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Optimizing the Formula of Composite Non-Rice Carbohydrate Sources for Simulated Rice Grain Production

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Abstract—Food diversification program is becoming more importance to reduce the dependence on rice as a staple food in Indonesia. Simulated Rice Grain (SRG) made of non-rice carbohydrate sources was expected to be a subtitute of rice. SRG was formulated based on nutritional value and physichochemical properties of local Ciherang rice flour as a standard. Goal Linier Programming (GLP) was used as optimization method to formulate SRG using various non-rice carbohydrate sources, including arrowroot starch, canna starch, sago starch, sugar palm starch, *beneng* taro flour, white sweet potato flour, tapioca flour, white corn flour, sorghum flour and breadfruit flour. Optimization parameter used were nutritional value (protein,fat,amylose,amylopectin,carbohydrate,ash),and physical properties (color index,bulk density and angle of repose).The result showed that optimum composite non-rice carbohydrate sources for SRG (SRG flour) consisted of arrowroot starch (30 percent), *beneng* taro flour (42 percent) and sorghum flour (28 percent). The optimum SRG flour had a predicted nutritional value of 11.78 percent of moisture, 1.97 percent of ash, 1.32 percent of fat, 6.22 of percent protein, 1.28 percent of food fiber, 1.74 percent of crude fiber, 1.46 percent of total sugar, 22.52 percent of amylose, 63.48 percent of amylopectin, and physical properties of 39.01 degree of angle of repose, 68.59 percent degree of color, and 446.21 kg/m^3 of bulk density. Our results showed that these predicted nutritional and physical properties value of SRG flour is similar to that of analyzed values.

Index Terms - Simulated rice grain, various sources of non-rice carbohydrate, goal linier programming, optimization

1 Introduction

Meeting the needs of staple food can be carried out in three ways i.e. farming intensification, land extensification and product diversification. Intensification is an effort to maximize land potency by a variety of activities. This condition will certainly reach the optimum point of production activity both in terms of seed, fertilization, irrigation and land management. Meanwhile, extensification is an effort to meet needs for food by expanding land area. This effort should consider land condition in order to prevent high environmental risk and cost. Food product diversification is an effort to meet needs for carbohydrate instead from rice.

Indonesia has great potency in terms of carbohydrate sources such as cassava, arrowroot, canna, breadfruit, sweet potato, corn, taro, *gembili, suweg, gadung, huwisawu, kimpul,* Java potato and sago. With 52 million Ha of forest which managed to produce wood, 1,560 million tonnes per year of food stuffs can be produced [1]. Various carbohydrate sources have similar basic component with rice. Thus, they have potency as alternative material sources for rice substituon.

Recently, there is a tendency of decreasing number of rice consumption per capita and increasing number of imported food stuffs such as wheat and increasing number of potatoes [2]. This shows that food diversification has actually been implemented by Indonesian people. However, this program should also consider with Indonesian people psychology which indicates that eating is represented by eating rice. Eating rice gives its own pleasure and not boring so there is a tendency to consume rice continously and in large amount although it is not healthy enough [3].

An effort in making grain-like rice had been introduced in several grain name, ingredients and technology. Artificial rice is made from various flour source by adding certain nutrient and flavor which not contained in rice and then produced using roll-type granulator [4]. Simulated Rice Grain (SRG) had been made through fortification technique using *Ferrous sulfate heptahydrate*(FSH) through extrusion process [5]. SRG had also been made from rice flour, iron compound and 25% of water using single screw-extruder[6] and addition of micronutrients [7]. In making grain-like rice, extrusion technology had been employed together with rice flour and 30% of starch [8]. Composition of 70% of maize flour and 30% of starch using extrusion process produced good result of analogue rice [9].

A study on composing formula of SRG flour made from various non-carbohydrate sources is importantly needed to produce rice grain materials or enriched rice materials.

