JJBS

Volume 14, Number 3, September 2021
ISSN 1995-6673
Pages 389 – 393
https://doi.org/10.54319/jjbs/140302

Jordan Journal of Biological Sciences

The Characteristics and Predicted of Glycemic Index of Rice Analogue from Modified Arrowroot Starch (*Maranta arundinaceae* L.)

Damat Damat[1,*], Roy Hendroko Setyobudi[2], Joko Susilo Utomo[3], Zane Vincēviča-Gaile[4], Anas Tain[1] and Devi Dwi Siskawardani[1]

[1]Department of Food Technology, Faculty of Agriculture and Animal Science, University of Muhammadiyah Malang, Jl. Raya Tlogomas No 246, Malang 65144, East Java, Indonesia;[2]Department of Agriculture Science, Postgraduate Program, University of Muhammadiyah Malang, East Java Indonesia;[3]Indonesian Legumes and Tuber Crops Research Institute, Jl. Raya Kendalpayak No.66, Malang 65162, East Java, Indonesia;[4]Department of Environmental Science, University of Latvia, Jelgavas Street 1, Room 302, Riga LV-1004, Latvia

Received: Feb 20, 2021; Revised: May 28, 2021; Accepted May 29, 2021

Abstract

The modification of arrowroot starch is able to increase its resistant starch (RS) levels, as the result improve the functional characteristic of rice analogue for healthy diabetics. Therefore, the purpose was to determine the physical characteristics, digestibility, hydrolysis index (HI) and predicted glycemic index (PGI) of rice analogue obtained from modified arrowroot starch. The completely randomized design using single factor was conducted. The proportions of the modified arrowroot starches used were 0 %, 25 %, 50 %, 75 %, and 100 %. The procedure consisted of formulation, extrusion, and analysis parameter. According to the results, the proportions of the modified arrowroot starch had a significant effect on the microscopy as well as the rice analogue digestibility. The amount of rice analogue obtained from the 100 % modified arrowroot starch was 649 μm, which was the highest, the digestibility value at 180 min was 14.23 % ± 0.17 %, HI values at 32.14 ± 0.20 and PGI 56.79 ± 0.14, which was the smallest when compared with other treatments. It can be concluded that higher proportions of the modified arrowroot starch, resulted in higher grain size, but lower digestibility, hydrolysis index and predicted glycemic index of gluten-free rice analogue.

Keywords: Digestibility, Food diversification, Functional rice, Gluten-free rice, Healthy diabetics, Hydrolysis Index

1. Introduction

Arrowroot (*Maranta arundinaceae* L.) is a type of tuber, which is cultivated in some areas in Indonesia (Deswina and Priadi, 2020; Sholichah *et al*., 2019). Carbohydrate is the main component of this plant and various studies have been conducted to examine its starch constituents (Charles *et al*., 2016; Damat *et al*., 2017; Villas-Boas and Franco, 2016). However, the focus of this research was generally on the physical and chemical characteristics of arrowroot starch. Also, research has been conducted on the modification of arrowroot starch through esterification (Damat *et al*., 2008), cross-linking (Maulani *et al*., 2013), acetylation (Abba *et al*., 2014), gelatinization-retrogradation (Damat *et al*., 2019b; Pepe *et al*., 2015) as well as through physical modification methods (Astuti *et al*., 2018).

In addition, the previous research was conducted to the application of arrowroot starch as raw material of rice analogue (Damat *et al*., 2019b). However, there was not research on the modification of arrowroot starch through gelatinization-retrogradation and its application for functional rice analogue. Moreover, there was not research on the digestibility and predictions of the glycemic index of functional rice analogue obtained modified arrowroot starch.

According to Damat *et al*. (2019a), the modification of arrowroot starch through gelatinization-retrogradation increased its resistant starch (RS) levels. Consequently, the rice analogue resulting was rich in RS and low in GI. Damat *et al.* (2008); Damat *et al.* (2020) reported the importance of food products, which are rich in RS in controlling blood glucose since they had slower digestion rates. Control of blood glucose level was one goal of a healthy diet plan for diabetes sufferers (Al-Jamal and Alqadi, 2011; Bhaskar and Ajay, 2009); therefore, the rice analogues were usually consumed (Budijanto and Yuliana, 2015; Wahjuningsih *et al.*, 2018). The metabolism of RS occurred 5 h to 7 h after eating (Lestari *et al*., 2017); hence, it had the ability to reduce the postprandial glucose levels (Setyobudi *et al.*, 2019). This research aimed to evaluate the microscopic physical properties, in vitro digestibility, hydrolysis index (HI) and the predicted glycemic index (PGI) of the functional rice analogue from modified arrowroot starch.

