

Product diversification of banana cv. Mas Kirana off grade by using a double rotating screw extruder

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Abstract. Extrusion technology is today's favorite technology since it has a varied, practical and consistent product form. The purpose of this research was to get precise composite flour composition so that the quality of the resulted product has optimum quality for breakfast meals. The experimental design used was Design Expert vs. 7 with response surface box-behnken. The flour composition and level to be inputted to the program were banana flour (10-50g), mung beans (10-30g), egg flour (10-20g). Formula made was based on 200 g with addition of maize flour if the amount is less than 200 g. The extrusion tool used is a Thermo Scientific double rotating screw; with Haake Reomax OS. The best results in terms of carbohydrate content is the Formula 8 with a composition of 60 g of banana flour, 20 g eggs, 20 g of green beans and 100 g maize flour. The proximate chemical content of this formula is carbohydrate 84.04%, protein 8.55%, fat 5.49%, ash content 1.24%. K-calories per 100 g is 419.5 which is higher than the standard of breakfast meals calories.

Keywords : Banana off grade, breakfast meals, double rotating screw, green bean flour, maize flour,

1. Introduction

Banana production in Indonesia in 2014 reached 6,862,558 tonnes, is the highest among fruit commodities [1]. Varieties of bananas grown by Indonesian farmers can be banana table *i.e* Ambon (white), Ambon (yellow), Lampung, Cavendish, Raja Sere, Raja Bulu, Ambon Lumut, Ambon Buai, Mas whilst variety of banana processing and plantain are banana Tanduk, Uli, Nangka, Kapas, Kepok. There are many research result on shelf life on table banana has been done. Requirement of research on banana processing is not only life extension on fresh produce but also research on technique of processing. Usually off grade market of table banana are also considered as raw materials of processing.

Internationally bananas are processed into various types such as the manufacture of ordinary banana flour [2] including the convection drying model [3]; banana flour modified with acid [4]; banana fritters [5]; banana Puree [6]; banana-milk powder, ultrasonic dried banana, cookies, spray dried banana powder, rich fiber powder, high fructose syrup [7]; Banana starch film [8]; composite banana custard [9]; banana starch [10]. One type of banana preparations that has not been studied extensively is the extrusion product for snacks.



Extrusion is a process whereby food is forced to flow during mixing, high temperature heating and shear by means of a mold designed to form a puff dry extrusion pattern in short time [11]. Extrusion technology is not a new technology but has long been found and at this time continues to grow and demand by all technology users. According to SNI No 2886-2015 [12], extruded snacks are ready-to-eat snacks made from food sources of carbohydrates and / or proteins through extrusion processes with or without the addition of other foods and food additives permitted with or without frying process .

There are 2 types of extruder viz. single screw and double screw. Single screw extruder has been widely produced by local manufacturers of Indonesia, while twin extruder is still not much to make. One of the modern extruder machines is made by Thermoscientific because it has been equipped with sensors and monitors for a more accurate process [13]. Currently extrusion snack products can be made from various ingredients, one of the foodstuffs often used independently for extrusion materials is corn. This is because corn is cheap and has sufficient expansion, and has good texture [14]. Generally in the manufacture of extrusion products is done by mixing various types of flour and materials to achieve the desired goal.

The purpose of this study was to obtain an appropriate formulation in producing extrudate from banana flour, green beans, and eggs.

2. Materials and Methods

2.1. Material and equipment

The research material was obtained in the form of banana (*Musa paradisiaca* L) cv. Mas obtained from 'Pasar Anyar', Bogor with commercial maturity, and not yet ripe. Furthermore, the bananas are brought into the laboratory at ICAPRD for producing banana flour. Other ingredients of corn flour, green bean flour and eggs also come from 'Pasar Anyar'. The raw materials of banana flour, maize flour and green bean flour were , starch (%), amylose (%), amylopectin (%), moisture content (%), ash content (%), fat (%), protein (%), carbohydrates (%). For analyses method see sub chapter analyses.

The extruder used was the Thermoscientific twin barrel extruder (made in Germany), with computer equipment from Haake [13]. In addition, other standard equipment such as, stainless steel pan for preparation of raw materials, glass equipment and laboratory equipment standards for analysis.

