through 70-mesh screen and allowed to sediment.

Modification of cassava starch: The wet cake was treated using modified methods as reslurried with distilled water and soaking for 16 h at 30°C or soaking in 1% (w/w) lactic acid solution for 16 h at 30°C as described by Vatanasuchart *et al.* (2005, 2003) or soaking in tap water for 16 days. After fermentation, liquid was drained and the wet starch samples was placed into steel trays with 2 mm thickness and then were subjected to further modification under following conditions: 50°C hot air oven and sun drying. The dried starch samples were pulverized and kept in a seal container at room temperature until further analysis.

Moisture content and degree of acidity: Moisture was determined by drying triplicate 5 g samples to constant weight in an air oven at 105°C (AOAC, 1995). Degree of acidity was determined by taking 10 g of the sample with 100 mL ethanol 70% which has been neutralized using phenoplthalein indicator and then stirred on magnetic stirrer. The suspension was filtered on Whatman paper No.1. The 50 mL of filtrate were titrated by NaOH 0,1 N. The degree of acidity was calculated as follows:

$$\text{Degree of acidity} = \frac{100/50 \times \text{mL NaOH} \times \text{NNaOH} \times 100}{\text{Sample weight (g)}}$$

Color (whiteness) and paste clarity: Color of modified starch was determined using a colour meter (ColorTec-PCM) using L* a* b* colour system and the whiteness was expressed by L-value. The clarity of modified starch was measured by a 1% aqueous suspension of starch near neutral pH, heated in a boiling water bath for 30 min with intermittent shaking. The suspension was cooled for 1 h at 25°C. Then light transmittance at 650 nm (UV Spectrophotometer, Genesys 21) was read against water blank (Wattanachant *et al.*, 2002).

Solubility: Starch (0.5000 g) was mixed with 15 mL distilled water in a centrifuge tube and heated in an 85°C water bath for 15 min. The sample was then centrifuged for 15 min at 2,200 rpm. The aliquot was transferred to a pre-weighed beaker and dried at 100°C. Solubility was calculated according to Schoch (1964).

Water and oil absorption index: Water and oil absorption index were determined by a modification of the methods of Valdez-Niebla *et al.* (1993), Ju and Mittal (1995) and Subrahmanyam and Hoseney (1995). This is a centrifugal procedure. Starch samples (1 g) were suspended in 5 mL water (for water absorption index) or vegetable oil (for oil absorption index) in a centrifuge tube. The slurry was shaken on a platform tube rocker for 1 min at room temperature and centrifuged at 3000 rpm for 10 min. The supernatant was poured carefully into a tared evaporating dish. Water or oil absorption index was calculated as follows (g/g):l weight of wet sediment/initial weight of starch sample.

Pasting properties: Viscosity of starch pastes at a concentration of 0.1% (w/v) were measured by a Brookfield DV II Pro Viscometer with a rotational speed of 100 rpm. Starch (1 g) and 10 mL distillated water (0.1% of starched pastes concentration) were mixed in a sample cup and temperature was controlled by a TC-02 thermostat waterbath. The temperature was increased until 95°C with the rate of temperature increasing was 1.5°C per min. After temperature reaches 95°C, it was hold for 10 min and then the temperature was decreased with the same rate until 50°C.

Total microorganisms: Total microorganisms in fermented cassava starch were calculated by Total Plaste Count (TPC) method and expressed by Coloni Form Unit (cfu)/mL.

Statistical analysis: A Completely Randomized Design (CRD) was assigned in this experiment. The properties for the modified starch samples were measured in triplicates and reported in means. The main effect of treatments was statistically analyzed using ANOVA and Tukey Test at the 95% level of confidence.

RESULTS AND DISCUSSION

The process of fermentation and drying of cassava starch produced different physico chemical and functional characteristics of modified cassava starch, as shown in Table 1-4.

Fermentation method affected whiteness, paste clarity, water absorption capacity, solubility, viscosity at 50°C and peak viscosity of starch. The starch soaking in tap water for 16 days gave the highest value of paste clarity, water absorption capacity and solubility, as shown in Table 5. Drying method had only significant effect on color, degree of acidity and oil absorption capacity of starch.