2. Materials and Methods

The arrowroot starch was obtained from the farmers in Malang Regency, East Java. This research was

* Corresponding author e-mail: damatumm@gmail.com

conducted in two stages, i) the production of the modified arrowroot starch through gelatinization-retrogradation method (Damat *et al*., 2018) and ii) the production of the rice analogue. The Completely Randomized Design (CRD), with one factor, which included K0 (Control), K1 (100 % Natural Arrowroot Starch); K2 (75 % Natural Arrowroot Starch: 25 % Modified Arrowroot Starch); K3 (50 % Natural Arrowroot Starch: 50 % Modified Arrowroot Starch); K4 (25 % Natural Arrowroot Starch: 75 % Modified Arrowroot Starch); and K5 (100 % Modified Arrowroot Starch) were applied. The result expected was to increase the resistant starch, followed to reduce the degree of hydrolysis and predict the glycemic index of rice analogue.

2.1. Formulation

The ingredient formulation consisted of cornstarch, modified cassava flour, natural arrowroot starch, modified arrowroot starch, and water. Moreover, GMS (glycerol monostearate) as an emulsifier was added. The exact formula is presented in Table 1.

Table 1. Formula of rice analogue

Raw material	Ko	K1	K2	K3	K4	K5
Cornstarch (g)	250	0	0	0	0	0
Modified cassava flour (g)	250	0	0	0	0	0
Natural arrowroot starch (g)	0	500	375	250	125	0
Modified arrowroot starch (g)	0	0	125	250	375	500
Water (mL)	110	110	110	110	110	110
Emulsifier: GMS (g)	5	5	5	5	5	5

2.2. Extrusion

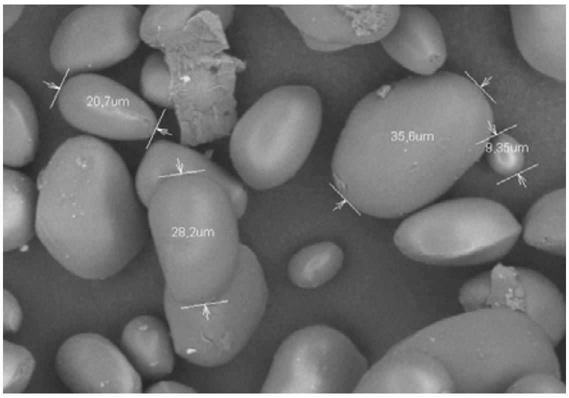
The ingredients were mixed and steamed for 30 min at 80 °C. The steamed materials were directly inserted into an extruder in order to form the analogue rice. After analogue, rice granules were formed; they were dried in a dryer cabinet at 50 °C for 20 h.

Then, analyses of the microscopic properties of the rice analogue was carried out using the modified version of Scanning Electron Microscope by Han *et al*. (2018), the resistant starch levels (Fabbri *et al*., 2016), and those of the digestibility, hydrolysis index (HI) and predicted glycemic index (PGI) conducted in vitro in accordance to Ratnaningsih *et al*. (2017). The research data were expressed as mean ± deviation standards in triplicate independent analyzes. One-way ANOVA was conducted on the data using SPSS version 17.

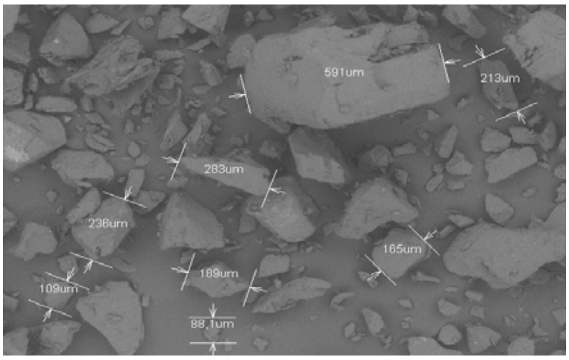
3. Results and Discussion

Arrowroot starch with different granule morphology were scanned used SEM (Figure 1). Unmodified arrowroot starch resulted round to elliptical granules with a size 9 µm to 36 µm. The starch granules had a smooth surface, and it was consistent with the granular shape of arrowroot starch reported by Charles *et al*. (2016). While, in the modified arrowroot starch granules showed different, it had a rough and irregular surface (Figure 1).