A process of producing SRG needs optimization process in order to produce simulated rice with close characteristic to rice. The purpose of this research was to determine the optimum formula of composite non-rice carbohydrate sources as a material for SRG production.

2 MATERIALS AND METHODS

The research was conducted for 9 months started from March untill November 2013 in Laboratory of Food Analysis -

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This research was carried out under these following stages: i) Prepare ten non-rice carbohydrate sources and Ciherang variety of local rice in the form of flour, ii) Evaluate the nutrient content and physical properties of flour made from non-rice carbohydrate sources and Ciherang of local rice variety, iii) Develop mathematic model that will be processed using Goal Linear Programming (GLP), iv) Evaluate the nutrient content and physical properties of flours mixture based on the optimum formula resulted from GLP.

Materials used in this experiment were obtained from local farmers consisted of arrowroot starch (*Maranta arundinacea* Linn.), canna (*Canna edulis* Ker.), *Beneng* taro (*Colocasia esculanta*(L.) Schott), white sweet potato (*Ipomoea batatas* Poir), tapioca flour (*Manihotutilissima* Pohl.), white corn (*Zea mays* L.), sago (*Metroxylonsagu* Rottb.) which obtained from Jakarta, sugar palm starch (*Arengapinnata* Merr), sorghum (S*orghum bicolor* (L.) Moench) Nambru variety, and breadfruit flour (*Artocarpus communis* Forst), rice (*Oryza sativa* L.) of Ciherang variety. All materials were in the form of flour and sifted using 120 mesh sieve size. Those materials were then analyzed to determine the nutrient contents and physical properties of the flours.

Moisture, ash, crude fibre content were analyzed using Gravimetri method, fat content by Soxhlet method, protein content by Kjeldahl method, carbohydrate used method of by difference,dietary food fiber content by enzymatic method and total sugar content by titration method. Starch content and proportion of amylose and amylopectin was determined by spectrophotometer method. Angle of repose was measured using AOAC(1984), whiteness degree by whiteness meter and bulk density were determined by weighing the sample at specified volume of glass cylinder[10]

Those carbohydrate source materials were formulated to be used as material for simulated rice grains (SRG) production (SRG flour). The formula of SRG flour was then optimized using Goal Linear Programming (GLP) [11], [12].

Eq.1 to Eg.3 were developed based on desired physicochemical properties, and Eq.4 as objective function was developed based on defined penalty weight which then subjected to minimization. Convert the objective function which subjected to minimization into linear programming program (Eq. 5). The constraint functions were Eq. 6 (protein), Eq. 7 (amylose content), Eq. 8 (color index), Eq. 9 (moisture content), Eq. 10 (ash content), Eq.11 (fat content), Eq. 12 (food fiber), Eq.13 (crude fiber), Eq. 14 (total sugar), Eq. 15 (amylopectin), Eq.16 (angle of repose), Eq. 17 (density) and the minimum requirement of starch flour ratio was 30 percent [8] (Eq.18).

$$\sum_{i=1}^{10} a_{4i} x_i \geq a_{4st} \qquad (1)$$

$$\sum_{i=1}^{10} a_{8i} x_i \geq a_{8st} \qquad (2)$$

$$\sum_{i=1}^{10} a_{11i} x_i \geq a_{11st} \qquad (3)$$

Objective Function

Minimum

$$z = W_4\left(\sum_{i=1}^{10} a_{4i} x_i - a_{4st}\right)^- + W_8\left(\sum_{i=1}^{10} a_{8i} x_i - a_{8st}\right)^+ + W_{11}\left(\sum_{i=1}^{10} a_{11i} x_i - a_{11st}\right)^- \qquad (4)$$

