Assessment of Corn-Based Rice Analogues Made from Modified Corn Flour and Cassava Starch Which Processed by Granulation Method as Functional Food

Beni Hidayat[1*] Syamsu Akmal[1] M. Muslihudin[1] Bambang Suhada[2]
1.Agricultural Technology Department, State Polytechnic of Lampung, 10 Soekarno-Hatta Street, Bandar Lampung 35144, Indonesia
2.Economy Faculty, Muhammadyah University of Metro, Indonesia

Abstract
Compared to extrusion method, granulation method will produce rice analogues more characterised as a functional food. Corn-based rice analogues granulation method (CRAGM) made from modified corn flour and cassava starch have a good cooking quality and have a potency to be developed as a functional food. The objective of this research was to assess the potential of CRAGM made from modified corn flour (MCF) and cassava starch (CS) as a functional food. CRAGM made from MCF and CS (with formulation of CS as 20%, 30%, dan 40%) have characteristics as functional food reflected from the lower of glycemic index value (34.79 to 40.77), the higher content of dietary fiber (14.53% to 15.48%), the higher content of resistant starch (6.17% to 10.44%), and the lower content of digestible starch (57.64% to 62.71%).
Keywords: rice analogues, granulation method, functional food

1. Introduction
The increasing of cases of obesity, diabetes, and cardiovascular diseases has attracted many researchers to develop staple food with a low glycemic index (GI). Development of staple food with low glycemic index (GI) has been reported by Noviasari et al. (2015); Hidayat et al. (2016[a]) in the form of rice analogues and by Walter et al. (2005) in the form of parboiled rice. Compared to parboiled rice, rice analogues more potential to be developed cause by easier to be fortified (Mishra et al., 2012) and can be developed into a functional food with lower GI, lower digestible starch (DS), higher resistant starch (RS), and higher dietary fiber (Hidayat et al., 2016[a,b]). Rice analogues with higher resistant starch content also potential to be developed as a new source of prebiotic food.

Rice analogues can be processed by extrusion method (Noviasari et al., 2015; Mishra et al., 2012) and granulation method (Hidayat et al., 2016[a,b]). Processing of rice analogues by extrusion method will decrease the functional component content, resistant starch especially. Haralampu reported that extruded cereal will be lost as 22% of the RS due to high shear damage in the extruder. Compared to extrusion method, granulation method will produce rice analogues more characterized as a functional food; due to the lack of shear damage effect (Haralampu, 2000) and the presence of the cooling stage (Perdon et al., 1999). Hidayat et al. (2016[a]), reported that corn-based rice analogues granulation method (CRAGM) made from modified corn flour (MCF) and cassava flour (CF) have characteristics as functional food that is reflected from the lower of GI value, the higher of resistant starch (RS) content, and the lower of digestible starch (DS) content. Although have characteristics as functional food, corn-based rice analogues granulation method (CRAGM) made from modified corn flour and cassava flour have a poor cooking quality. Therefore, need to be developed CRAGM which have characteristics as functional food but have a good quality cooking.

The further research by Hidayat et al. (2016[b]), showed that CRAGM made from MCF and cassava starch (CS) with the formulation of CS as 20%, 30%, and 40% have a good quality cooking and preferred by the organoleptic panelist. The objective of this research was to assess the potential of CRAGM made from MCF and CS (formulation of CS as 20%, 30%, dan 40%) as a functional food.

2. Materials and Methods
2.1 Preparation of Corn-Based Rice Analogues
The raw materials were yellow corn var. Bisi II from Practice Gardens of Lampung State Polytechnic, harvested in July 2016. Modified corn flour was prepared by the wet milling and pre-gelatinization method based on Hidayat et al. (2013), through the stages of sorting of whole maize, coarse grinding (20 mesh), separation of the epidermis and core by soaking, wet milling, partial pre-gelatinization, drying followed by fine grinding (60 mesh).

Production of corn-based rice analogues granulation method (CRAGM) were done through the following stages: mixing of modified corn flour (MCF) with cassava starch (CS) and water according as treatment (Table 1), granulating with granulator, steaming, cooling for 12 hours, and drying with cabinet dryer to obtain instant CRAGM.

Table 1. Formulation of CRAGM with addition of cassava starch

Formulation	Modified Corn Flour (%)	Cassava starch (%)	Water (%)
Cassava starch 20%	80	20	45
Cassava starch 30%	70	30	45
Cassava starch 40%	60	40	45

2.2 Analysis of Chemical Compositions

Analysis of chemical compositions was done to modified corn flour (MCF). The moisture, crude protein, crude ash, and lipid content were measured according to the method of AOAC International (1999). Dietary fiber was determined by the enzymatic method (Asp et al., 1983), total starch based on Goni, et al. (1997) method with slight modifications by using DNS, and amylose content by colorimetric measurement of the blue amylose-iodine complex (Juliano, 1971).

2.3 Analysis of Functional Component

Analysis of functional component, included: dietary fiber by enzymatic method (Asp et al., 1983), resistant starch (RS) and digestible starch (DS) based on Englyst et al. (1992).