2.2. Determination of Formula composition

The composition of the ingredients or Formula is the main factor that becomes the basis as well as the treatment factor and becomes the limit determinant on the manufacture of this snack. Formulation using the main ingredient of maize flour, which is mixed with other raw materials with the composition of 10-50% banana flour, 30% and eggs 10-20%. Each Formula was made in a 200 g experimental unit. The amount of maize flour added was the difference of 200 g minus the amount of Formula formed. Each Formula was added 10 g of tapioca starch and 10 ml of cooking oil.

2.3. Determination of treatment Formula

Determination of the Formula that was using Design Expert version 7 program with RSM (Response Surface Methodology) design method Box-Behnken Design 9 trial version) [15]. This program automatically performs the Formulation that will be used. The results of the Formula obtained from Design Expert version 7 are 17 Formulas (Table 1). The range or spacing between the initial formulas generated was adjusted automatically with the limits given at the time of the input variables available in the Design Expert program version 7.

Table 1. Formula of extrudate snack from design expert vs. 7

Formula	Banana (g)	Green bean (g)	Egg (g)	Maize (g)
1	60	20	40	80
2	60	60	40	40
3	60	40	30	70
4	60	60	20	60
5	20	40	20	120
6	100	20	30	50
7	60	40	30	70
8	60	20	20	100
9	20	40	40	100
10	60	40	30	70
11	60	40	30	70
12	60	40	30	70
13	20	60	30	90
14	20	20	30	120
15	100	40	20	400
16	100	40	40	20
17	100	60	30	10

2.4. Preparation of extrudate product

The extruder used for this study was a double screw thread [13]. The initial heating temperature of the extruder was carried out at six points: T1 50°C, T2 50°C, T3 60°C, T4 100°C, T5 140°C, and T6 145°C, threaded rotation of 115 rpm. Injectable water which was added 2.5 ml / min. All ingredients *i.e* banana flour, green bean flour, and eggs were weighed in accordance with the initial formulations made by Design Expert version 7 (Table 1). The extrusion process for 1 Formula was carried out for 1 hour continuously. The extrusion snack that was formed still has high moisture content, so it needs a 3 hour oven with 60°C temperature. Every hour were sampled to see the water content.

2.5. Analyses

Proximate analyses include moisture oven method [17], ash [18], Microkjeldal for protein [22], fat method of soxhlet [17] and total carbohydrate [17] contained in the snack. Total carbohydrate calculation analyses by way of 100 minus the amount of water content, ash, protein and fat. The starch analysis of Luff Schroll [17] method, amylose was determined by spectrophotometry [19]. Amylopectin content can be determined as a difference between the starch content and amylose.

3. Results and Discussion

3.1. Properties of raw material

Starch is an important factor in the manufacture of extrusion snacks, because the starch content in raw materials affects the texture of the snack. Starch consists of amylose and amylopectin, where amylopectin is very influential on the development of extrusion snack so that the amylopectin content must be greater than its amylose content [14]. In the analysis of starch showed that banana flour has the highest starch content among other raw materials that is 70.20%. In the amylose analysis, green bean flour has the highest percentage of 27.33%, and the highest amylopectin content of banana flour with a percentage of 49.55%.

The results of the proximate analysis of raw materials can be seen in Table 2. The green beans have the highest parameter content among other raw materials, the values are ash content, fat content, and protein, the percentage of respective values respectively 3.22%, 1.64% and 10.26% . Green beans are added into Formula of produce snacks for its high protein content. The highest water content is maize with percentage of 10.71%, and highest carbohydrate content is corn with percentage 84.20%. The results of the analysis on these raw materials will be linked to the results of the analysis on extrusion snack, to find out which feedstock has the most influence on water content, ash content, protein content, fat content, carbohydrate, starch, amylose and amylopectin of extrusion snack.

