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Soy Flour-Based Snack Bar as Potential Snack Alternative for Diabetes Mellitus

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ABSTRACT

This study aimed to determine the Glycaemic Index (GI), Glycaemic Response (GR) and Glycaemic Load (GL) of soy flour-based snack bars in healthy volunteers. An open label randomized controlled trial with crossover study design was done involving eighty adults aged 18–50 years. The glycaemic index was calculated using Incremental Area Under the Blood Glucose Response Curve (iAUC). Friedman's test was used to determine difference of glucose iAUC between WF and SF. Wilcoxon test was used to determine difference of blood glucose peak, time to blood glucose peak, GI and GR between snack bars. The result observed that median (Q1–Q3) of GI were 88.4 (42.3–115.8); WF: 36.6 (21.8–47.9) (Product SF3, Banana); 36.3 (18.9–49.2) (Product SF6, Crispy White Chocolate Macadamia); 29.9 (22.0–43.3) (Product SF5, Crispy Vanilla); 25.9 (17.8–35.4) (Product SF4, Strawberry); 20.2 (15.3–22.2) (Product SF1, Almond Chocolate); and 7.1 (5.4–17.0) (Product SF2, Raisin Almond). We found that GL of WF was (17.7). While, the GL of snack bars made from SF were 4.9 (Product SF3, Banana), 4.1 (Product SF4, Strawberry), 1.9 (Product SF1, Almond Chocolate); 1.8 (Product SF6, Crispy White Chocolate Macadamia), 1.6 (Product SF5, Crispy Vanilla), and 0.9 (Product SF2, Raisin Almond). Friedman statistical test showed significant differences on the blood glucose iAUC between SF and WF ($p<0.001$). SF snack bar showed different GR results, where the area of each products (SF1–SF6) curve was significantly lower than WF. Based on Wilcoxon test, the GI and GR of SF were significantly lower than WF ($p<0.05$). In conclusion, SF snack bars can be classified as a low GI-source snack bar with a low category of glycaemic load; and had relatively high fibre, protein, and fat content which contributed to a lower GI value. Thus, it is a potential snacks alternative for people with blood glucose concerns.

Keywords: diabetes, glycaemic index, glycaemic load, snack bar, soy flour

INTRODUCTION

Globally, the prevalence of diabetes in adults continue to increase (Cho *et al*. 2018). The prevalence of diabetes in 2017 was estimated to be 8.4% and it is expected to rise to 9.9% in 2045 (Cho *et al*. 2018). In Indonesia, the prevalence of diabetes is also increasing. Basic Health Research (2013) showed that prevalence of diabetes in people aged ≥15 years were 6.9%, based the 2011 Perkeni (Indonesian Endocrinology Association) criteria (Kemenkes RI 2013). However, using the criteria of Perkeni 2015, Basic Health Research (2018) found that the prevalence was 10.9% (Kemenkes RI 2018).

Diet plays an important role in diabetes management. In the dietary intervention, alongside with the main foods, the use of appropriate snacks are positively associated to blood glucose control throughout the day (Morris *et al*. 2020). Especially, food with low-Glycaemic Index (GI), high fibre and protein are widely recognized to improve insulin sensitivity or stimulate insulin secretion, slow down the food movement in the digestive tract and improve enzyme activity; thus it is useful in blood glucose regulation (Manullang *et al*. 2020). In addition, diets low in Glycaemic Load (GL) have been found relevant to the prevention and management of diabetes (Augustin *et al*. 2015).

A recent systematic review and meta-analysis showed that low-Glycaemic Index (GI) diets were effective in decreasing Fasting Plasma Glucose (FPG) and Glycated Haemoglobin (HbA1c) (Zafar *et al*. 2019). Another systematic review and meta-analysis study by Reynolds *et*

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al. (2020) observed that increased daily fibre intake (15–35 g) was able to improve in measures of glycaemic control, e.g. HbA1c, FPG, insulin, Homeostatic Model aAssessment of Insulin Resistance (HOMA-IR). While in the other hand, high protein diets were also effective in improving Glycemic Control (HbA1c) (Ajala *et al*. 2013).

Soy is a food with low GI (Blair *et al*. 2006) and a source of protein, fibre, vitamin, mineral, good fat, isoflavone and phytoestrogen (Lokuruka 2010). Several studies suggested that soy is both beneficial in lowering the risk of type 2 diabetes mellitus in healthy subjects (Mueller *et al*. 2012) and improving glucose response in patients with type 2 diabetes mellitus (Sun *et al*. 2017).