Conversion into LP model

$$y_1 = \sum_{i=1}^{10} a_{4i} x_i - a_{4st} \quad y_2 = \sum_{i=1}^{10} a_{8i} x_i - a_{8st} \quad y_2 = \sum_{i=1}^{10} a_{11i} x_i - a_{11st}$$

and

$$y_1 = y_1^+ - y_1^-; y_1^+ \geq 0; y_1^- \geq 0 \quad y_2 = y_2^+ - y_2^-; y_2^+ \geq 0; y_2^- \geq 0$$

$$y_3 = y_3^+ - y_3^-; y_3^+ \geq 0; y_3^- \geq 0$$

Minimum

$$z = W_4 y_1^- + W_8 y_2^+ + W_{11} y_{11}^- \qquad (5)$$

Constraint;

$$\sum_{i=1}^{10} a_{4i} x_{xi} - (y_1^+ - y_1^-) = a_{4st} \qquad (6)$$

$$\sum_{i=1}^{10} a_{8i} x_{xi} - (y_2^+ - y_2^-) = a_{8st} \qquad (7)$$

$$\sum_{i=1}^{10} a_{11i} x_{xi} - (y_3^+ - y_3^-) = a_{11st} \qquad (8)$$

$$\sum_{i=1}^{10} a_{1i} x_i \geq a_{1st} \qquad (9)$$

$$\sum_{i=1}^{10} a_{2i} x_i \geq a_{2st} \qquad (10)$$

$$\sum_{i=1}^{10} a_{3i} x_i \geq a_{3st} \qquad (11)$$

$$\sum_{i=1}^{10} a_{5i} x_i \geq a_{5st} \qquad (12)$$

$$\sum_{i=1}^{10} a_{6i} x_i \geq a_{6st} \qquad (13)$$

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$$\sum_{i=1}^{10} a_{7i} x_i \geq a_{7st} \quad (14)$$

$$\sum_{i=1}^{10} a_{9i} x_i \geq a_{9st} \quad (15)$$

$$\sum_{i=1}^{10} a_{10i} x_i \geq a_{10st} \quad (16)$$

$$\sum_{i=1}^{10} a_{12i} x_i \geq a_{12st} \quad (17)$$

$$7x_1 + 7x_2 + 7x_5 + 7x_7 + 7x_8 - 3x_3 - 3x_4 - 3x_6 - 3x_9 - 3x_{10} \geq 0 \quad (18)$$

Non-negativity constraint

$$x_i \geq 0, i = 1...10$$

3 Results and Discussions

3.1 Nutrient Content and Physical Properties of Various Carbohydrate-based Flours

The analysis result of nutrient content and physical properties of arrow root starch (x_1), canna starch (x_2), *Beneng*taro flour (x_3), white sweet potato flour (x_4), tapioca flour (x_5), white corn flour (x_6), sago starch (x_7), sugar palm starch (x_8), sorghum flour (x_9), breadfruit flour (x_{10}) and Ciherang variety of local rice flour (x_{st}) that were used as coefficient to formulate the constraint in GLP is shown in Table 1. The nutrient contens and physical properties values will be used as coefficient to formulate the contraint in GLP.

Eq. 5 could produce SRG flour with have close characteristic of protein and amylose content and whiteness degree to Ciherang rice flour. The desired protein content of SRG was 8.58 percent. This value was difficult to obtain as the protein content of SRG material ranged between 0.69 to 8.38 percent. Therefore, another non-carbohydrate source which have higher protein content should be added. The desired amylose content of SRG was 23.61 percent or lower. This value was in the range of amylose content of the material which ranged between 14.92 to 37.3 percent. The desired whiteness degree of SRG was 92.1 percent. This value was in the range of the whiteness degree of raw materialwhich ranged between 52.1 to 93.6 percent

3.2 Model Execution Process using Linear Programming

The used of linear programming to solve Eq.5 as objective function and Eq. 6 to 18 as constraint functions produced the optimum value (z) for various penalty weight i.e. W_4 (penalty weight for protein), W_8 (penalty weight for amylose) and W_{11} (penalty weight for color index) is shown in Table 2.

