Antidiabetic Potency and Characteristics of Corn Flour and Cassava Flour-Based Rice Analog Added with *R. mucronata* Mangrove Fruit Flour and *E. cottonii* Seaweed Flour

Hardoko¹,*, Yahya Abdul Hafidz¹, Bambang Budi Sasmito¹, Yuniwaty Halim²

¹Department of Fish Processing Technology, Faculty of Fisheries, Brawijaya University, Malang, Indonesia
²Department of Food Technology, Universitas Pelita Harapan, Lippo Karawaci, Tangerang, Indonesia

*Corresponding author. Email: hardoko@ub.ac.id*

**ABSTRACT**

Rice analog can be made from various sources of carbohydrate other than rice itself and can be designed to become functional rice by adding ingredients that have functions on health. The aim of this research was to determine the antidiabetic potency and characteristics of corn flour and cassava flour-based rice analog that has been added with mangrove fruit flour and seaweed flour. The research was done using experimental method by adding mangrove fruit *R. mucronata* flour (5%, 10% and 15% w/w) and seaweed *E. cottonii* flour (0%, 3%, 5% and 7% w/w). The method used to prepare rice analog was extrusion method. Results showed that addition of mangrove fruit flour and seaweed flour could increase inhibition activity towards α-glucosidase enzyme but decrease the panelists’ acceptance. The selected rice analog that is potential to be antidiabetic food product was formulation of rice analog with addition of 5% *R. mucronata* rice flour and 5% *E. cottonii* seaweed flour. This rice analog has IC₅₀ of 185.59 ppm, overall hedonic score of 3.65 (slightly dislike to neutral), cooking time of 7.09±0.05 minutes, texture score of 3.44 (slightly sticky), protein content of 3.24% and total dietary fiber of 9.71%.

**Keywords:** analog rice, IC₅₀, mangrove, seaweeds

I. INTRODUCTION

Rice is main staple food that is consumed frequently by most of Indonesian people. It can be seen from rice consumption level in Indonesia that reaches 95%. The average rice consumption in Indonesia from 2002-2013 is about 103.18 kg/person/year with decreasing rate of about 0.88% per year. Rice production in Indonesia nowadays is quite high, but in the future, there is a concern that the availability of rice cannot fulfil rice consumption needs. Therefore, there needs to be an effort to support national food security, namely by diversifying food in the form of analog rice [1].

Rice analog is also known as artificial rice. Rice analog is rice made from non-rice sources with carbohydrate content similar to or higher than rice, with a form resembling rice and can come from a combination of local flour [2]. There are two methods to produce rice analog, i.e. granulation method and extrusion method. The difference between these two methods is in dough gelatinization and moulding stages. The moulding result from the granulation method is granular, whereas the results of the extrusion method are oval round and resemble the shape of rice [3].

Other than fulfilling food needs, rice analog can also be utilized as a functional food that is beneficial for health by adding active or bioactive compounds from plants or animals that have positive effects on health. One of bioactive sources is mangrove plant that live on the coast and have many benefits ranging from ecological benefits to benefits as a food source and medicine. There are several bioactive compounds in mangrove, such as saponin, flavonoid and tannins, that can be used as raw materials for medicine [4;5], also steroid and triterpenoid [6]. A type of mangrove that has been used widely as medicine and food source is *R. mucronata* mangrove fruit [7]. Tannin in *R. mucronata* mangrove fruit is reported to be able to reduce hypermotility of intestine during diarrhea [8], whereas alkaloid and triterpenoid can inhibit sedangkan α-glucosidase [9], therefore it is potential to become antidiabetic agent. Potency of *R. mucronate* as antidiabetic agent has been reported to be quite good [10; 11; 12]. Thus, it is expected that addition of *R. mucronata* fruit flour to rice analog can produce functional rice analog particularly for diabetics.