Table 1: Moisture content, total titrable acidity, whiteness and paste clarity of modified starch from four varieties of cassava

Cassava varieties	Fermentation methods	Moisture content (%)		Degree of acidity (%)		Whiteness		Paste clarity (%T)	
		P1	P2	P1	P2	P1	P2	P1	P2
Adira 1	F1	17.87	15.87	1.13	2.33	89.72	90.69	65.60	58.67
	F2	14.14	9.51	0.99	2.32	89.74	91.27	58.83	61.00
	F3	15.64	13.49	0.93	1.06	91.31	91.09	58.60	58.57
Malaysia	F1	14.33	14.81	0.86	1.60	89.74	90.10	65.17	67.60
	F2	13.52	8.75	0.93	0.73	90.85	90.94	61.90	65.90
	F3	11.68	13.03	0.66	0.53	90.73	90.89	59.83	60.43
Tahunan	F1	13.16	15.97	0.80	0.87	90.34	90.92	63.80	58.73
	F2	16.95	12.86	0.87	0.87	91.09	91.17	58.33	60.87
	F3	12.71	9.56	0.80	0.67	90.97	91.38	61.57	56.90
Gunting saga	F1	15.95	16.24	0.40	1.27	90.53	90.80	62.50	64.83
	F2	16.31	8.34	0.47	0.47	90.97	91.55	58.93	58.00
	F3	9.52	9.99	0.53	0.73	90.76	91.39	60.30	60.00

F_1: Fermented starch by soaking in tap water for 16 days, F_2: Fermented by soaking starch in distilled water for 16 h, F_3: Fermented starch by soaking in 1% lactic acid solution for 16 h, P_1: Sun drying, P_2: Oven drying

Table 2: Effect of fermentation methods on water and oil absorption capacity and solubility pasting properties of 4 varieties of cassava starch in different drying methods

Cassava varieties	Fermentation methods	Water absorption capacity (g g^{-1})		Oil absorption capacity (g g^{-1})		Solubility (g/100 g)	
		P_1	P_2	P_1	P_2	P_1	P_2
Adira 1	F_1	1.72	1.94	2.34	2.11	31.92	28.46
	F_2	1.73	1.75	2.01	2.03	27.68	28.87
	F_3	1.73	1.85	2.48	2.31	28.60	31.98
Malaysia	F_1	1.94	1.76	2.09	2.13	31.29	22.69
	F_2	1.76	2.00	2.24	2.00	24.30	23.80
	F_3	1.77	1.78	2.14	2.03	23.27	32.34
Tahunan	F_1	1.86	1.79	1.99	2.28	31.43	36.10
	F_2	1.84	2.13	2.25	2.37	31.33	35.80
	F_3	1.66	1.90	2.19	2.06	33.52	36.43
Gunting saga	F_1	1.75	1.77	2.10	2.31	36.73	31.92
	F_2	1.83	1.93	2.24	2.10	32.45	32.77
	F_3	1.87	1.81	2.06	2.03	32.87	32.75

F_1: Fermented starch by soaking in tap water for 16 days. F_2: Fermented by soaking starch in distilled water for 16 h, F_3: Fermented starch by soaking in 1% lactic acid solution for 16 h, P_1: Sun drying, P_2: Oven drying

Sun dried starch had the highest whiteness, total titrable acidity and oil absorption capacity but had no significant different effect on the clarity of paste, water absorption, solubility in cold water, paste characteristics and total microbes, as shown in Table 6.

Fermentation of cassava starch by soaking in tap water for 16 days gave the highest degree of acidity and tended to have higher solubility and water absorption when dried under the sun. Water absorption is important in bulking and consistency of products, as well as in baking applications.

The highest color value of modified starch was obtained at the highest fermentation process by soaking in lactic acid solution during 16 days (F3) i.e., 91,058 and the lowest one was produced

Table 3: Effect of fermentation methods on pasting properties of 4 varieties of cassava starch in different drying methods

Cassava varieties	Fermentation methods	Pasting temperature		Peak temperature		Viscosity at 50°C (cp)		Peak viscosity (cp)	
		P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
Adira 1	F_1	68.75	66.70	87.85	76.90	1772.8	1392.0	1964.8	1827.2
	F_2	68.15	67.90	81.60	84.20	3008.0	2828.8	3851.2	2972.8
	F_3	69.45	67.20	81.30	88.35	3158.4	2425.6	3468.8	3662.4
Malaysia	F_1	65.85	65.65	81.60	73.45	1574.4	1280.0	1686.4	2192.0
	F_2	65.80	67.35	81.60	75.85	2342.4	2396.8	2652.8	3046.4
	F_3	65.60	68.10	81.25	76.40	2176.0	2281.6	2348.8	2870.4
Tahunan	F_1	66.60	67.40	78.85	86.95	1644.8	1040.0	1836.8	1158.4
	F_2	67.60	70.15	81.85	81.75	2534.4	2387.2	2822.4	2574.2
	F_3	68.15	68.60	82.15	82.65	2307.2	2278.4	2390.4	2400.0
Gunting saga	F_1	67.90	66.24	88.50	76.45	1772.8	1292.8	1785.6	2048.0
	F_2	66.50	67.25	88.35	87.65	2476.8	2745.6	2598.4	3206.4
	F_3	67.15	67.50	86.90	88.95	2412.8	2688.0	2534.4	3043.2

