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Effects of Cassava Chips Fermentation Conditions on The Produced Flour Properties

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A fermentation process to produce soft-texture and low cyanogenic content cassava flour had been studied, in particular the effects of temperature, circulation of the fermentation media, and chips size, on fermented cassava flour (fercaf) properties. Fermentation was shown to affect properties of cassava flour: reducing the cyanogenic content, swelling power, as well as solubility, whereas on the other hand increasing the amylose content and correspondingly the measured DE. Further, the properties of the produced flour were affected by the implemented fermentation operation conditions. Fermentation temperature was found to significantly affect amylose content. Media circulation was found to significantly affect the measured Dextrose Equivalent. On the other hand, the size of cassava chips significantly affected the cyanogenic content and solubility of the flour.

Keywords : fercaf, fermentation, circulated reactor, flour properties

INTRODUCTION

Cassava (*Manihot utilissima*) is rich in carbohydrate and dietary fibers and also one of the highly productive crops. Due to the large availability it can serve as a potential alternative carbohydrate source. However its typical smell and color may inhibit further used. Another obstacle in cassava utilization is its toxic cyanogenic content. This cyanogenic compound can be oxydized to cyanide that is toxic and becomes very dangerous. Processing of fresh cassava should be done to reduce the cyanogenic content. Besides it can also be done to increase its shelf life, to add its value, to widen its use, or to facilitate subsequent processing, such as making the cassava flour.

Gaplek (cassava flour) and tapioca are the typical cassava flour available in the market. However, both have the characters which are less flexible than the wheat flour (Chukwuemeka, 2007). Cassava fermentation was reported to improve or change some properties of the produced cassava flour (Brauman, *et al*., 1996; Putri *et al*., 2012). The produced cassava flour is known as foofoo (Brauman *et al*., 1996), modified cassava flour or shortly mocal/mocaf (Subagio, 2008). Here the term fermented cassava flour (fercaf) will be used, as it described the process more properly.

Gaplek has a yellowish color and fermentation eliminated the color component of cassava, producing whiter flour. Wahjuningsih (2011) reported that 72 hours fermentation would produce the whitest flour. Further, fermentation time and the concentration of microbial starter were reported to affect the swelling power, solubility and tensile strengh of the produced flour (Zulaidah, 2011). Cassava fermentation can be performed hygienically in a circulation reactor (Kresnowati *et al*., 2014). It was also reported that the media circulation and temperature would improve the fermentation performance and the reduction of glucocyanogenic content (Kresnowati *et al*., 2014).

It was the general objective of this study to determine the properties of fermented cassava flour, or the so called fercaf. We analyzed which operation condition influencing the properties of fermented cassava flour, in particular the size of cassava chips, the circulation of fermentation media and the temperature of fermentation.

MATERIALS AND METHODS

Raw Materials

Fresh cassava was obtained from local market and can be stored maximally for 24 hours before used. Cassava tubers were peeled, washed, and chipped before further used.

Starter Culture

The starter culture microorganisms, as dried powder, was kindly provided by Mr. Cahyo Handriadi, PT Cassava, Trenggalek, East Java, Indonesia. Identification of starter culture composition was performed in Laboratory of Microbiology, School of Life Sciences, Bandung Institute of Technology and it revealed that it contained *Bacillus carboniphilius, B. amyloliticus, B. gelatini, B. simplex, and B. residui*. Innoculum for cassava fermentation was prepared by mixing 100 g of cassava chips, 1 L of water, 1.5 g of starter culture powder, and 3 g of sugar. The solution was incubated at 30°C for 24 hours before further used.

Fermentation

The fermentor system used in this study comprises of a cylindrical fiber glass reactor, 26 cm in diameter and 50 cm in high, as has been described in Kresnowati *et al*. (2014). The reactor is also equipped with a temperature controller and a water pump to circulate the water.

1 kg of cassava chips was used in each batch of fermentation experiment and followingly the innoculum solution and ±18 L of water was added. Cassava chips samples were taken periodically from random position of the fermentor. All samples were analysed for its cyanogenic content whereas only samples from fermentation time 2 and 12 hours were analysed for other flour properties.

Experimental Design

Experiments to study the effect of operation conditions on the fercaf properties were conducted based on full factorial experimental design on 3 factors, that were the size of cassava chips, the circulation of fermentation media and the temperature of fermentation. Each run was conducted in duplo and the obtained data was statistically analyzed using Minitab 16.