Another ingredient that has been reported to have antidiabetic properties is *E. cottonii* seaweed [13], which also has hypocholesterolemia properties [14]. It is
The development of rice analog with antidiabetic properties is important for Indonesian society because there are many diabetics that are difficult to change the rice consumption habit. Moreover, diabetics in Indonesia also occupy the top position. Diabetes is characterized by hyperglycemia and metabolic disorder on carbohydrate, fat and protein, related to absolute or relative lack of insulin work or secretion [18, 19]. Control of hyperglycemia after eating is believed as an important thing in diabetes treatment. Control can be done by consuming food with hypoglycemic properties or able to inhibit starch hydrolyzing enzyme, such as α-glucosidase [20].

Considering the Indonesian society that cannot be separated from rice as staple food, and the benefits of *R. mucronata* mangrove fruits that are potential to cure diabetes, a research to develop corn flour and cassava flour-based rice analog added with *R. mucronata* mango flour combined with *E. cottonii* seaweed flour, should be done. This is also to determine its α-glucosidase inhibitory activity.

### II. METHODS

#### A. Materials and Equipment

Materials used in rice analog making were *R. mucronata* mango fruit, dried *E. cottonii* seaweed, cassava flour, and corn flour. *R. mucronata* mango fruit, *E. cottonii* seaweed, cassava flour and corn flour were obtained from Pasar Besar Malang. Materials used for inhibitory activity assay were α-glucosidase enzyme (Megazyme, England), p-Nitrophenyl α-glucopyranoside (PNPG) substrate (Megazyme), dimethyl sulfoxide (DMSO), pH buffer, 200 mM Na2CO3, K2HPO4, 0.2 M NaOH, 2 N HCl and acarbose.

Equipment used to prepare mangrove flour were stainless steel knife, tray, digital balance, oven, Erlenmeyer, dessicator, disc mill, 60 mesh sieve and basin. Equipment used to prepare seaweed flour were basin, blender, tray and oven. Equipment used to prepare rice analog were analytical balance, digital balance, porridge maker, disc mill, 80 mesh sieve, single screw extruder, steamer, thermometer, basin and plastic bags.

#### B. Method

Research method used was experimental method. Rice analog was prepared with treatment of *R. mucronata* fruit flour addition (5%, 10%, 15%) and *E. cottonii* flour addition (0%, 3%, 5%, 7%) to tapioca flour and corn flour.

Rice analog was made using extrusion method. Rice analog preparation includes weighing according to formulation, mixing, extrusion and drying. Mixing process was done in two stages, i.e. mixing of cassava flour and mango powder, then added with 15% water and mixed until homogenous. Afterwards, mixing was done between corn flour and seaweed flour; then added with 30% water and mixed until homogenous. Steaming process was done for 10-15 minutes. Then, mixing was done between two steamed flours (according to composition) in warm condition (before the flours became hard when cooled). Mixing was done until the flours are mixed thoroughly. The dough was then put into a screw conveyor for 5 minutes. The purpose is to ensure that dough is mixed well and easier to control extrudate obtained from the extrusion process. Afterward, the extrusion of dough was done in the extruder at a temperature of 85-90 °C. Extrudate rice was then sun-dried at ±30 °C for 2 days. This process was done to reduce the water content of rice analog to reach <14%.

Parameters observed were α-glucosidase inhibition activity [22], organoleptic tests, i.e. hedonic dan scoring [23], dietary fiber [24], cooking time [25], cooking loss [26], volume expansion [27], rehydration properties [28].