Indonesian people usually consume soy in the form of tempeh, tofu, soy sauce, and soy milk which were usually included as side dishes in a meal. A current study conducted in Indonesia found that products made from tempeh are proven to improve blood glucose (Maya *et al*. 2020). Other product such as soy flour based snack bar could be a potential alternative product for healthy or diabetic people. In a trial study involving normal healthy subjects with normal fasting blood glucose, a normal range of glycaemic response by consumption of snack made from soy flour as additional ingredients after 120 min, has been observed (Agustia *et al*. 2019). A study in Japan indicated that the blood glucose and blood insulin response of diabetic patients after ingestion of a soy nutrition bar made of whole soy flour were significantly lower than test cookie (Urita *et al*. 2012).

Taken together, these mentioned study results suggest that soy flour snack bar has a potential glucoregulatory effect in healthy or diabetic people, but further clinical trial study needs to be performed to strengthen the available evidences. Therefore, this study was aimed to determine the Glycaemic Index (GI), Glycaemic Response (GR) and Glycaemic Load (GL) of soy flour-based snack bars in healthy volunteers, compared to Wheat Flour-based snack bar (WF).

METHODS

Design, location, and time

This study used an open label randomized controlled trial with a crossover study design, which determine the GI and GL of snack bars by investigating the response change of blood glucose after the ingestion of snack bars. Glycaemic index and response test were done at Chemical and Nutrition Analysis Laboratory and Nutrition Clinic Department of Community Nutrition, Faculty of Human Ecology, IPB University. The study protocol was approved by Human Research Ethics Committee of IPB University No. 142/IT3.KEPMSM-IPB/SK/2019. Written informed consent was signed and obtained from all volunteers in Bahasa Indonesia. The study was conducted in March 2019 to December 2019.

Sampling

Eighty healthy subjects were recruited into the study. The inclusion criteria were man or woman aged 18–50 years with normal body mass index (BMI) of 18.5–22.9 kg/m^2 (Asia-Pacific criteria), no history of Diabetes Mellitus (DM), no gastrointestinal disorder, did not consume medication, oral contraceptive and supplement, did not consume alcoholic beverage, did not smoke and willing to participate in the study. The exclusion criteria were history of food allergy and/or intolerance and fear of needles or not willing to be punctured on the fingers.

Screening for participants recruitments was conducted 1 week prior to the first meal glucose tolerance test. Subjects were interviewed on individual and family health history using a structured questionnaire by a general physician. Physical examination, measurement of body height and weight were also done. Body height was measured using stadiometer and body weight was measured using digital weighing scale (Omron BF508). For the participants who met the inclusion criteria in this screening phase, measurements of weight and height were done twice and the average value was used in the analyses.

Data collection

Test snack bar. The test snack bars were six variants of Soy Flour (SF) based snack bar (SOYJOY®): product SF1 (Almond Chocolate); product SF2 (Raisin Almond); product SF3 (Banana); product SF4 (Strawberry); product SF5 (Crispy Vanilla) and product SF6 (Crispy White Chocolate Macadamia). Wheat flour (WF, Strawberry) was used as the test snack bar. The nutrition profiles of test snack bars per 100 g is described in Table 2. Proximate analysis of test snack bars was done at an accredited laboratory, PT. Saraswanti Indo Genetech Bogor, Indonesia. Standard glucose (glucose anhydrous, D-glucose MERCK®, SG) were used as the reference food.

SF1–SF6 has been registered in Indonesia National Agency for Drug and Food Control (NADFC) under BPOM RI and certified halal under LPPOM MUI No. 00100086950118. In contrast, the comparison product, WF was not registered and a handmade product developed in R&D Laboratory of PT. Amerta Indah Otsuka, Sukabumi, Indonesia.

The composition of SF were vary depend on its variant. In general, the composition consists of soy flour (25–46%), fruit ingredients (4–14%), margarine, egg, sugar, soluble food fibre, salt, and synthetic flavor. While, WF was made with the same form and ingredients with the SF4 product, except wheat flour was used instead of soy flour. The SF4 was chosen as the basic formula to developed WF considering the GI result from PT. Otsuka Japan study (Murakami *et al*. 2006).

Glycaemic index test. Measurement procedure for glycaemic index test was conducted according to ISO 26642:2010 Food products – Determination of the Glycaemic Index (GI) and recommendation for food classification (ISO 2010). The procedure consisted of two steps, accordingly preparation and blood glucose measurements.