Analysis

Fermented cassava samples were analyzed for its cyanogenic content, amylose content, and starch content, as well as Dextrose Equivalent, swelling power, solubility, and SEM analysis. The cyanogenic content was measured as HCN concentration from fresh cassava chips samples by titration following Tanya *et al.* (1997). Other properties were analyzed from fercaf flour. Fresh cassava chips samples were first sundried and grinded before the analysis. Amylose content of the cassava flour was measured by iodine binding following Larson *et al.* (1953). Dextrose Equivalent was analyzed by Lane and Eynon's method (Moresco *et al.*, 2008). The swelling power was analyzed by measuring the percentage of pasta and initial weight of the sample following Daramola and Osanyinlusi (2006). The flour solubility was analyzed by measuring the percentage of sediment dry weight and initial weight of the sample according to the method of Kainuma *et al.* (1967). SEM analysis was performed in Physics Research Center, LIPI Bandung, Indonesia. As a comparison, *gaplek* and commercial modified cassava flour (mocaf) were also used. *Gaplek* was selft prepared by drying cassava without prior fermentation and grinding it into flour. Commercial mocaf flour kindly provided by Mr. Cahyo Handriadi, PT Cassava, Trenggalek, East Java.

RESULTS AND DISCUSSION

Effects of Fermentation on the General Fercaf Properties

The physical appearance of fercaf is different from *gaplek*. As was reported

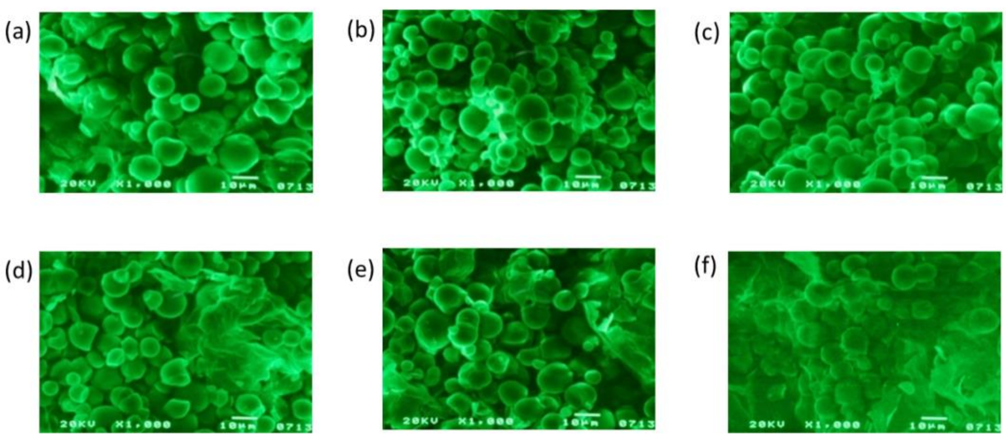

Fig. 1: SEM images (1000x magnification) of gaplek (a), commercial mocaf (b), Fercaf produced from fermentation with media circulation, at 30^0C, and 0.1 cm chips' size (c); Fercaf produced from fermentation with media circulation, at 40^0C, and 0.1 cm chips' size (d), Fercaf produced from fermentation without media circulation, at 30^0C, and 0.1 cm chips' size (e), Fercaf produced from fermentation with media circulation, at 30^0C, and 1 cm chips' size (f).

earlier (Wahjuningsih, 2011), the color of g*aplek* tends to be yellowish whereas fercaf looks whiter. Besides, g*aplek* still keep the characteristics aroma of cassava, whereas fercaf has neutral aroma. These indicated that the fermentation of cassava altered some properties of the produced flour.

The SEM observation showed that the starch granules size of *gaplek* was bigger than those of fercaf (Figure 1). During the fermentation the cell walls were broken down and the starch were converted into smaller components. However, the multiphase-nature of this fermentation and the nonhomogenity due to unsufficient mixing may contribute to the variation of the obtained granules size and shape.

Effects of Fermentation on Cyanogenic Content

Despite the common problem of cyanogenic content in cassava, the cyanogenic content of fresh cassava chips used in these experiments were measured to be low, in the range of 26 – 44 ppm, and safe for consumption. However, the cyanogenic content is not good for long term consumption.