### III. RESULTS AND DISCUSSION

#### A. α-glucosidase Inhibitory Activity of Rice Analog

The function of the α-glucosidase enzyme is to break down the carbohydrate into glucose in digestion, especially in the small intestine. α-glucosidase activity assay was done to compare rice analog added with *R. mucronata* mango fruit flour and *E. cottonii* seaweed flour, with acarbose as the positive control. Statistical analysis (Anova) result showed that addition of *R. mucronata* mango fruit flour and *E. cottonii* seaweed flour and interaction of both gave significant effect (p<0.05) on IC50. The result of the post hoc test using Duncan can be observed on Figure 1. Figure 1 shows that the average IC50 value of rice analog added with *R. mucronata* mango fruit is 138.99-214.42
IC\textsubscript{50} value of rice analog was obtained from treatment of addition of 15\% \textit{R. mucronata} mangrove fruit flour and 5\% \textit{E. cottonii} seaweed flour. The highest IC\textsubscript{50} value of rice analog was obtained from treatment of addition of 5\% \textit{R. mucronata} mangrove fruit flour and 0\% \textit{E. cottonii} seaweed flour. The lowest IC\textsubscript{50} value of rice analog (138.99 ppm) is higher than IC\textsubscript{50} value of \textit{acarbose} (59.57 ppm), but lower compared to control (375.61 ppm). This result indicates that rice analog is less effective in inhibiting \(\alpha\)-glucosidase enzyme compared to \textit{acarbose}, but more effective compared to control.

Figure 1. IC\textsubscript{50} value of corn flour and cassava flour-based rice analog (300 g) with addition of \textit{R. mucronata} (TRm) flour and \textit{E. cottonii} (TEc) flour

Note: different superscript notation shows significant difference \(p<0.05\)

The ability of rice analog in inhibiting \(\alpha\)-glucosidase enzyme is by delaying the breakdown of oligosaccharides into monosaccharides, therefore, reducing sugar absorption in the body. Hyperglycemia is the condition in which glucose concentration in the blood is above normal, such as in diabetics [31]. Inhibition of \(\alpha\)-glucosidase enzyme can help body to overcome hyperglycemia condition because of lesser amount of monosaccharides that can be absorbed by intestine.

B. Hedonic Organoleptic Result of Rice Analog

Overall hedonic is the assessment of a panelist’s preference in overall towards a certain product. There are several parameters assessed in rice analog using overall hedonic assessment, i.e. taste, colour and texture. Statistical analysis (Anova) result shows that the addition of \textit{R. mucronata} mangrove fruit flour and \textit{E. cottonii} seaweed flour and interaction of both gave significant effect \((p<0.05)\) on overall hedonic score. The result of post hoc test using Duncan can be observed on Figure 2.

Figure 2. Overall hedonic score \(1 = \) extremely dislike; \(7 = \) extremely like) of corn flour and cassava flour-based rice analog (300 g) with addition of \textit{R. mucronata} (TRm) flour and \textit{E. cottonii} (TEc) flour

Note: different superscript notation shows significant difference \(p<0.05\)

C. Cooking Time of Rice Analog

Statistical analysis (Anova) result shows that that addition of \textit{R. mucronata} mangrove fruit flour and \textit{E. cottonii} seaweed flour and interaction of both gave significant...
effect (p<0.05) on cooking time of rice analog. Result of post hoc test using Duncan can be observed on Figure 3.

Figure 3 shows that average cooking time of corn-based and cassava flour-based analog added with 5% *R. mucronata* mangrove fruit flour and 5% *E. cottonii* seaweed flour, whereas the longest cooking time is obtained from rice analog added with 15% *R. mucronata* mangrove fruit flour and 7% *E. cottonii* seaweed flour.

Cooking time of rice analog made from white corn is 4.06 minutes [32]. On the other hand, the shortest cooking time of rice analog added with *R. mucronata* is 7.09 minutes. Longer the cooking time of rice analog indicates the longer time required by rice analog to be fully cooked. The higher the concentration of *R. mucronata* added the longer the cooking time. It is because higher concentration of *R. mucronata* added makes rice analog obtained becomes more compact. Thus, affecting the rice cooking process.

**D. Texture Organoleptic Result of Rice Analog**

Scoring of texture is done to give assessment on texture of a food product with score from 1 to 7, where 1 = extremely not sticky, 2 = not sticky, 3 = slightly sticky, 4 = sticky, 5 = slightly stickier, 6 = very sticky, 7 = extremely sticky. Statistical analysis (Anova) result shows that the addition of *R. mucronata* mangrove fruit flour and *E. cottonii* seaweed flour and interaction of both gave significant effect (p<0.05) on texture scoring of rice analog. Result of the post hoc test using Duncan can be observed in Figure 4.