Modified arrowroot starch granules had a size of 88 µm to 591 µm, which is larger than natural arrowroot starch. Majzoobi *et al*. (2016) suggested that the increase in grain size might be related to the absorption of acid, causing some internal transformation in the granules. The alteration in the size of starch granules can cause starch digestibility and increase resistant starch level (Damat *et al*., 2019b). Modification of starch through gelatinization-retrogradation accompanied by cooling changed in the surface of the starch grains becomes uneven. Starch retrogradation generate the granules are difficult to swell and strengthen the grains, to be more heat and shear resistant leading to a lower viscosity. Changes in the structure, size and shape of starch grains induced alteration in the regularity structure of short distances, viscosity, solubility and swelling (Lin *et al*., 2015).



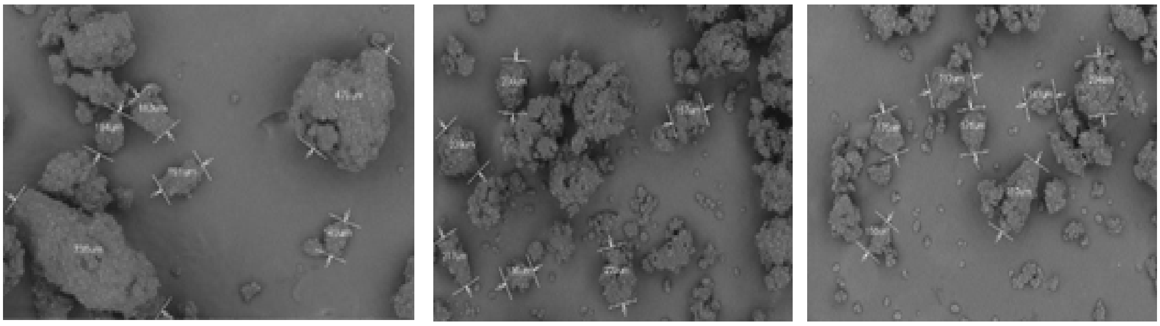
Natural arrowroot starch granules



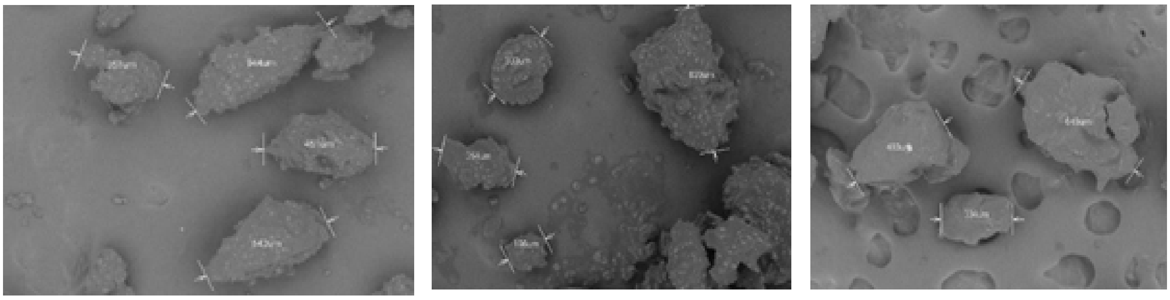
Modified arrowroot starch granules

Figure 1. Granules of natural arrowroot starch and modified arrowroot starch

The sizes and the shapes of starch granule rice analogue produced were shown in Figure 2. The K1 treatment (100 % natural arrowroot starch) was almost the same as K0, with the size was smaller ranging from 136 µm to 229 µm. Furthemore, enhancement of modified arrowroot starch induced more irregular and larger size of rice analogue granule. This was due to the incorporation of amylose in the cooling process to form crystals, which different to natural starch. The granule size of rice analogue ranged from 175 µm to 649 µm, with the biggest size ranging from 334 µm to 649 µm, found in the K5 treatment (100 % modified arrowroot starch).



a) K0 starch granule rice analogue b) K1 starch granule rice analogue c) K2 starch granule rice analogue



d) K3 starch granule rice analogue e) K4 starch granule rice analogue f) K5 starch granule rice analogue

Figure 2. Starch Granule Rice analogue under the Scanning Electron Microscope (SEM) at 100× magnification