The preparation steps including room preparation and subject preparation. Room for taking blood samples should be cool with maximum temperature 20^{o}C. Subjects were required to fast 10-h overnight. During fasting, subjects were only allowed to consume plain water. Blood glucose measurement was done in the next morning between 8 to 10 a.m., thus subjects were required to fast since 8 p.m. the previous night. Subjects were prohibited to exercise in the morning before test.

Blood samples were taken by trained medical professional (general physician). Before intervention, fasting blood glucose was taken. Then, subjects were given reference food and test snack bar, which was consumed equal to 25 g available carbohydrate per oral. According to ISO 26642:210 (ISO 2010) recommendation, the use of 25 g available carbohydrate can be provided for low GI food, and under certain condition such as for some of the snack bars, portion sizes providing 50g available carbohydrate were found to be too large for subjects to consume comfortably within 10–15 min. Therefore, portions tested provided 25 g available carbohydrate. Calculation of food weight used the following formula:

Carbohydrate per serving size: Serving size (g) x available carbohydrate (g)/100

The snack bar should be consumed within 10 min for reference food and 10–15 min for test snack bar. Each snack bar were given in separate days as follows: 1). Week 1: glucose standard (25 g); 2). Week 2: SF (product SF1: ±84 g; product SF2: ±60 g; product SF3: ±58 g; product SF4: ±47 g; product SF5: ±90 g; product SF6: ±126 g); 3). Week 3: WF (±37.5 g). During 120 min after consumption of test snack bar, blood samples was taken as much as 2 µl using finger-prick capillary method at 30, 60, 90, and 120 min. Blood glucose concentration were analysed using finger prick capillary blood samples by Accu-check Active®.

Data analysis

Glycaemic response obtained from every point of time were plotted into curve correlating x-axis and y-axis. Time (min) as x-axis and blood glucose concentration (mg/dl) as y-axis. Incremental Area Under Curve (iAUC) approach was used. Calculation ratio used was f:r which was calculations for each subject. The f represented areas under curve for test food of each subjects and r represented areas under curve for reference food of each subjects. The mean value of f:r of each subjects multiply by 100% were calculated to obtain glycaemic index of test food (Brouns *et al*. 2005). The calculation was done using Microsoft Excel 2019. According to Eleazu (2016), GI value is classified into high (>70), moderate (55–70) and low (<55). Glycaemic load is derived by multiplying the GI value by carbohydrate per serving size (g) of the snack bar and then dividing the results by 100. Then, GL value is categorized into high (≥20), moderate (11–19) and low (≤10).

Data analysis was conducted using IBM Statistical Product and Service Solution (SPSS) version 20.0 for Windows. Friedman's test was used to determine difference of glucose iAUC between glucose standard, WF and SF. Wilcoxon test was used to determine difference of blood glucose peak, time to blood glucose peak, GI and GR between test snack bars. The p-value less than 0.05 was considered as significant.

RESULTS AND DISCUSSION

Characteristics of subjects

A total of 96 healthy subjects joined the screening phase. Of 96 screened subjects, 16 were excluded because they had underweight, overweight or obese BMI. Therefore, in total, 80 healthy subjects were recruited for the study with the mean age of subjects was 21.9±0.9 years. The mean body height and body weight were 163.8±7.2 cm and 55.7±5.5 kg, respectively. The subjects had a normal BMI 20.7±1.2 kg/m^2 and fasting blood glucose 84.6±6.4 mg/dl.

Glycaemic index and glycaemic load

Table 1 describes the GI/GL values for snack bars. The median GIs measured for SF were low, ranging from 7.1 (5.4–17.0) to 36.6 (18.9–49.2), with the lowest value come from product SF2. On the other hand, WF had the highest GI value of 88.4 (42.3–115.8). Based on Wilcoxon test, there was significant difference between all SF snack bars (SF1–SF6) and WF, indicating the glycaemic index of SF was lower compared to WF ($p<0.05$).

In particular, the lower GI of SF snack bar assessed in the current study is similar with that observed in the previous study in which low GI category was observed (Natalia & Astawan 2010). In addition, GL values from SF snack bar were multiple times lower than WF snack bar. The present study results strengthen the available evidence on the potential of GI/GL as a predictor for glycaemic response. Research finding has shown that low GI-source foods with a low category of GL is correlated with a better glycaemic control (Vlachos *et al*. 2020). In addition, foods with low GI and/or low GL may have a beneficial effect on health, especially in reducing risk factors for diabetes mellitus (Agustia *et al*. 2019). Their finding indicated that all products with additional soybean flour have a low GI value (50.2±21.6). Also, considering the GL value per serving size, the value obtained was also classified as low (13.8±5.9). Overall, the present study results for SF snack bars support this outcome; with all variants had a low GI/GL value.