Figure 4 shows that average scoring for texture of corn based and cassava flour-based analog added with 5% *R. mucronata* mangrove fruit flour and 5% *E. cottonii* seaweed flour is about 3.15-5.54, which shows that rice analog was perceived as slightly sticky to slightly stickier, in terms of texture, by the panelists. The highest scoring value was obtained from rice analog added with 15% *R. mucronata* mangrove fruit flour and 7% *E. cottonii* seaweed flour, with score of 5.65, which shows that the texture was slightly stickier.

**E. Selected Rice Analog**

Based on the overall hedonic test result, the selected rice analog formulation was rice analog added with 5% *R. mucronata* mangrove fruit flour and 5% *E. cottonii* seaweed flour, with score that shows slightly like by the panelists. The physicochemical characteristics of selected rice analog can be seen in Table 1.
Table 1 shows that best formulation of rice analog from black mangrove flour and sago flour added with chitosan [33] was made using 70% black mangrove flour, 30% sago flour, added with 0.5% chitosan. This formulation has yield of 81.94%, moisture content of 13.48%, starch content of 70.99%, protein content of 3.57% and dietary fiber of 8.16%. Moreover, the best formulation of rice analog from mocaf flour and E. cottonii flour [34] was the one added with 5% E. cottonii flour. This formulation has yield of 99.00%, moisture content of 8.76%, protein content of 0.86%, fat content of 0.15%, ash content of 1.96% and dietary fiber of 49.76%. Moisture content of rice analog obtained has already fulfilled the standard of SNI 6128: 2015, i.e. less than 14%. Another research of rice analog made from mocaf flour, corn starch, CMC (Carboxy Methyl Cellulose) and okara flour [35] shows that the best rice analog was obtained from the addition of 1.5% CMC and 5% okara flour. This formulation has a moisture content of 8.00%, starch content of 84.86%, the volume of expansion of 142.58%, rehydration of 155.06%, the cooking time of 12.45 minutes, cooking loss of 0.85% and protein content of 1.88%.

IV. CONCLUSION

Higher amount of R. mucronata mangrove fruit flour and E. cottonii seaweed flour into rice analog increases the inhibitory activity towards α-glucosidase enzyme but decreases the panelists’ acceptance. The selected rice analog is corn flour based and cassava flour-based rice analog added with 5% R. mucronata mangrove fruit flour and 5% E. cottonii seaweed flour.

The selected rice analog has yield of 64.06±0.47%, rehydration of 40.37±0.84%, volume of expansion of 44.16±0.83%, cooking time of 7.09±0.05 minutes, cooking loss of 16.86±0.53%, moisture content of 9.47±0.19%, starch content of 70.99±0.72%, protein content of 3.24%, soluble dietary fiber content of 1.83%, insoluble dietary fiber content of 7.88%, IC50 value of 185.59 ppm, overall hedonic score of 3.65 (slightly dislike-neutral) and texture score of 3.44 (slightly sticky).