F_1 : Fermented starch by soaking in tap water for 16 days, F_2: Fermented by soaking starch in distilled water for 16 h, F_3: Fermented starch by soaking in 1% lactic acid solution for 16 h, P_1: Sun drying, P_2: Oven drying, cp: Centipoise

Table 4: Effect of fermentation methods on total microorganisms of 4 varieties of cassava starch in different drying methods

Cassava varieties	Fermentation methods	Total microorganisms ($\times 10^2$ cfu mL^{-1})	
		Sun drying	Oven drying
Adira 1	F_1	2.67	4.00
	F_2	2.33	6.33
	F_3	3.67	5.67
Malaysia	F_1	5.33	1.33
	F_2	2.67	1.67
	F_3	3.67	1.33
Tahunan	F_1	4.33	5.33
	F_2	4.33	5.67
	F_3	1.67	2.67
Gunting saga	F_1	3.00	3.33
	F_2	2.67	1.67
	F_3	1.33	2.00

F_1: Fermented starch by soaking in tap water for 16 days, F_2: Fermented by soaking starch in distilled water for 16 h, F_3: Fermented starch by soaking in 1% lactic acid solution for 16 h

from the fermentation process by soaking in water for 16 days (F1) i.e., 90,356 (Table 5). This is not in line with the value of clarity of starch pastes, where the lower value of the highest clarity of paste was obtained at fermentation of F1 and F3. Starch produced by fermentation for 16 days, produced darker starches color, slightly darker than the starch produced by the other two fermentation methods.

Starch viscosity will be changed with temperature. In general, viscosity was related to molecular weight, granular composition, pH and electrolytes of the solution (Aurand *et al*., 1987). In cold water, starch viscosity is low but after heating, the thick paste will be formed with increased viscosity. High viscosity is an indication of good quality starch and the low viscosity showed the starch has undergone some degree of degradation during storage (FAO, 2000). But in modified starch as raw material for food industries, the lower viscosity was the good one. In this research,

Table 5: Effect of fermentation method on the physicochemical and functional characteristics of cassava starch

Parameters	F_1	F_2	F_3
Color (L value)	90.356[b]	90.948[b]	91.058 [a]
Paste clarity (%T)	63.363[a]	60.471[ab]	59.525[b]
Titratable acidity (g/100 g)	1.1559[a]	0.9545[ab]	0.7400[b]
Moisture absorption (g/g)	1.9177[a]	1.7848[b]	1.7873[b]
Oil absorption (g/g)	2.1689[a]	2.1569[a]	2.1617[a]
Solubility (g/100 g)	29.685[a]	25.948[b]	26.511[ab]
Total microoganisms ($\times 10^2$ cfu)	3.67[a]	3.42[a]	2.75[a]
Pasting temperature (°C)	66.808[a]	67.588[a]	67.719[a]
Peak temperature (°C)	81.556[a]	82.856[a]	83.494[a]
Peak viscosity (cp)	1758.6[b]	2841.2[a]	2714.8[a]
Viscosity at 50°C (cp)	1524.0[b]	2590.0[a]	2466.0[a]

Cp: Centipoise, F_1: Fermented starch by soaking in tap water for 16 days, f_2: Fermented by soaking starch in distilled water for 16 h, f_3: Fermented starch by soaking in 1% lactic acid solution for 16 h. Mean values of triplicate. Values in a row with the same superscript are not significantly different at 5% by Tukey difference test

Table 6: Effect of drying method on physicochemical and functional characteristics of modified cassava starch

Parameters	Sun drying	Oven drying
Color (L-value)	90.563[a]	91.012[b]
Paste clarity	61.28[a]	60.96[a]
Titratable acidity	0.7804[a]	1.1198[b]
Moisture absorption	1.7783[a]	1.8816[a]
Oil absorption	2.7789[a]	2.1472[b]
Solubility	30.449[a]	31.1595[a]
Total plate count ($\times 10^2$ cfu mL^{-1})	3.14[a]	3.42[a]
Pasting temperature (°C)	67.292[a]	67.504[a]
Peak temperature (°C)	83.642[a]	81.629[a]
Peak viscosity (cp)	2453.1[a]	2490.7[a]
Viscosity at 50°C (cp)	2290.4[a]	2096.3[a]

Cp: Centipoise, Mean values of triplicate. Values in a row with the same superscript are not significantly different at 5% by Tukey difference test

the lower viscosity found in the fermented starch soaking in tap water for 16 days (F_1) under the sun drying. It was related to the high degree of acidity. The similar results were found in previous studie of which starch hydrolysis was proposed as a main factor for the evidences (Vatanasuchart *et al.*, 2005).