2.4 Analysis of The Glycemic Index Value

The tests of glycemic index were carried out on ten healthy volunteers, i.e. non-diabetic, have the normal level of fasting blood glucose (70-120 mg/dl) and value of Body Mass Index (BMI) in the normal range of 18.5 to 25 kg/m^2. The tests were conducted based on the ethical clearance issued by the Faculty of Medicine, University of Lampung with number 1396/UN26/8/DT/2015.

Preparation of CRAGM various formulations were conducted by cooking using the rice cooker with the ratio of CRAGM and water were 1 : 1. The measurement method of GI value was based on Jenkins et al. (1981) with slight modifications, by providing CRAGM on an amount equivalent to 50 g of carbohydrates.

As standard testing, was used 50 g of pure glucose. Blood sampling for determination of GI value of pure glucose was performed on different days with a minimum interval of three days. Blood sampling for pure glucose was made by the same procedure as the samples. The GI, was calculated following the procedure of Wolever et al. (1991).

2.5 Data Analysis

The analysis was carried out in six replicates for all determinations, except GI data. The data were analyzed by one-way analysis of variance (ANOVA) and the results are reported as mean ± SD on the dry basis (db). The significance of the differences was defined as $P<0.05$. Data of GI (glycemic index) was the average value of the 10 volunteers.

3. Results and Discussion

3.1 Chemical Composition

Modified corn flour has higher content of amylose as 43.91% (Table 1), compared to conventional corn flour as 25.13% (Hidayat et al., 2013). Pereira and Leonel (2014), reported that the higher of amylose content will promote the formation of resistant starch type 3 (RS 3); due to the presence of higher amounts of the linear component of starch (Sagum and Arcot, 2000). The higher of amylose content will also decrease starch digestibility (Hu et al., 2004; Themeier et al, 2005), increase dietary fiber content (Zhu et al., 2011) and decrease IG value (Foster-Powell et al., 2002).

Tabel 1. Chemical composition of modifed corn flour (mean ± SD), % dry basis (db)

Component	Composition
Ash	0.23 ± 0.03
Dietary fiber	4.22 ± 0.23
Lipid	1.82 ± 0.18
Protein	10.31 ± 0.12
Total starch	81.88 ± 0.22
Amylose	43.91 ± 0.02

3.2 Resistant Starch (RS)

Increasing of cassava starch formulation will be significantly ($p<0.05$) decreased the resistant starch content of corn-based rice analogues granulation method (CRAGM) from 10.14% to 6.17% (Table 2). Decreasing of resistant starch content was associated with decreased of amylose content. Modified corn flour has amylose content as 43.91% higher than cassava starch as 84.28% (Hidayat et al., 2009). The amylose content will promote the formation of resistant starch type 3 (Pereira and Leonel, 2014). The formation of resistant starch type 3 (RS 3) also initiate by cooling stage for 12 hours on granulation method which leads the intensification of retrogradation process. The formation of RS 3 due to retrogradation process were reported also by Fredriksson et al. (1998); Vasanthan and Bhatty (1998); Farhat et al. (2001); Thompson (2001); Fuentes-Zaragoza et al. (2011). Fabbri et al. (2016) and Perdon, et al. (1999) reported that cooling process will stimulate the formation of RS 3.

Tabel 2. Resistant Starch (RS) and Digestible Starch (DS) of CRAGM on various formulations of cassava starch (mean ± SD), % dry basis

Formulation	RS	DS
Cassava starch 20%	10.44 ± 0.48c	57.64 ± 0.32a
Cassava starch 30%	8.72 ± 0.52b	59.64 ± 0.85b
Cassava starch 40%	6.17 ± 0.33a	62.71 ± 0.33c

For each parameter (column), values with the same letters are not significantly different (P > 0.05).

Based on resistant starch (RS) content as 6.17%-10.44%, CRAGM have potency as functional food. The content of RS can be used to identify of functional food (Walter et al., 2005). Compare to RS content of rice as 0,77%-0,94% (Zhang et al., 2007) and RS content of corn-based rice analogues processed by extrusion method as 2.59% (Noviasari, et al., 2015); CRAGM have higher content of RS. The lower of RS content of corn-based rice analogues processed by extrusion method due to high shear damage in the extruder (Haralampu, 2000; Unlu and Faller, 1998). The food with high resistant starch content can be considered as prebiotic (Fuentes-Zaragoza et al., 2011).

3.3 Digestible Starch (DS)

Table 2 shows, the increasing of cassava starch formulation will be significantly ($p < 0.05$) increased the digestible starch content of corn-based rice analogues granulation method (CRAGM) from 57.64% to 62.71% (Table 2). The content of digestible starch has been positively correlated to resistant starch of CRAGM. CRAGM has lower DS as 57.64%-62.71% compared to DS of rice as 79.69% (Goni et al., 1997), and has DS equal with parboiled rice as 62.6% (Walter et al., 2005).

The lower of DS content is due to the increasing of RS content (Table 2). Resistant starch on CRAGM has been dominated by RS 3 as a result of retrogradation. Retrogradation will increase crystallinity degree of starch (Alsaffar, 2011; Haralampu, 2000). As a result, starch becomes less susceptible to hydrolysis with amylolytic enzymes and decrease of starch digestibility (Gallant et al., 1992; Buleon et al., 1998). The decreasing of starch digestibility along with the increasing of RS content, also reported by Chung et al. (2006); Mir et al. (2013); and Zhu et al. (2011).