The highest starch resistant rice analogue was found in the treatment K5, which was 16.71 % ± 0.40 %. The rice analogue with the lowest hydrolysis index and predicted glycemic index obtained this treatment were 32.14 ± 0.20 and 56.79 ± 0.14 respectively (Table 2). The results showed that the higher amount of modified arrowroot starch added produced higher levels of the resistant starch in rice analogue. However, there was a positive correlation between the resistant starch content enhancement, to the decreasing degree of hydrolysis (HI) and predicted glycemic index (PGI). According to Figure 3, the rice analogue with the lowest total hydrolyzed starch was found in treatment K5, which was 7.80 % at 30 min and 14.23 % at 180 min.

Table 2. The Resistant Starch (RS), Hydrolysis Index (HI), and Predicted Glycemic Index (PGI) of Rice Analogue

F Treatment	RS level (%)	Hydrolysis Index (HI)	Predicted Glycemic Index (PGI)
K0 (Control)	3.92 ± 0.31a	66.15 ± 0.12f	76.03 ± 0.32f
K1 (NAS 100 %, MAS 0 %)	5.81 ± 0.23b	65.68 ± 0.17e	75.77 ± 0.19e
K2 (NAS 75 %, MAS 25 %)	8.36 ± 0.35c	44.79 ± 0.23d	64.30 ± 0.24d
K3 (NAS 50 %, MAS 50 %)	11.22 ± 0.27d	40.81 ± 0.20c	62.11 ± 0.20c
K4 (NAS 25 %, MAS 75 %)	14.21 ± 0.24e	35.37 ± 0.19b	59.13 ± 0.22b
K5 (NAS 0 %, MAS 100 %)	16.71 ± 0.40f	32.14 ± 0.20a	56.79 ± 0.14a

Note: Number followed by the same letter is not significantly different according to Duncan's Test α= 5 %,

This is due to the differences in granule size and the levels of resistant starch in the rice analogue. In addition, Dundar and Gocmen (2013) stated that the increased level of the resistant starch was caused by modification through gelatinization-retrogradation method. The results obtained were similar to those of Ratnaningsih *et al.* (2017), the ability of enzymes to hydrolyze starch was strongly influenced by amylose content, resistant starch content and granule size. In accordance with Damat *et al*. (2008) and Damat *et al.* (2020), food products with high contents of resistant starch (RS) had a hypoglycemic effect as well as a low glycemic index. Resistant starch included to food fiber.

Supparmaniam *et al.* (2019) described that increasing levels of food fiber from starch were able to reduce the glycemic index of the product. In addition~~,~~ resistant starch, ratio of amylose-amylopectin, the interaction between starch, and other components contained in the product also influenced the glycemic index (Bakar *et al*., 2019). Moreover, starchy foods with low glycemic index are very good for diabetic and hypertriglyceridemia patients. Ratnaningsih *et al*. (2017) reported that functional ~~such~~ food products provide a longer feeling of satiety and increase the fermentation process in the colon.

In vitro, analogue rice starch hydrolysis was presented in Figure 3. The analogue rice starch hydrolysis speed and bread as a control increased with time. Analogue rice produced from modified arrowroot starch (MAS) had a lower starch hydrolysis speed than plain bread and natural arrowroot starch at all observation times. Analogue rice made from 100 % MAS has the lowest hydrolysis rate. The analogue rice starch hydrolysis speed was similar to raw green bean starch (Kaur *et al*., 2015), but it was lower than that reported by Ambaigapalan *et al*. (2014) on black bean, and pinto bean starch, also on field pea starch (Liu *et al*., 2015). The analogue rice digestibility of modified arrowroot starch was influenced by the absence of pores on the starch granule surface and the strong interaction between amylose chains due to the gelatinization-retrogradation process. The low digestibility of analogue rice starch was considered related to high amylose content and starch granule size (Hoover *et al*., 2010; Liu *et al*., 2015).