Consistent with previous observation (Kresnowati *et al.*, 2014) the cyanogenic content of cassava chips decreased significantly during the first 2–3 hours of fermentation and remained constant afterwards. By a 12- hours-fermentation the cyanogenic content can be reduced up to 35% of its initial value. Mostly presents as linamarin, the cyanogenic content of cassava will decrease due to the hydrolysis of linamarin into HCN by the linamarase enzyme. The hydrolysis of cassava cell walls during the fermentation also released the linamarase (Bainbridge *et al.*, 1998), thus enhancing the reduction of cyanogenic content of cassava.

The effects of various operation conditions, fermentation temperature, media circulation, and chips' size on the reduction in the cyanogenic content are presented in Table 1. Further statistical analysis showed that the reduction in cyanogenic content was only significantly affected by cassava chips'size (Figure 2a). Thicker cassava chips provide less area of contact and followingly less cell wall and cyanogenic content degradation.

Effects of Fermentation on Amylose Content

We observed that the fermentation of cassava chips increased the amylose content of the produced flour and that the amylose content increase along with the fermentation time (Table 1). Microbial activity during the fermentation produced lactic acid that will catalyze the hydrolysis of complex-carbohydrate-starch into simpler compounds, reducing the amylopectin content and making more amylose (Brauman *et al.*, 1996).

The average amylose content of fercaf after 12 hours fermentation was measured to be 7.9 ppm. The largest increase in the amylose content was observed at fermentation temperature of 30°C, chips' size of 0.1 cm, and without media circulation, resulting in an increased of amylose content by 17% compared to *gaplek* (Table 1). Further statistical analysis showed that temperature significantly effects the amylose content of fercaf

Table 1: Effects of cassava chips' size, media circulation, and fermentation temperatures on fermented cassava flour properties

Run	Chips' size (cm)	Media circulation**	Fermentation temperature (°C)	Change in cyanogenic content (%)	Change in amylose (ppm)*	Change in DE*	Change in Swelling Power (%)*	Change in Solubility (%)*
1	0.1	C	30	47.88	0.538	0.51	-0.48	-0.018
2	1	C	30	37.09	0.486	3.51	-0.13	-0.036
3	0.1	NC	30	47.36	1.61	2.22	-0.79	-0.236
4	1	NC	30	37.46	0.633	1.58	-1.41	-0.032
5	0.1	C	40	56.53	0.322	3.29	-2.86	-0.23
6	1	C	40	38.92	0.504	0.51	-1.84	-0.006
7	0.1	NC	40	46.63	0.115	3.51	-3.16	-0.246
8	1	NC	40	45.53	0.569	3.84	-0.06	-0.068
9	0.1	C	30	45.62	1.223	0.58	-0.53	-0.042
10	1	C	30	38.37	1.189	2.88	-0.15	-0.048
11	0.1	NC	30	55.52	1.404	4.61	-0.85	-0.102
12	1	NC	30	35.08	0.436	2.69	-0.42	-0.024
13	0.1	C	40	50.48	0.346	4.14	-3.79	-0.07
14	1	C	40	41.31	0.631	2.47	-2.07	-0.052
15	0.1	NC	40	51.95	0.444	5.68	-3.48	-0.118
16	1	NC	40	42.04	0.47	2.74	-0.44	-0.012

*data shown represent the difference value between samples taken at fermentation time 2 hours and 12 hours, except for the change in cyanogenic content which showed the total reduction in the cyanogenic content

** C (circulation) and NC (no circulation)

(Figure 2b). This may be related to the optimum temperature for the particular microorganims' activities.

Effects of Fermentation on Dextrose Equivalent

Dextrose Equivalent (DE) presents the total reducing sugar content of starch in the flour. The higher the DE indicates the more fraction of complex carbohydrate that has been hydrolyzed into simple sugars. Consistent with the increase in the amylose content of the produced flour, fermentation of cassava chips increased the DE value of the produced flour (Table 1). This proves that the activities of microorganisms during the fermentation lead to the hydrolysis of starch into reducing sugars.

The average DE of fercaf after 12 hours fermentation was measured to be 5.9. The largest increase in DE was observed at fermentation temperature of 30°C, chips' size of 0.1 cm, and without media circulation, resulting in an increased of amylose content by 17% compared to gaplek. Further statistical analysis showed that the circulation of fermentation media significantly effects on DE (Figure 2c). Higher DE value was obtained from the fermentation without media circulation. The effects of other operation conditions, chips' size and fermentation temperature, were found to be insignificant.