At $W_4 \geq W_8$and $W_8 \leq W_{11}$, it was obtained $(y_1^+ - y_1^-) = 0, (y_2^+ - y_2^-) = 25.59, (y_3^+ - y_3^-) = 57.74,\ y_1^- = 0,\ y_2^- = 0\ , y_3^- =$ 0, z minimum was only determined by W_8. Referring to eq. 6, 7 and 8, the optimum protein was 8.58 percent, surplus of amylose 25.59 percent and surplus of color index was 57.74 percent. Using total composition of x_1 = 0.6554, x_3=0.9224 and x_9=0.6068, total protein became 6.22 percent, amylose 22.52 percent and color index 68.59 percent.

If $W_4 \geq W_8$and $W_8 \leq W_{11}$ were not met, $(y_1^+ - y_1^-) = -4.71, (y_2^+ - y_2^-) = 23.25 (y_3^+ - y_3^-) = 41.35,\ y_1^- = 4.71,\ y_2^- = 0\ , y_3^- = 0$ was obtained, then z minimum was only determined by W_4 and W_8. Referring to Eq. 6, 7 and 8, the protein was 3.87 percent, amylose was surplus 23.25 percent and color index was surplus 41.35 percent. Using totalcomposition of x_1 = 0.5054, and x_9=1.1772, the total protein became 2.31 percent, amylose was 27.86 percentand color index was 79.35 percent.

With z minimum value of 25.59 percent, it produced optimum composite non-rice carbohydrate sources for SRG with the following composition: 0.66 portion or 30 percent of arrowroot starch, 0.92 portion or 42 percent of *Beneng* taro flour and 0.61 portion or 28 percent of sorghum flour.

3.3 Nutrient Value and Physical Properties of Optimum Composite Non-rice Carbohydrate Sources for SRG

Optimum flour for SRG found using GLP (30 percent of arrowroot starch, 42 percent of *beneng* taro flour and 28 percent of Sorghum flour) was analyzed for its nutritional value and physical properties. Predicted nutritional values of flour for SRG obtained from optimization result as compared to that of analyzed values, and flour from Ciherang variety of local rice are shown at Table 3 and Table 4.

3.4 Protein and Amylose Content

The SRG flour optimization with composition of 30 percent of arrowroot starch, 42 percent of *beneng* taro flour and 28 percent of sorghum flour by using Eq.6 and minimum z value produced protein content 6.22 percent. This value was still lower than the desired result i.e. 8.58 percent. This could be due to the protein value of the composite materials (3.40± 3.09) percent with large variance. Some raw materials of the composite flour had higher protein content than rice; however Eq.18 indicated that starch content for lower protein content was set up to 30 percent [8].

The optimum SRG flour has amylose content of 22.52 percent while the standard value was 23.61 percent. The amylose content of SRG flour and Ciherang rice is in medium range [3]. The optimum amylose content of SRG was still in the range of its raw material i.e. (28.01±6.05) percent. The simulation result using penalty weight of amylose content higher than penalty weight of protein and higher or similar to penalty weight of color index produced SRG flour with amylose content 27.86 percent; protein content 2.31 percent and higher color index i.e. 79.35 percent. The resulted composition was arrowroot starch 30 percent and sorghum flour 70 percent.

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Table 1. Physicochemical properties of various carbohydrate sources