REFERENCES

[1] Adicandra, R. M., dan T. Estiasih, “Beras analog dari ubi kelapa putih (Discorea alata L.),” Jurnal Pangan Dan Agroindustri vol. 4 no. 1, pp. 383-390, 2016.
[2] M.Y. Samad, “Pembuatan beras tiruan (Artificial Rice) dengan bahan baku ubi kayu dan sagu,” Prosiding Seminar Teknologi untuk Negeri vol. 2, pp 36-40. Jakarta : BPPT, 2003.
[3] S.S. Widara, “Formulasi dan karakterisasi gizi beras analog terbuat dari campuran tepung sorgum, mocaf, jagung, maizena, dan sago aren.” Bogor : Skripsi. IPB, 2012.
[4] A. Kustanti, “Manajemen Hutan Mangrove,” Bogor : IPB Press, pp. 248-249, 2011.
[5] G. Sahoo, N.S.S. Mulla, Z.A.Ansari, dan C. Mohandas, “Antibacterial activity of mangrove leaf extracts against human pathogen,” Indian J. Pharm. Sci. vol. 74 no. 4, pp. 349-357, 2012.
[6] F. Podungee, “Ekstraksi dan Formulasi Ekstrak Buah Bakau Hitam Sebagai Minuman Fungsional,” Bogor : Tesis Pascasarjana IPB, pp. 75, 2016.
[7] S. Purwaningsih, E. Salamah, A.Y.P. Sukarno, dan E. Deskawati, “Aktivitas antioksidan dari buah mangrove (Rhizophora mucronata lamk.) pada suhu yang berbeda,” Jurnal Pengolahan Hasil Perikanan Indonesia vol. 16 no. 3, pp. 199-206, 2013.
[8] T.D. Sulistiyati, dan Y.E. Puspitasari, “Kerupuk mangrove antidiare dari buah bakau Rhizophora mucronata.” Journal of Innovation and Applied Technology vo. 1 no. 1, pp. 82-87, 2015.
[9] W. Benalla, S. Bellahcen, dan M. Bnouham, “Antidiabetic medicinal plants as a source of alpha glucosidase inhibitors.” Current Diabetes Reviews vol. 6, pp.247-254, 2010.
[10] Hardoko, B.B. Sasmito, Y.E. Puspitasari, Y.D Okviani, Y. Halim, “The Effect of Heating Temperature on Inhibitory Activity of Mangrove Rhizophora mucronata Fruit Extract toward α-Glucosidase.” Asian J Pharm Clin Res. vol 11 no. 7, pp. 237-241, 2018.
[11] Hardoko, B.B. Sasmito dan Y. E. Puspitasari, “Antidiabetic and antioxidant activities of tannin extract of Rhizophora mucronata leaves.” Journal of Chemical and Pharmaceutical Research vol 8 no. 3, pp.143-148, 2016.
[12] Hardoko, E. Suprayitno, Y.E. Puspitasari, dan R. Amalia, “Study of ripe Rhizophora mucronata fruit flour as functional food for antiobesity,” International Food Research Journal vol. 22 no. 3, pp. 953-959, 2015.
[13] Hardoko, “Studi Penurunan Glucosa Darah Diabetik dengan Konsumsi Rumput Laut Eucheuma cottonii,” Jurnal Perikanan (J. Fish. Sci.) vol. 9 no 1, pp. 27-35, 2007.
[14] Hardoko, “Pengaruh konsumsi gel dan larutan rumput laut (Eucheuma cottonii)” terhadap hiperkolesterolemia darah tikus wistar,” Jurnal Teknologi dan Industri Pangan vol.19 no.2, pp. 97-104, 2008.
[15] M. Astawan, T. Wresdiyati, dan A.B. Hartanta, “Pemanfaatan rumput laut sebagai sumber serat pangan untuk menurunkan kolesterol darah tikus,” Jurnal Hayati vol. 12 no. 1, pp. 23-27, 2005.
[16] E. Syamsir, “Pembuatan susu jagung”, Bogor : Departemen Ilmu dan Teknologi Pangan. IPB, 2008.
[17] Direktorat Gizi Departemen Kesehatan Republik Indonesia, “Daftar Komposisi Bahan Makanan,” Jakarta : Bhratara Karya Aksara, p. 56, 1981.
[18] H. Buraerah, “Analisis faktor risiko diabetes melitus tipe 2 di Puskesmas Tanrutedong, Sidenreng Rappang,” Jurnal Kedokteran Indonesia vol. 35 no. 4, pp. 228-237, 2010.

[19] Y. Zhenhua, Z. Wei, F. Fajin, Z. Yong, dan K. Wenyi, “α-Glucosidase inhibitors isolated from medicinal plants,” Food Science and Human Wellness vol. 3, pp. 136-174, 2014.

[20] A. E. Febrinda, A. Made, W. Tutik, dan D. Y. Nancy, “Kapasitas antioksidan dan inhibitor alfa glukosidase ekstrak umbi bawang dayak.” Jurnal Teknologi dan Industri Pangan vol. 24 no. 2, pp. 67-74, 2013.