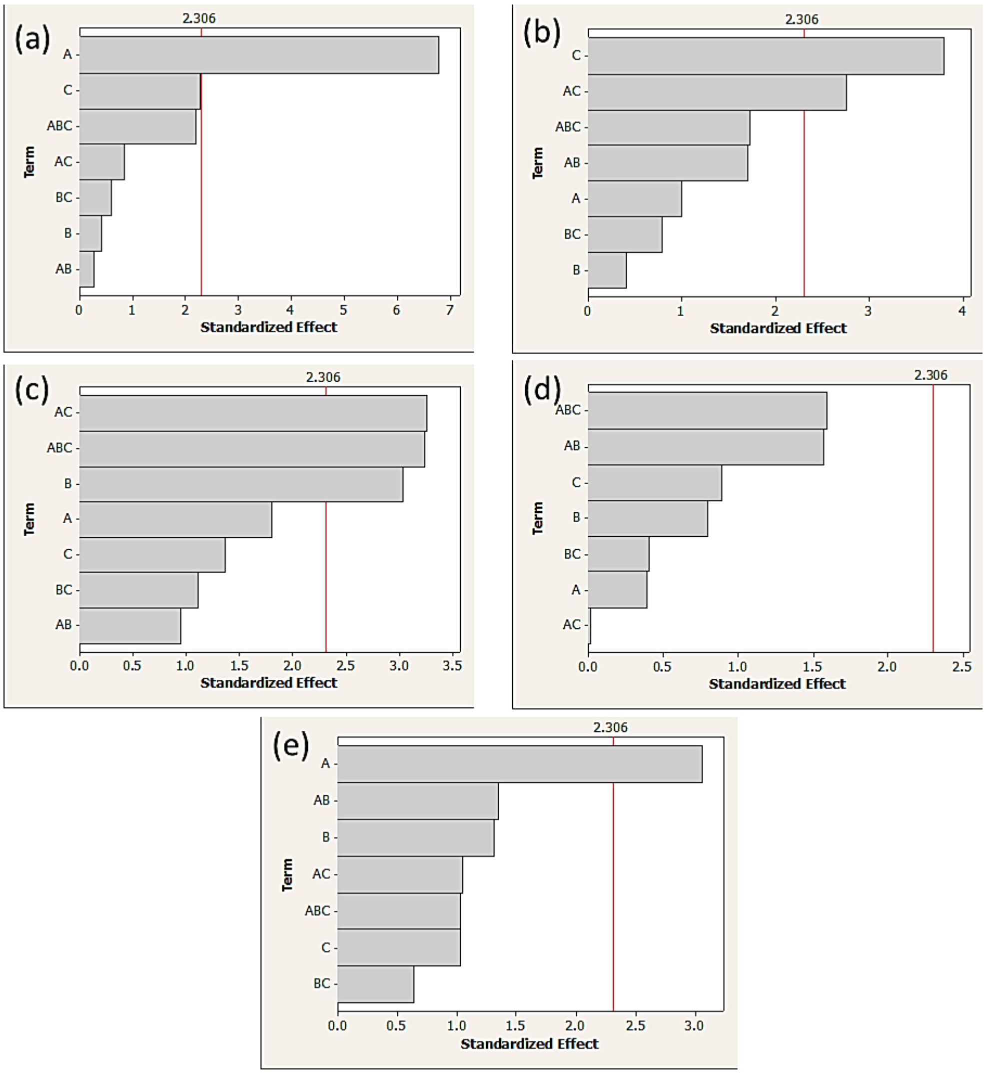

Fig. 2: Pareto chart, the standardized effects for (a) HCN, (b) amylose content, (c) Dextrose Equivalent, (d) swelling power, and (e) solubility (A= chips size, B= media circulation, C= temperature)

Effects of Fermentation on Swelling Power and Solubility

Swelling power and solubility indicate the interaction between starch molecule and water. Water molecules form hydrogen interactions (hydrogen bonds) with the hydroxyl groups of amylose and amylopectin in the starch, and thus the starch molecule absorbs water molecule and swells (Winarmo, 2002). On the other hand solubility is the ability of the material to dissolve in water so as not to form an emulsion. The high swelling power makes poduct more fluffly. The high solubility makes flour easier to dissolve in water when making dough for food product.