Nutrient content/physical properties of starch/flour	Flour material										
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{st}
Moisture (%,wd) (a_{1i})	(9.9 ± 0.19)	(16.86 ± 0.12)	(11.93 ± 0.14)	(7.26 ± 0.01)	(4.62 ± 0.01)	(3.60 ± 0.10)	(14.59 ± 0.04)	(12.57 ± 0.01)	(11.28 ± 0.10)	(9.03 ± 0.13)	(11.08 ± 0.00)
Ash (%,db) (a_{2i})	(0.27 ± 0.03)	(0.20 ±0.01)	(4.32 ± 0.06)	(1.96 ± 0.08)	(0.06 ± 0.00)	(0.49 ± 0.04)	(0.23 ± 0.04)	(0.22 ± 0.06)	(0.54 ±0.02)	(3.47 ± 0.41)	(0.33 ± 0.08)
Fat (%,db)(a_{3i})	(0.36 ± 0.00)	(0.45 ±0.15)	(0.9 ± 0.03)	(0.59 ± 0.05)	(0.29 ± 0.01)	(2.03 ± 0.07)	(5.58 ± 0.05)	(0.47 ± 0.01)	(0.96 ±0.02)	(4.34 ± 0.15)	(0.43 ± 0.03)
Protein (%,db)(a_{4i})	(0.65 ± 0.09)	(0.69 ±0.07)	(6.86 ±0.08)	(5.52 ± 0.23)	(0.46 ± 0.00)	(8.38 ± 0.13)	(5.36 ± 0.05)	(0.66 ± 0.00)	(6.39 ± 0.04)	(5.83 ± 0.03)	(8.58 ± 0.01)
Food fiber (%,db)(a_{5i})	(2.67 ± 0.23)	(2.38 ±0.15)	(2.47 ± 0.10)	(2.34 ±0.14)	(1.52 ± 0.07)	(3.16 ± 0.19)	(1.50 ± 0.06	(1.74 ± 0.15)	(4.65 ± 0.25)	(2.47 ± 0.21)	(6.88 ± 0.17)
Crude fiber (%,db) (a_{6i})	(0.49 ± 0.01)	(0.57 ±0.04)	(3.24 ± 0.02)	(2.57 ± 0.01)	(0.37 ± 0.03)	(0.32 ± 0.09)	(0.41 ± 0.01)	(0.48 ± 0.06)	(0.80 ± 0.02)	(0.54 ± 0.06)	(0.32 ± 0.02)
Total sugar (%,db) (a_{7i})	(1.03 ± 0.30)	(1.47 ± 0.07)	(2.00 ± 0.05)	(4.32 ± 0.18)	(1.09 ± 0.04)	(2.21 ± 0.10)	(0.32 ± 0.11)	(1.33 ± 0.13)	(1.10 ± 0.13)	(1.69 ± 0.09)	(1.16 ± 0.16)
Amylose (%,db)(a_{8i})	(28.55 ± 0.93)	(37.3 ±0.29)	(14.92 ± 0.35)	(25.28 ± 0.20)	(29.54 ± 0.25)	(24.11 ±0.52)	(32.99 ±0.36)	(31.99 ± 0.58)	(27.57 ±0.19)	(23.28 ± 0.46)	(23.61 ± 1.21)
Amilopectin (%,db)(a_{9i})	(65.98 ± 0.79)	(56.68 ± 0.51)	(65.31 ± 0.21)	(57.43 ± 0.42)	(66.68 ± 0.01)	(59.30 ±0.66)	(53.60 ± 0.36)	(63.11 ±0.48)	(58.34 ± 0.32)	(58.38 ± 0.86)	(58.69 ± 0.99)
Angle of repose (degree)(a_{10i})	(35.1 ± 0.44)	(45.27 ± 3.04)	(34.27 ± 0.05)	(32.5 ± 0.33)	(25.34 ± 4.86)	(49.16 ± 1.14)	(41.47 ± 0.65)	(40.08 ±0.01)	(50.46 ±1.00)	(40.16 ± 0.54)	(42.85 ± 0.99)
Color index (%)(a_{11i})	(83.6 ± 0.05)	(72.67 ± 0.05)	(52.05 ±0.05)	(70.5 ± 0.00)	(93.6 ± 0.05)	(82.5 ± 0.00)	(59.15 ± 0.24)	(70.7 ± 0.12)	(77.53 ± 0.10)	(69.08 ± 0.30)	(92.13 ± 0.13)
Density (kg/m^3)(a_{12i})	(514 .±10.5)	(498 ± 5.26)	(396.32 ± 0.09)	(487.2 ± 3.02)	(467.7 ± 0.47)	(399.08 ± 5.86)	(498.68 ± 4.09)	(540.86 ± 1.21)	(448.5 ± 1.72)	(367.5 ± 3.07)	(467.47 ± 2.09)