[21] Hardoko, E. Suprayitno, Y.E. Puspitasari, dan R. Amalia, “Study of ripe Rhizophora mucronata fruit flour as functional food for antidiabetic,” International Food Research Journal vol. 22 no. 3, pp. 953-959, 2014.

[22] S. Sugiwati, S. Siswati, dan E. Anwar, “Antihyperglycemic activity of the mahkota dewa (Phaleria macrocarpa (Scheff).iBoerl) leaf extracts as an-alpha-glucosidase inhibitor,” Jurnal Makara Kesehatan vol. 13 no. 2, pp. 74-78, 2009.

[23] S.T. Soekarto, “Penelitian organoleptik untuk industri pangan hasil pertanian, Jakarta : Bhatara Karya Aksara, pp 77-83, 1989.

[24] AOAC, “Official methods of analysis. Association of Official Analytical Chemists,” Washington : Benjamin Franklin Station, 2005.

[25] T. Muhandri, A.B. Ahza, R. Syarief, dan Sutrisno. Optimasi proses ekstraksi mi jagung dengan metode permukaan respon.” Jurnal Teknologi dan Industri Pangan vol. 22 no. 2, pp. 97-104, 2011.

[26] N.H. Oh, P.A. Seib, C.W. Deyoe, dan A.B. Ward, “Noodles : The surface of cooked noodles from soft and hard wheat flours, American Association of Cereal Chemists Inc. vol. 62 no. 6, pp. 431-436, 1985.

[27] S. S.Yuwono, dan T. Susanto, “Pengujuan fisik pangan,” Malang : Fakultas Teknologi Pertanian UB, pp. 365-366, 2001.

[28] S. Ranggana, “Manual of Analysis of Fruit and Vegetable Product.”. New Delhi: MCGraw-Hill Publishing Company Limited, pp. 121-122, 1997.

[29] I.W.R. Widarta, dan I.W. Arnata, “Stabilitas aktivitas antioksidan ekstrak bekatul beras merah terhadap oksidator dan pemanasan pada berbagai pH”, Jurnal Teknologi dan Industri Pangan vol. 25 no. 2, pp. 193-199, 2014.

[30] T. Dewanti, N. Wijayanti, D. Handayani, dan N. Rochmawati, Hipoglikemik ekstrak cincau hitam (mesona palustris bl) pada tikus wistar diabetes yang di induksi alloxan, Jurnal Kedokteran Brawijaya vol. 28 no. 3, pp. 202-20, 2015

[31] A.E. Febrinda, A. Made, W. Tutik, dan D.Y. Nancy, “Kapasitas antioksidan dan inhibitor alfa glukosidase ekstrak umbi bawang Dayak,” Jurnal Teknologi Dan Industry Pangan vol. 24 no. 2, pp. 57-66, 2013.

[32] S. Noviasari, F. Kusnandar, A. Setiyono, dan S. Budijanto, “Beras analog sebagai pangan fungsional dengan indeks glikemik rendah”, Jurnal Gizi Pangan vol. 10 no. 3, pp. 225-232, 2013.

[33] T. Hidayat, “Buah lindur (Brugueira gymnorrhiza) sebagai bahan baku pembuatan beras analog dengan penambahan sagu dan kitosan,” Bogor : Skripsi, Institut Pertanian Bogor 2014, pp. 1-78

[34] Agusman, S.N.K. Apriani., dan Murdinah, “Penggunaan tepung rumput laut eucheuma cottonii pada pembuatan beras analog dari tepung modified cassava flour (mocaf),” Jurnal Pengembangan dan Bioteknologi Perikanan vol. 9 no 1 pp. 1-10, 2014.

[35] Yuwono, dan A. A. Zulfiah, “Formulasi beras analog berbasis tepung mocaf dan maizena dengan penambahan CMC dan tepung ampas tahu,” Jurnal Pangan dan Agroindustri vol. 3 no. 4, pp. 465-1472, 2015.