Glycaemic response

Blood glucose response (0–120 min) to test snack bar (SFs and WF) is described in Figure 1. There were significant differences between blood glucose responses at 15, 30, 45, 60, and 120 min after ingestion of SF compared with WF ($p<0.05$). The magnitude of the blood glucose iAUC was significantly lower in subjects who consumed SF snack bar with product SF2 and product SF4 had the greatest difference, followed by product SF1, product SF5, product SF6 and product SF3; than in those who consumed WF snack bar. Also, the change in blood glucose

Table 1. Glycaemic index and glycaemic load of test snack bars

Test Snack bars	Serving size (g)	GI[†]	Category[‡]	Available carbohydrate per serving size (g)	GL[§]	Category[¶]
SF1	30.0	20.2 (15.3–22.2)[a]	Low	9.3	1.9	Low
SF2	30.0	7.1 (5.4–17.0)[a]	Low	12.3	0.9	Low
SF3	30.0	36.6 (21.8–47.9)[a]	Low	13.5	4.9	Low
SF4	30.0	25.9 (17.8–35.4)[a]	Low	15.9	4.1	Low
SF5	25.0	29.9 (22.0–43.3)[a]	Low	5.2	1.6	Low
SF6	25.0	36.3 (18.9–49.2)[a]	Low	5.0	1.8	Low
WF	30.0	88.4 (42.3–115.8)[b]	High	20.0	17.7	Moderate

[†]Data are median (Q1‒Q3); [ab]Different letters within the same column indicates difference between snack bar ($p<0.05$)
GI: Glycaemic Index; GL:Glycaemic Load
[‡]Glycaemic indexes were categorized as high (>70); moderate (55‒70) and low (<55)
[§]Glycaemic loads were calculated by GI value x carbohydrate per serving size (g)/100 and [¶]categorized as high (≥20); moderate (11‒19); low (≤10)

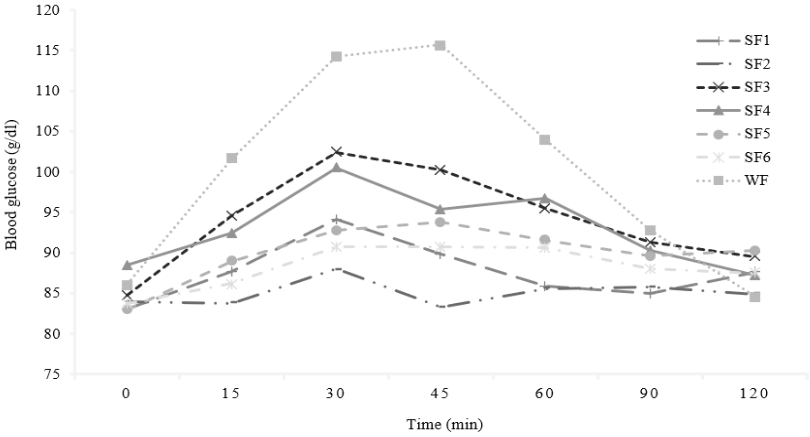

Figure 1. Changes in blood glucose concentration after the ingestion of soy flour snack bar (SF) and wheat flour snack bar (WF).

concentration after consumption of product SF1, SF2, SF5, and SF6 tend to be stable for 120 min and did not increase blood glucose more than 10 mg/dl. This is consistent with the observed GI value on the four snack bars which classified as products with lower GI/GL values compared to other products (GI <55; GL≤10).

The previous study explained that the variation of glycaemic responses to carbohydrate foods are influenced by the GI/GL value, which then is assumed to be associated to several factors, such as the quantity and type of carbohydrate, food processing method, rate of gastric emptying, and nutrition profiles in food such as fiber, fat, and protein (Gao & Chilibeck 2019). In the present study, SF snack bar was assumed to be able to maintain a steadier blood glucose level, due to nutrition profile of this snack bar was specially composed to offer a low glycaemic response. For instance, product SF1, SF5 and SF6 has the highest average of nutrition profiles with approximately 30:20:10 ratio of proportion of energy from total fat, protein and fibre, respectively (Table 2). The high total fat content tends to delay gastric emptying, allowing slower digestion in the gut (Forouhi *et al*. 2014); which in turn may lead to lower glycaemic index and positively affects glycaemic response. In addition, protein and fibre favorably influence shape and extend of postprandial blood glucose