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Table 2. Optimum value for various penalty weights

penalty weight			optimun							physicochemical		
W_4	W_8	W_{11}	$y1^{-+}$	$y1^{-}$	$y2^{+}$	$y2^{-}$	$y3^{+}$	$y3^{-}$	Value Z	Protein (%)	Amylose (%)	Color Index(%)
1	1	1	0.00	0.00	25.59	0.00	57.74	0.00	25.59	6.22	22.52	68.59
1	1	5	0.00	0.00	25.59	0.00	57.74	0.00	25.59	6.22	22.52	68.59
1	1	9	0.00	0.00	25.59	0.00	57.74	0.00	25.59	6.22	22.52	68.59
1	5	1	0.00	4.71	23.25	0.00	41.35	0.00	120.96	2.31	27.86	79.35
1	5	5	0.00	4.71	23.25	0.00	41.35	0.00	120.96	2.31	27.86	79.35
1	5	9	0.00	4.71	23.25	0.00	41.35	0.00	120.96	2.31	27.86	79.35
1	9	1	0.00	4.71	23.25	0.00	41.35	0.00	213.55	2.31	27.86	79.35
1	9	5	0.00	4.71	23.25	0.00	41.35	0.00	213.55	2.31	27.86	79.35
1	9	9	0.00	4.71	23.25	0.00	41.35	0.00	213.55	2.31	27.86	79.35
5	1	1	0.00	0.00	25.59	0.00	57.74	0.00	25.59	6.22	22.52	68.59
5	1	5	0.00	0.00	25.59	0.00	57.74	0.00	25.59	6.22	22.52	68.59
5	1	9	0.00	0.00	25.59	0.00	57.74	0.00	25.59	6.22	22.52	68.59
5	5	1	0.00	0.00	25.59	0.00	57.74	0.00	127.96	6.22	22.52	68.59
5	5	5	0.00	0.00	25.59	0.00	57.74	0.00	127.96	6.22	22.52	68.59
5	5	9	0.00	0.00	25.59	0.00	57.74	0.00	127.96	6.22	22.52	68.59
5	9	1	0.00	4.71	23.25	0.00	41.35	0.00	230.32	2.31	27.86	79.35
5	9	5	0.00	4.71	23.25	0.00	41.35	0.00	230.32	2.31	27.86	79.35
5	9	9	0.00	4.71	23.25	0.00	41.35	0.00	230.32	2.31	27.86	79.35
9	1	1	0.00	0.00	25.59	0.00	57.74	0.00	25.59	6.22	22.52	68.59
9	1	5	0.00	0.00	25.59	0.00	57.74	0.00	25.59	6.22	22.52	68.59
9	1	9	0.00	0.00	25.59	0.00	57.74	0.00	25.59	6.22	22.52	68.59
9	5	1	0.00	0.00	25.59	0.00	57.74	0.00	127.96	6.22	22.52	68.59
9	5	5	0.00	0.00	25.59	0.00	57.74	0.00	127.96	6.22	22.52	68.59
9	5	9	0.00	0.00	25.59	0.00	57.74	0.00	127.96	6.22	22.52	68.59
9	9	1	0.00	0.00	25.59	0.00	57.74	0.00	238.32	6.22	22.52	68.59
9	9	5	0.00	0.00	25.59	0.00	57.74	0.00	238.32	6.22	22.52	68.59
9	9	9	0.00	0.00	25.59	0.00	57.74	0.00	238.32	6.22	22.52	68.59