Table 2. Proximate analyses of raw material

Raw material	Moisture content %	Ash content %	Fat content %	Protein Content %	Carbohydrate content %	Starch (%)	Amylose (%)	Amylopectin(%)
Banana	8.72	2.15	0.71	4.44	83.97	70.20	20.65	49.55
Green bean	8.09	3.22	1.64	10.26	76.79	60.29	27.33	32.96
Maize	10.71	0.15	0.68	4.26	84.20	68.26	25.18	43.08

3.2. Extrudate snack

Starch content. Starch is part of the carbohydrate that is polysaccharide composed by two groups of macromolecules, amylose and amylopectin. Both these macromolecules play a significant role in the physical, chemical and functional properties of starch [17]. Generally, starch contains higher amylopectin than amylose [14]. Based on the results of the analysis of variance done with Design Expert version 7 program on the response of starch content to all the formulas, showed that the Formula significantly influence the response of starch content ($p < 0.05$), at 95% confidence interval with $p = 0.0017$; has significantly effect on product starch content. In Table 5 it can be seen that the lowest starch content in Formula 14 is 53.28%, the highest in Formula 6 is 60.28%.

Starch has an important role for extrusion products, in addition to the effect on texture, also affect the durability. The effect of starch is mainly due to ratio of amylose to amylopectin. Amylopectin is known to stimulate the puffing process, so that extrusion products derived from starch with high amylopectin content will be light, porous, crisp, and crunchy. Starch with high amylose tends to produce a hard product due to the limited development process [11]. Another factor affecting the development of snack is the moisture level of the dough that will affect the yield of the dough temperature and the amount of starch that is gelatinised during the extrusion process [22].

Amylose and amylopectin. Amylose and amylopectin are constructed by an α -D-glucose monomer that binds to each other via a glycoside bond. The comparison between amylose and amylopectin varies for different sources of starch. Generally, the amylopectin content is greater than amylose (70-80%) [18]. Based on result of analysis of variance conducted by Design Expert version 7 program on amylose and amylopectin response significantly influenced by Formula made, amylose and amylopectin ($p < 0.05$), at 95% confidence interval with p value of amylose = 0.0017 and p amylopectin = 0.0293 . Snack with the highest amylose content of Formula 6 which is 22.48%. The highest amylopectin level in Formula 17 which is 38.95%.

The content of amylopectin and amylose has a major influence in determining the nature or characteristics of the extrusion snack. Amylopectin can improve the nature of product development

and crispy-ness, while amylose can improve the dryness (crunchy-ness) and texture strength of the product [14]. The initial temperature of heating affects the process of starch gelatinization and affects the properties of the ingredients at cooking time and in the development of the extrusion snack [24]. In general the temperature of starch gelatinization at the extrusion will increase as the amylose content increases. Amylose and amylopectin content of banana flour, corn flour, and green bean flour have generally higher amylopectin content than amylose content. The addition of tapioca also has an effect on snack characteristics because tapioca has high enough amylopectin content so that the resulting extrusion product is light, crisp, and crunchy [11].

3.2.3. Proximate analyses. The result of proximate analysis on extrusion snack is moisture content in the range of 0.37-2.95%, ash content 1.03-2.32%, protein content 8.24-14.36%, fat content 5.32-6.88%, and carbohydrate 75.17-84.04%. Proximate analysis of the 17 snack formulas are presented in Table 3.