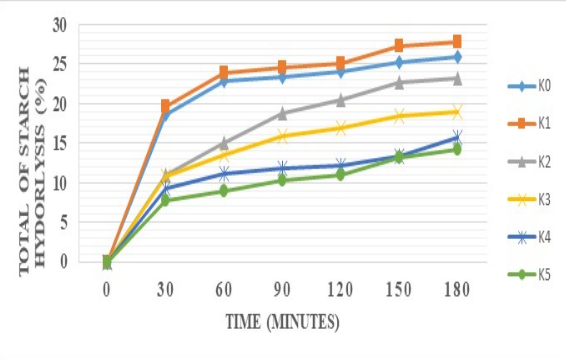


Figure 3. Starch hydrolysis pattern

4. Conclusion

The modified arrowroot starch's proportion had a significant effect on the microscopy and digestibility of rice analogue. The modified arrowroot starch enhancement resulted in larger granule size and resistant starch (RS) of rice analogue produced. Moreover, the increasing levels of RS and digestibility, the hydrolysis index (HI), and predicted glycemic index (PGI) of the rice analogue decreased, and rice analogue with low PGI is recommended for healthy diabetics.

Acknowledgements

The authors wish to thank the Ministry of Research and Technology, Republic of Indonesia, for funding for this research (E.5c/092/DPPM/L/IV/2019).

References

Abba H, Ibrahim A, Shalllangwa GA, Uba S and Dallatu YA. 2014. Effect of acetylation on stability to retrogradation of starch extracted from wild polynesian arrowroot (*Tacca leontopetaloides* (L.) Kuntze) for utilization as adhesive on paper. *J. Polym.* **732174**:1−9.

Al-Jamal A, and Alqadi T. 2011. Effects of rosemary (*Rosmarinus officinalis*) on lipid profile of diabetic rats. *Jordan J Biol Sci* **4(4):** 199–204.

Ambigaipalan P, Hoover R, Donner E, and Liu Q. 2014. Starch chain interactions within the amorphous and crystalline domains of pulse starches during heat-moisture treatment at different temperatures and their impact on physicochemical properties. *Food Chem.* **143**:175−184.

Astuti RM, Widaningrum, Asiah N, Setyowati A and Fitriawati R. 2018. Effect of physical modification on granule morphology, pasting behavior, and functional properties of arrowroot (*Marantha arundinacea* L) starch. *Food Hydrocoll*, **81**:23−30.

Bakar NAFA, Rashid AAA, Ishak MF and Jalil AMM. 2019. Glycemic index of starch-based foods commonly consumed in Terengganu, Malaysia. *Malays Appl Biol*, **48(4)**:129−138.

Bhaskar VH and Ajay SS. 2009. Antihyperglycemic and antihyperlipidaemic activities of root extracts of *Calotropis procera* (Ait.) R.Br on streptozotocin induced diabetic rats. *Jordan J Biol Sci* **. 2(4):** 177−180.

Budijanto S and Yuliana ND. 2015. Development of rice analog as a food diversification vehicle in Indonesia. *J. Sustain. Agric.* **10**: 7−14.

Charles AL, Cato K, Huang T, Chang Y, Ciou J, Chang J and Lin H. 2016. Functional properties of arrowroot starch in cassava and sweet potato composite starches. *Food Hydrocoll.* **53**:187−191.

Damat D, Marsono Y, Haryadi and Cahyanto MN. 2008. Hypocholesterolemic and hypoglicemic effects of butyrylated arrowroot starch on Sprague Dawley rats. *Indones. J. Pharm*. **19(3)**:109−116.

Damat D, Tain A, Handjani H and Chasanah U. 2017. Microscopy and organoleptic properties of functional pastries form modified arrowroot starch (*Maranta arundinaceae* L.). *Jurnal Aplikasi Teknologi Pangan,* **6(4)**:161−166.

Damat D, Tain A, Handjani H, Chasanah U and Putri DN. 2018. **Modified Starch Technology and it's Benefits for Health**. UMM Press, Malang, Indonesia.

Damat D, Anggriani R, Setyobudi RH and Soni P. 2019a. Dietary fiber and antioxidant activity of gluten-free cookies with coffee cherry flour addition. *Coffee Sci,* **14(4)**: 493−500.

Damat D, Tain A, Handjani H, Chasanah U and Siskawardani DD. 2019b. Functional cake characteristics of modified arrowroot starch (MAS) with the gelatinization-retrograde method. *IOP Conf. Ser.: Mater. Sci. Eng.* **532 (012017)**: 1–6.

Damat D, Setyobudi RH, Soni P, Tain A, Handjani H and Chasanah U. 2020. Modified arrowroot starch and glucomannan for preserving physicochemical properties of sweet bread. *Cienc. e Agrotecnologia* **44(e014820)**: 1–9.