The fermentation of cassava chips were observed to decrease the swelling power and solubility of fercaf. The maximum decrease of swelling power was observed at fermentation without media circulation, temperature of 40°C, and chips' size of 0.1 cm (Table 1). This obtained value is, however, still higher than the swelling

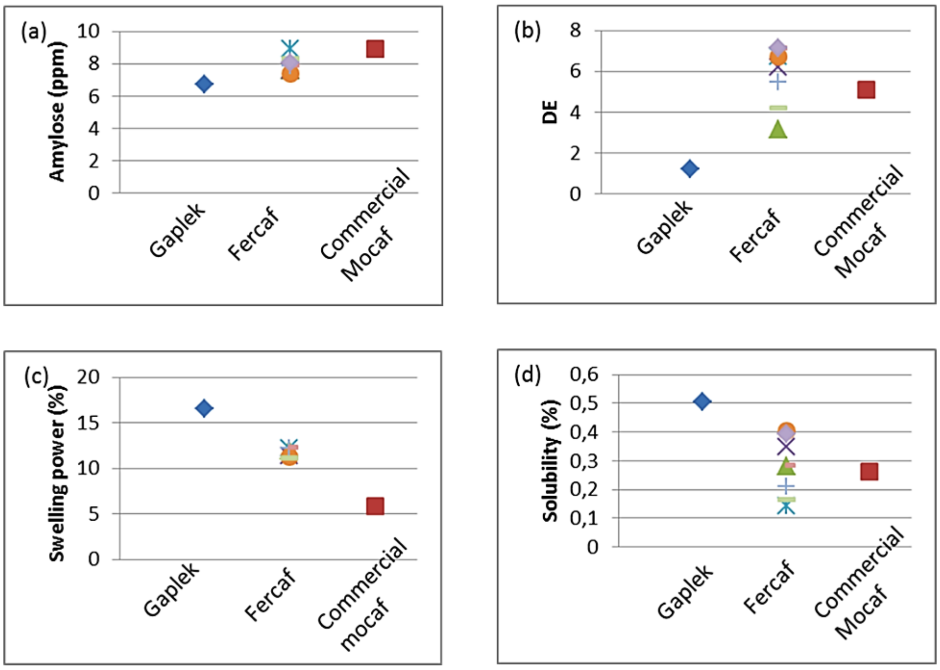

Fig. 3: Effects of fermentation on the produced flour properties: (a) amylose contents, (b) dextrose equivalent, (c) swelling power and (d) solubility

power of commercial fermented cassava flour (Figure 3). Further, no such operation conditions was found to have a significant effect on the swelling power (Figure 2d).

Maximum decrease of solubility was observed at fermentation without media circulation, temperature of 30°C, and chips' size of 0.1 cm (Table 1). The chips' size was observed to have a significant effect on the solubility (Figure 2e). The chips' size may be related to the availability of contact area for hydrolysis and thus resulting in starch with lower molecular weight. Consequently, the flour becomes more soluble. Even though the solubility of starch is usually related with its amylose content, the temperature of fermentation which was earlier found to significantly effect the amylose content of the flour, was not observed to have a significant effect on solubility.

Comparison with Other Flour

Figure 3 shows the comparison between measurement results of amylose content, Dextrose Equivalent, swelling power, and solubility of *gaplek*, fercaf and commercial mocaf flour. Overal, we observed that cassava chips fermentation increases the amylose content and the Dextrose Equivalent of the produced flour. On the other hand, the fermentation was obseved to decrease the swelling power and the solubility of the produced flour. The properties of fercaf produced in these series of experiments were comparable or were in the same range with the commercial mocaf, except for the swelling power in which the swelling power of fercaf was measured to be significantly higher than commercial mocaf.

The obtained results also show that the method and operation conditions used in this experiment could be applied for commercial production of fercaf, subtituting commercial mocaf. This means shortening the fermentation time, from 24 hours to 12 hours. In order to check the suitability of fercaf to subtitute other commercial starch flour, such as wheat flour or rice flour, further study will be necessary.

CONCLUSION

The obtained results showed that fermentation affects the properties of cassava flour. It reduced the HCN content, swelling power, and solubility. On the other hand, it increased the amylose content and correspondingly the measured DE. Fermentation temperature was found to significantly affect amylose content. Media circulation was found to significantly affect the measured DE. On the other hand, the size of cassava chips only significantly affect the cyanogenic content and solubility.

ACKNOWLEDGEMENT

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