Table 3. Result of proximate analyses of extrudate snack*

Formul a	B:G:E:M ^a	Water content %	Ash content %	Fat content %	Protein content %	Carbohyd rate content %	Starch (%)	Amylose (%)	Amylopec tin (%)
1	60:20:40:80	2.33	1.03	5.95	10.00	80.69	55.63	19.71	35.92
2	60:60:40:40	2.74	1.98	6.88	13.23	75.17	55.55	19.80	35.75
3	60:40:30:70	2.01	1.64	6.62	10.93	78.80	57.88	20.28	37.60
4	60:60:20:60	0.37	2.32	6.12	11.68	79.51	57.31	20.15	37.16
5	20:40:20:120	0.69	1.59	5.50	11.44	80.78	54.25	18.81	35.44
6	100:20:30:50	1.01	1.31	5.75	8.24	83.69	60.28	22.48	37.80
7	60:40:30:70	2.15	1.58	5.69	10.65	79.93	53.70	19.61	34.09
8	60:20:20:100	0.68	1.24	5.49	8.55	84.04	55.53	20.77	34.76
9	20:40:40:100	2.95	1.68	5.94	12.37	77.06	56.68	19.54	37.14
10	60:40:30:70	2.12	1.39	5.23	10.83	80.43	55.49	21.21	34.28
11	60:40:30:70	1.95	1.62	5.81	11.01	79.62	55.60	21.11	34.49
12	60:40:30:70	1.43	1.86	5.79	11.22	79.70	54.93	21.20	33.73
13	20:60:30:90	0.97	2.27	6.62	14.36	75.78	53.80	19.48	34.32
14	20:20:30:130	2.15	1.35	5.43	11.06	80.01	53.28	19.47	33.81
15	100:40:20:40	0.48	1.94	5.59	9.67	82.32	59.03	22.01	37.02
16	100:40:40:20	2.50	1.80	6.20	11.01	78.50	59.62	21.33	38.29
17	100:60:30:10	0.99	2.22	5.69	12.15	78.95	60.26	21.31	38.95

^aRemarks: B: Banana, G: Green bean, E:Egg, M: Maize

Water content. Water content is closely related to crispness properties of extruded products. Especially dried snack foods come from cereals. Water content is too high will cause the texture becomes less crisp and crunchy. Analysis of water content is necessary because the water content becomes one of the factors that greatly affect the decline in the quality of food products. Water content of a high material the higher the possibility of the material will be damaged. Based on the results of analysis of variance conducted by the Expert program version 7 shows the Formula made significantly effect on the water content response ($p < 0.05$), at 95% confidence interval with value $p = 0.0001$.

The lowest moisture content in the product is 0.37%, the highest is 2.95% with an average of 1.62% while the water content based on standard [12] is a maximum of 4% (w / w). This indicates that the extrusion snack made meets the SNI water content standard, but the water content of the snack is very low when compared to the SNI, presumably due to drying by using oven done after the finished product. Drying by oven was done because the water content in the extrusion snack was still high so oven drying will lower the water content. In the snack Formula with the addition of 40 g eggs gives the highest water content compared to other treatments (Table 3) because the egg contains moisture content of 73.70%. Other factors that affect the water content is the composition of raw materials. Corn flour has the highest water content when compared with other raw materials that is equal to 10.71%. The addition of corn starch of 100 g also gives the highest water content compared to other treatments.

Water added to the Formula is one of the key factors for controlling the dough behaviour in the extruder and the properties of the final product. High moisture content will result in the starch gelatinization being reduced and the bubble growth will be inhibited resulting in the end product which is not expanding [21].

Ash content. Determination of ash content aims to know the amount of mineral content contained in the resulting product. The principle of the ash analysis is by weighing the residue from the combustion of organic matter components at a temperature of about 550°C [18].

Based on the result of variance analysis conducted by Design Expert version 7 program, it showed that the Formula that made significantly effect ash content ($p < 0.05$), at 95% confidence interval with $p = 0.0001$. The lowest ash content on snack was 1.03% and the highest was 2.32% with an average of 1.69%. Factors that affect the high content of ash in snack is green bean flour, because based on green bean analyst, it has the highest ash content among other raw materials that is equal to 3.22%. The Formula that has the highest ash content is Formula 4 (Table 3).

A similar study conducted [20] on ash content of soy sorghum extrudate products was 2.9% and from the mixture of broken rice and wheat bran showed ash content ranged from 0.7 to 5.1%.

Fat content. Based on result of analysis of variance conducted by Design Expert version 7 programme show that Formula made significantly effect fat content response ($p < 0.05$), at 95% confidence interval with p value = 0.0391.

Table 6 shows the lowest fat content of 5.23% and the highest is 6.88% with an average of 5.90%. The extracted fat content of the extracted snack meets the requirements of standard [12] which is below 30%. Fat content is influenced by the ingredients that exist in the snack. The amount of cooking oil, green beans and eggs in the ingredients affects the fat content of the product. Addition of cooking oil in every Formulas are the same which is 10 ml. An increase in the number of green beans and eggs will increase the fat content of extrusion snacks because the highest levels of green beans fat are compared to corn and bananas. Green bean fat content of 1.64% and eggs also have a high fat content of 11.20%. Formula 2 is the Formula with the highest percentage of fat content with the composition of green beans as much as 60 g and eggs as much as 40 g. In the extrusion process, fat acts as a lubricant because it reduces the friction force between particles in the mix and between the screw and barrel surfaces with molten dough [20].