Deswina and Priadi D. 2020. Development of arrowroot (*Maranta arundinacea* L.) as functional food based of local resource. *IOP Conf. Series: Earth and Environ. Sci.* **439 (012041)**: 1−11.

Dundar AN and Gocmen D. 2013. Effects of autoclaving temperature and storing time on resistant starch formation and its functional and physicochemical properties. *Carbohydr Polym,* **97(2)**:764−771.

Fabbri ADT, Schacht RW and Crosby GA. 2016. Evaluation of resistant starch content of cooked black beans, pinto beans, and chickpeas. *NFS Journal.* **3:** 8−12.

Han W, Jiao H and Fox D. 2018. Scanning electron microscopy. In: Wang R, Wang C, Zhang H, Tao J and Bai X. (Eds.) **Progress in Nanoscale Characterization and Manipulation.** *Springer Tracts in Modern Physics.* **272**: 35−68. Springer Singapore.

Hoover R, Hughes T, Chung HJ, and Liu Q. 2010. Composition, molecular structure, properties, and modification of pulse starches: A review. *Food Res. Int.* **43(2)**: 399−413.

Kaur M, Sandhu KS, Ahlawat R and Sharma S. 2015. *In vitro* starch digestibility, pasting and textural properties of Mung Bean: Effect of different processing methods. *J Food Sci. Technol.* **52(3)**:1642−1648.

Lestari LA, Huriyati E and Marsono Y. 2017. The development of low glycemic index cookie bars from foxtail millet (*Setaria italica*), arrowroot (*Maranta arundinacea*) flour, and kidney beans (*Phaseolus vulgaris*). *J. Food Sci. Technol.* **54(6)**:1406−1413.

Lin L, Huang J, Zhao L, Wang J, Wang Z and Wei C. 2015. Effect of granula size on the properties of lotus rhizome C-type starch. *Carbohydr. Polym.* **134**: 448−457.

Liu C, Wang S, Copeland L and Wang S. 2015. Physicochemical properties and *in vitro* digestibility of starches from field peas grown in China. *LWT Food Sci Technol.* **64(2)**:829−836.

Majzoobi M, Kaveh Z and Farahnaky A. 2016. Effect of acetic acid on physical properties of pregelatinized wheat and corn starch gels. *Food Chem*. **196**:720−725.

Maulani RR, Fardiaz D, Kusnandar F and Sunarti TC. 2013. Characterization of chemical and physical properties of hydroxypropylated and cross-linked arrowroot *(Marantha arundinacea*) starch. *J. Eng. Technol.Sci.* **45(3)**:207−221.

Pepe LS, Moraes J, Albano KM, Telis VRN and Franco CML. 2015. Effect of heat-moisture treatment on the structural, physicochemical, and rheological characteristics of arrowroot starch. *Food Sci. Technol. Int.* **22(3)**:256−265.

Ratnaningsih N, Suparmo, Harmayani E and Marsono Y. 2017. In vitro starch digestibility and estimated glycemic index of Indonesian cowpea starch (*Vigna unguiculata*). *Pak. J. Nutr.* **16(1)**:1−8.

Setyobudi RH, Zalizar L, Wahono SK, Widodo W, Wahyudi A, Mel M, Prabowo B, Jani Y., Nugroho YA, Liwang T, and Zaebudin A. 2019. Prospect of Fe non-heme on coffee flour made from solid coffee waste: Mini review. *IOP Conf. Series: EES.* **293(012035)**:1−24.

Sholichah E, Deswina P, Sarifudin A, Andriansyah CE and Rahman N. 2019. Physicochemical, structural and morphological properties of some arrowroot (*Maranta arundinacea*) accessions growth in Indonesia. *AIP Conf. Proc.* **2175(020008)**:1−9.

Supparmaniam H, Hussin N and Jalil AMM. 2019. Glycaemic index, palatability, acceptability and perceived satiety of cookies prepared with durian (*Durio zibethinus* Murr.) and β-glucan. *Malays Appl Biol.* **48(4)**:89−99.

Villas-Boas F and Franco CML. 2016. Effect of bacterial β-amylase and fungal α-amylase on the digestibility and structural characteristics of potato and arrowroot starches. *Food Hydrocoll*. **52**: 795–803.

Wahjuningsih SB, Haslina H and Marsono M. 2018. Hypolipidaemic effects of high resistant starch sago and red bean flour- based analog rice on diabetic rats. *Mater. Sociomed.* **30(4)**: 232–239.