Based on the lower of DS content, CRAGM has potency as functional food. Food with lower DS has potential as functional food to improve human health (Ai et al., 2013). Ludwig et al. (2009) and Willett et al. (2002) reported, over-consumption of starchy foods with fast starch hydrolysis rates has been criticized for causing metabolic syndrome, including Type-2 diabetes, obesity, and cardiovascular diseases.

3.4 Dietary Fiber

Increasing of cassava starch formulation will be significantly ($p < 0.05$) decreased the dietary fiber content of corn-based rice analogues granulation method (CRAGM) from 14.53% to 15.48% (Table 3). Decreasing of the dietary fiber content is closely related to decreasing of resistant starch content. The lower of resistant starch content causes the lower of dietary fiber content of CRAGM. Resistant starch is defined as the amount of degradation product of starch that can not be absorbed by the human intestine and are grouped into dietary fiber (Fuentes-Zaragoza et al., 2011; Thompson, 2001; Fabbri et al., 2016).

Compared to corn-based rice analogues processed by extrusion method, CRAGM has higher dietary fiber content. Noviasari et al. (2015), reported that corn-based rice analogues use white corn as raw material which is processed by extrusion method has a total dietary fiber content as 5.35%. Onyango et al. (2005) reported that extrusion reduced total dietary fiber by 39–68%, redistributed soluble to insoluble fiber ratios and had a negligible effect on the formation of resistant starch (less than 1 g/100 g).

Tabel 3. Dietary fiber of CRAGM on various formulations of cassava starch (mean ± SD), % dry basis (db)

Formulation	Dietary fiber
Cassava starch 20%	15.48 ± 0.36a
Cassava starch 30%	14.90 ± 0.52b
Cassava starch 40%	14.53 ± 0.35c

Values with the same letters are not significantly different (P > 0.05)

According to the CAC (2009), food can be referred to as a source of dietary fiber if it content at least 3% dietary fiber, and called high-fiber if it content minimum of 6% dietary fiber. Based on CAC (2009), CRAGM can be categorized as high-fiber foods. The higher of dietary fiber content (14.53%-15.48%) shows that CRAGM has the characteristics as functional food.

3.5 The Glycemic Index Values

Increasing of cassava starch formulation will increased glycemic index value of of corn-based rice analogues granulation method (CRAGM) from 34.79 to 40.77 (Table 4). The higher of glycemic index value of CRAGM is related to the higher of starch digestibility, the lower of dietary fiber content, and the lower of resistant starch content.

Table 4. Glycemic index value of CRAGM on various formulation of cassava starch (mean ± SD)

Formulation	Glycemic index value
Cassava starch 20%	34.79 ± 2.11
Cassava starch 30%	37.47 ± 2.16
Cassava starch 40%	40.77 ± 2.12

Based on Table 4, CRAGM have a low of GI value (34.79-40.77), lower than rice which high GI value of 69 (Foster-Powell et al., 2002) or 81 (Goni et al., 1997); corn-based rice analogues processed by extruder method with GI value of 50-69 (Noviasari et al., 2015). The content of dietary fiber, resistant starch, and starch digestibility are all factors that interact to cause CRAGM have a low glycemic index value.

According to Elleuch et al. (2011), dietary fiber can decrease the glycemic response through the mechanism of the formation matrix beyond the starch granules that can inhibit the digestion of carbohydrates. Dietary fiber, especially dietary fiber water soluble can reduce the response of blood glucose caused by (1) an increase in viscosity in the stomach thereby slowing down the emptying of the stomach or intestines and cause a decrease in the amount of carbohydrates that can be digested (barrier against the enzyme) and simple sugars that can be absorbed, (2) dietary fiber causes changes in hormone levels in the digestive tract, absorption of nutrients and insulin secretion, (3) dietary fiber helps improve insulin sensitivity, stabilize blood glucose levels thereby protecting complications from diabetic (Turner and Lupton, 2011).

Resistant starch is included in insoluble dietary fiber, but has properties such as soluble dietary fiber. Resistant starch content has been positively correlated to the glycemic index (GI) of starchy foods (Alsaffar, 2011; Wolever et al., 1991). Resistant starch has slow digest so that the release of glucose in slowdown process. Resistant starch metabolism occurs 5-7 hours after ingestion. Digestion of resistant starch for 5-7 hours will increase the period of satiety so can reduce the IG value (Sajilata et al., 2006; Yamada et al., 2005; Ashraf et al., 2012).

5. Conclusion

Corn based-rice analogues granulation method (CRAGM) made from modified corn flour (MCF) and cassava starch (CS) with formulation of CS as 20%, 30%, dan 40% have characteristics as functional food reflected from the lower of glycemic index value (34.79 to 40.77), higher content of dietary fiber (14.53% to 15.48%), higher content of resistant starch (6.17% to 10.44%), and the lower content of digestible starch (57.64% to 62.71%).

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