Protein content. Proteins affect the texture and make the product crunchier. Based on the result of variance analysis conducted by Design Expert version 7 programme showed that the Formula made significantly influence the protein content ($p < 0.05$), at 95% confidence interval with p value = 0.0001.

Formula 2 has the highest protein content of 14.36% and Formula 6 has the lowest protein content of 8.24%. Protein content is strongly influenced by the content of green beans and eggs, because green beans with protein content of 10.26% (Table 2). Eggs also have a high protein content of 12.9% so that eggs and green beans can be a source of protein. Based on 17 Formulations, snacks resulting from the addition of green beans as much as 60 g gave the highest protein content compared with other treatments (Table 3).

Kocherla [16] reported that the extract products of sorghum raw material had a protein of 10.60% while the mixture of sorghum and soybeans increased protein content to 16.60%. Green beans have an effect on the level of protein extrusion products produced.

Carbohydrate content. Carbohydrates play an important role in human life, because carbohydrates become one of the energy sources needed by the body and can provide energy value of 4 Kcal / g. Based on result of analysis of variance conducted by Design Expert version 7 program show that Formula made significant effect to carbohydrate response ($p < 0.05$), at 95% confidence interval with p value = 0.000, meaning Formula made significant effect to product carbohydrate content.

Carbohydrate is present in the dominant number as the composition of nutritional value, in Table 6 it can be seen that the lowest carbohydrate level in Formula 2 is 75.17% and the highest is Formula 8 of 84.04%. The average carbohydrate value of 17 Formula is 79.55%. Raw materials that have the highest carbohydrate *i.e* banana flour so that the addition of banana flour affects the carbohydrate content of the snack. Based on raw material analysis, banana flour containing high carbohydrate that is 83.97% (Table 2). Snack produced by adding 100 g of banana flour gave the highest carbohydrate content compared to other treatments (Table 3).

The results of proximate analysis of extracted snack based on corn and green beans [14] show the percentage of water content, ash content, and higher protein content than the average of formulations made from bananas, green beans, corn and eggs, while the fat content and lower carbohydrate levels. This is because of the difference in composition used in the manufacture.

High levels of fat in formulations made from bananas, green beans, corn and eggs occur due to the addition of oil and eggs. The fat content is higher when compared to extrusion snacks made from corn and green beans, but their fat content meets the standards of [12], where the recommended fat content of SNI if the product without frying process is 30% (w / w) and with the frying process is a maximum of 38% (w / w). Water content in snack made from bananas, green beans, corn and eggs is very low because after the extrusion process finished the finished product in the first because the water content is still high. According to [11] water levels have a close relationship with the properties of "crisp" and the crisp extreme snack. The average carbohydrate content of snack is higher than that of corn extract and nuts. This is because of the difference in composition used, whereas based on analyses, bananas have a high carbohydrate content.

The protein content of corn and green bean extract snacks are higher, due to differences in composition, where green beans were more used in the formulas compared to banana-based snacks, green beans, corn and eggs. High protein content in green beans can affect protein levels in extrusion snacks. The ash content of corn extract snack and green beans is higher than that of banana, green beans, corn and eggs. This shows a consequence that extrudate of maize and green beans have a high mineral content.

4. Conclusion

Addition of green beans on snacks proved to increase protein levels, the addition of banana flour has an effect on the color of snack and starch content. The addition of maize affects moisture content, and carbohydrate content, and starch extrusion snack.

The result of analysis of variance to water content response, ash content, protein content, fat content, carbohydrate content, starch content, amylose content, amylopectin content, and color are significantly different ($p < 0.05$). Carbohydrate levels 75.17-84.04%. The best carbohydrate levels is 84.04% in Formula 8 which is also the best formula.

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