Table 2. Nutrition profiles of the test snack bars

	Per 100 g serving						
	SF1	SF2	SF3	SF4	SF5	SF6	WF
Total energy (kcal)	526	462	460	433	510	559	414
Food fibre (%)	9.3	8.8	8.6	8.9	10.5	13.9	5.1
Total fat (%)	32.8	21.9	21.4	15.2	30.7	37.2	11.9
Protein (%)	17.3	15.5	13.2	12.1	27.1	22.4	4.8
	Per test portion†						
	SF1	SF2	SF3	SF4	SF5	SF6	WF
Total energy (kcal)	424	275	255	204	611	706	155
Food fibre (%)	7.5	5.2	4.8	4.2	12.6	17.6	1.9
Total fat (%)	26.5	13.0	11.9	7.2	36.8	47.0	4.5
Protein (%)	13.9	9.2	7.3	5.7	32.4	28.2	1.8

†Different weights of the snack bars were given to subjects to provide 25 g of available carbohydrate for GI determination

as a consequence of the better glucose absorption (Çakir *et al*. 2019; Bell *et al*. 2015).

Blood glucose peak and time to peak. In comparison to WF, SF snack bar showed lower blood glucose peak with product SF2 and SF6 had the lowest value, 94 (91, 97) and 95 (92, 102) mg/dl (Table 3). There were significant discrepancies between SF snack bars: SF1-SF6 and WF ($p< 0.05$).

According to Lim *et al*. (2020), normal blood glucose peak value in healthy or subject without DM occurred at 30 min and reached at the lowest value at 120 min. Moreover, a delay in glucose peak time also suggests a higher glucose peak value and a decrease in insulin sensitivity and secretion; in which indicates impaired glycaemic control usually seen in T2DM (Wang *et al*. 2018). The present study volunteers had median blood glucose peaks occurring within 30-45 min after ingesting neither SF nor WF snack bar (Figure 1).

Taking all these findings together, consuming SF snack bars may offer distinctive benefits to human health. Firstly, the current study is phase one of the clinical trials where the subjects were healthy volunteers, not in diabetic individuals with insulin resistance problem. A blood glucose-regulating effect of SF snack bars were clearly observed with normal value of glycaemic response, glucose blood peak and time to blood glucose peak. Secondly, diet with lower GI/GL can be recommended to healthy individuals as a convenient alternative for a proportionate serving of a higher GI/GL snack bar; and can be considered as a reliable source of high-quality protein, fiber, and other nutrients, which may help with blood glucose regulation. This is important because unhealthy snacking is reported to be pervasive in Indonesia as well as among adolescent girls (Blum *et al*. 2019). Within the study, it was reported that adolescent girls snack multiple times daily on foods high in sugar, salt, and fat (Blum *et al*. 2019).

Table 3. Blood glucose peak after ingestion of soy flour snack bar (SF) vs. wheat flour snack bar (WF)

Snack bars	Blood glucose peak (mg/dl)[1]
SF1	96 (92.5–99)[a]
SF2	94 (91–97)[a]
SF3	109 (95–113.5)[a]
SF4	103.5 (101.5–107)[a]
SF5	97.5 (89.5–102)[a]
SF6	95 (92–102)[a]
WF	127 (122–135)[b]

Data are median (Q1–Q3); *p<0.05 by Wilcoxon test

[1]Maximal blood glucose excursion from the fasting value over the 120-min postprandial period

[ab]Different letters within the same column indicates difference between snack bar

CONCLUSION

The glycemic response of soy-flour (SF) based snack bar is lower than wheat-flour (WF) based snack bar. The glucose peak in SF is also lower compared to WF. Based on glycaemic index and load value, WF is categorized as a high GI-source snack bar with a medium level of glycaemic load. While, all SF snack bars are classified as a low GI-source snack bar with a low category of glycaemic load.

To conclude, SF snack bars had met the requirement of low GI food source and can be a potential snacks alternative for healthy people. But, the glycaemic response to the SF snack bars in diabetic people requires further investigation.

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AUTHOR DISCLOSURES

The authors have no conflict of interest. All authors disclose that the sponsor company had no influence in the execution of the study, including no input into the study design, in the data collection, analyses, or interpretation of the data, in the writing of the manuscript, and in the decision to publish the results.

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