The minimum and maximum value of angle of repose resulted from ten materials which were used for optimization were (25.3±4.86) degree and (50.5±1.00) degree with average number was (39.38±7.80) degree. Optimizing angle of repose was carried out to determine the optimum value of angle of repose of the mixture. This was expected that SRG flour could flow properly when fed into the moulding machine. The optimum angle of repose was 39.57 degree and testing result was 32.9 degree. The angle of repose of Ciherang rice was 42.85 degree at forming machine. It was higher than the optimization result or testing result of SRG. This condition made the flow of mixture could have better performance if using the angle of repose of Ciherang rice.

The minimum and maximum values of color index of ten materials were (52.05±0.05) degree and (83.60±0.05) degree with average number was (73.13±12.03) degree. The color index of flour made by Ciherang rice was (92.10±0.13) percent. Facing this condition, it would be very difficult to meet the color index standard as the number was out of ranges. The optimum color index of SRG flour was 68.59 degree and laboratory test result was (59.96±0.04), which were still lower than expected result.

The minimum and maximum density values of ten materials were (367.5±3.07) kg/m^3 and (540.85±1.21) kg/m^3 with average number was (461.82±57.38) kg/m^3. The density of flour made by Ciherang rice was (467.47± 0.209). The optimum density resulted from optimization was 446.21 kg/m^3 and laboratory test result was (455.0±0.00) kg/m^3. It was expected that density of SRG flour close to the density value of Ciherang rice flour.

Table 3. Predicted nutritional value of SRG flour obtained from optimization result as compared to that of analyzed values, and flour from Ciherang variety of local rice

Component	*Predicted value*	*Analyzed value*	*Ciherang variety of local rice*
Moisture (%,wb)	*11.78*	*(8.65±0.04)*	*(11.08± 0.00)*
Ash (%,db)	*1.97*	*(0.63±0.02)*	*(0.33± 0.08)*
Fat (%,db)	*1.33*	*(1.42±0.00)*	*(0.43±0.03)*
Protein (%,db)	*6.22*	*(8.30±0.11)*	*(8.58±0.01)*
Carbohydrate (%,db)	*90.48*	*(89.65±0.38)*	*(90.66±0.02)*
Dietary food fiber (%,db)	*1.28*	*(2.63±0.19)*	*(6.88.±0.12)*
Crude fiber (%,db)	*1.74*	*(0.55±0.01)*	*(0.32±0.02)*
Total sugar(%,db)	*1.46*	*(0.76±0.11)*	*(1.16±0.16)*
Starch (% ,db)	*86.00*	*(85.70±0.20)*	*(82.30±0.22)*
Amylosa(%,db)	*22.52*	*(26.16±0.23)*	*(23.61±1.21)*
Amylopectin(%,db)	*63.48*	*(59.54±0.07)*	*(58.69±0.99)*

Table 4. Predicted physical properties of SRG flour obtained from optimization result as compared to that of values analyzed, and flour from Ciherang variety of local rice

No	*Physical properties*	*Predicted value*	*Analyzed value*	*Ciherang variety of local rice*
1	*Angle of repose (degree)*	*39.01*	*(32.89±0.61)*	*(42.85± 0.99)*
2	*Color index (%)*	*68,59*	*(59.96±0.04)*	*(92.13± 0.13)*
3	*Density (kg/m³)*	*446.21*	*(455±0.00)*	*(467.47±2.09)*

4 Conclusion

Linear Programming method could be used in optimization process of simulated rice grain production by considering objective function (protein, amylose and color index) and constraint function. SRG flour formulated using 30 percent of arrowroot starch, 42 percent of *Beneng* taro flour and 28 percent of sorghum flour has similar physicochemical properties to that flour from Ciherang variety of local rice. Future research is still needed to explore various non-rice carbohydrate sources as an effort to produce closer rice physicochemical properties.

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