Spontaneously fermentation process of cassava starch, allowing the growth of microorganisms in modified starches. Microorganisms that grow on the modified starch can be either beneficial bacteria to alter the structure of starch such as Lactic Acid Bacteria (LAB) but can also be a bacterial pathagen that is not supposed to grow on the modified starch. In this research, only the number of total microbes was observed (Total Plate Count); therefore the type of vinicrobes cannot be determined. The average total plate count that grown on starch during the fermentation processing, can be seen in Table 4. The higher microorganism population would also account for the higher consumption of soluble sugar and faster drop in pH (Numfor, 1999).

Table 1-4, show that the modified cassava starch and cassava originated from Malaysia and Gunting saga had better physicochemical and functional characteristics of starch than the other types of cassava. Generally, it can be seen that the starch modification process produced starch that is not different in colors with the natural one. The average value of the color of dried starch was 90.563 (sun drying) and 91.021 (oven drying) as shown in Table 6.

The total microbes that grow on starch that is fermented for 16 days (F3), had higher but not significantly different value from the other fermentation methods. This is probably because of the drying process of starch surpassed the growth of microbes that grow during the fermentation process.

CONCLUSION

Four varieties of cassava widely growth in North Sumatera i.e., Adira1, Gunting Saga, Malaysia and Tahunan has a potential to be developed as a source of starch. The different methods of fermentation and drying produced different characteristics of modified cassava starch. The best method that produce modified cassava starches with the best physicochemical and functional characteristics was the fermentation with soaking cassava starch in tap water for 16 days and dried by sun drying. This is based on the whiteness, paste clarity and water and oil absorption capacity of starch produced.

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REFERENCES

AOAC, 1995. Official Methods of Analysis of the Association of Official Agricultural Chemists. 16th Edn., AOAC., Washington DC., USA.

Aurand, L.W., A.E. Woods and M.R. Wells, 1987. Food Composition and Analysis. Van Norstrand Reinhold Int. Co. Ltd., New York, ISBN: 9780442208165, pp: 513-521.

Benesi, M., 2005. Characterizatiion of malawian cassava germplass for diversity, starch extraction and its native and modified properties. Ph.D. Thesis, Free State University, South Africa.

Blagbrough, I.S., S.A.L. Bayoumi, M.G. Rowan and J.R. Beeching, 2010. Cassava: An appraisal of its phytochemistry and its biotechnological prospects. Phytochemistry, 71: 1940-1951.

Charles, A., Y. Chang, W. Ko, K. Sriroth and T. Huang, 2004. Some physical and chemical properties of starch isolates of cassava genotypes. Starch Starke, 56: 413-418.

Demiate, I.M., A.C. Barana, M.P. Cereda and G.Wosiacki, 1999. Organic acid profile of commercial sour cassava starch. Cienc. Technol. Alimen, Vol. 19.

Demiate, I.M., N. Dupuy, J.P. Huvenne, M.P. Cereda and G. Wosiacki, 2000. Relationship between baking behavior of modified cassava starches and starch chemical structure determined by FTIR spectroscopy. Carbohydr. Polym., 42: 149-158.

FAO, 2000. Processing of cassava. Agricultural Services Bulletin No. 8, Food and Agricultural Organization, Rome, Italy.

Ju, J. and G.S. Mittal, 1995. Physical properties of various starch-based fat substitutes. J. Food Process. Preserv., 19: 361-383.

Numfor, F.A., 1999. Physicochemical changes in cassava starch and flour associated with fermentation, effect in textural properties. J. Food Technol. Afr., 4: 31-35.

Schoch, T.J., 1964. Swelling Power and Solubility of Granular Starches. In: Methods in Carbohydrate Chemistry, Whistler, R.L., R.J. Smith and J.N. BeMiller (Eds.). Vol. 4. Academic Press, New York, USA., pp: 106-108.

Subrahmanyam, S.N. and R.C. Hoseney, 1995. Shear thinning properties of sorghum starch. Cereal Chem., 72: 7-10.

Valdez-Niebla, J.A., O. Paredes-Lopez, J.M. Vargas-Lopez and D. Hernandez-Lopez, 1993. Moisture sorption isotherms and other physicochemical properties of nixtamilized amaranth flour. Food Chem., 46: 19-23.

Vatanasuchart, N., O. Naivikul, S. Charoenrein and K. Sriroth, 2003. Effects of different UV irradiations on properties of cassava starch and biscuit expansion. Kasetsart J. Nat. Sci., 37: 334-344.

Vatanasuchart, N., O. Naivikul, S. Charoenrein and K. Sriroth, 2005. Molecular properties of cassava starch modified with different UV irradiations to enhance baking expansion. Carbohydr. Polym., 61: 80-87.

Wattanachant, S., S.K.S. Muhammad, H.D. Mat and R.A. Rahman, 2002. Suitability of sago starch as a base for dual-modification. Songklanakarin J. Sci. Technol., 24: 431-438.