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Glycemic Index of Sweet Corn and the Characteristics of their Flakes by Adding the Red Bean

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ABSTRACT

Consuming foods with a low glycemic index, such as sweet corn (Zea mays Saccharata), which has a high fiber content, can help lower the risk of diabetes. According to previous research, sweet corn is predicted to have a low glycemic index (GI). The study's goals were to determine the value of the glycemic index of sweet corn and to produce low glycemic index instant flake products made from sweet corn and red beans. The glycemic index value of sweet corn was determined using a glycemic index test technique based on ISO 26642:2010E. The flakes was made with the addition of red beans reported to have the lowest glycemic index among legume, i.e. 26 in order to enhance the crude protein content of the flakes. Flakes were made in two formulas based on the proportion of red beans to sweet corn, namely formula 1 (30:70) and formula 2 (70:30). Proximate analysis was done according to AOAC 2005, total dietary fiber analysis according to AOAC Official Methods 985.29, and total starch analysis according to AOAC 2002.02. Texture analysis of the flakes was carried out using a texture analyzer and color analysis using a chromameter. The sweet corn was found to have a low GI (<55) i.e. 36. Formula 1 flakes contained more fat (db), carbohydrate (db), and total starch (db); while formula 2 flakes had more moisture, protein (db), and resistant starch (db). The resulting flakes have crispy texture (hardness of 553±5.09 gf for formula 1 and 519.05±6.86 gf for formula 2) and have yellow color (both are included in the yellow chromatic area).

Keywords: *flakes, glycemic index, non-available carbohydrates, sweet corn*

INTRODUCTION

Diabetes mellitus (DM) is a serious health problem that takes many victims. Indonesia is the only Southeast Asian nation on the list of the ten countries with the greatest number of diabetics in the world (Saeedi *et al.,* 2019). Type 2 diabetes (DM) is a metabolic illness that causes a rise in blood sugar owing to a reduction in insulin production by pancreatic beta cells and/or decreased insulin action (insulin resistance).

A previous study has shown that the group consuming carbohydrates with a high glycemic index (GI) resulted in higher insulin resistance than the group consuming carbohydrates with a low glycemic index (Sacks *et al.,* 2014). Another study found that diabetic patients who consumed a low glycemic index diet experienced a 0.43% decrease in HbA1c (hemoglobin that bound with glucose) levels (CI 0.72—0.13) and a 7.4% decrease in glycosylated protein (protein that bound with glucose) levels. Research showed that dietary fiber-enriched cereal flakes (high in fiber) affected blood glucose levels and there was a decrease in post-prandial glucose levels (Kim *et al.,* 2016). Therefore, one way to prevent diabetes mellitus is to regulate a diet by eating foods high in fiber, hence having a low GI.

The GI is food categorization system according to its influence on blood sugar levels. In other words, the difference between the blood glucose reaction to meal and the blood glucose response to pure glucose. Glycemic index can help us to determine your blood glucose response depending on the type and amount of food you eaten (Evert *et al.,* 2014). Foods that quickly raise sugar levels will make the pancreas work hard to produce insulin after eating, which will eventually cause the insulin resistance. Carbohydrates themselves consist of two types, first is available carbohydrates, can be digested by digestive enzymes, absorbed in the form of glucose via the small intestine, and processed by body cells. The higher the food containing available carbohydrates such as glucose, disaccharides, oligosaccharides, and digestible starch, the higher the glycemic index value. Secondly, non-available carbohydrates are the opposite, so it has a low GI (Sentko, 2013).

Non-available forms of carbohydrates such as dietary fiber are found in many fruits and vegetables for example sweet corn and red bean (Afandi *et al.,* 2021). Dietary fiber can be a source of energy after

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going through the fermentation process. The energy produced from dietary fiber is very low, which is between 1.5–2.5 kcal/g, some even do not provide energy (Staffolo *et al.,* 2017).

The previous study reported that corn was predicted (not verified yet) to have the third lowest glycemic index in the cereal category (Afandi *et al.,* 2021). Corn is the third source of carbohydrates consumed by Indonesians (18.9%) after rice (53.5%) and cassava (22.2%) (Budijanto and Yuliana, 2015). Sweet corn (*Zea mays Saccharata*), is the most common variety of corn (Sheng *et al.,* 2018) and is easy to find in the market. In this study, we attempted to develop sweet corn-based instant products in the form of flakes.

Before product formulation, we first determine the glycemic index value of corn, especially sweet corn. Flakes were developed with a combination of sweet corn and red bean. The red bean was used because they have the lowest glycemic index value (GI 26) in the legume category in the study of Afandi *et al*. (2021) and to enhance the crude protein content of the flakes. The combination of ingredients that have a low GI value was carried out in the hope of producing a low-GI instant product. The research aimed to verify the results of a meta-analysis of sweet corn glycemic index values which were previously predicted to be classified as low glycemic index. Verification is carried out using the glycemic index test method based on ISO 26642:2010E (ISO, 2010). Sweet corn was then developed into an instant product which is predicted to have a low glycemic index because it combines raw materials with a low glycemic index, namely sweet corn and red beans.

MATERIALS AND METHOD

Materials

The materials used as a sample in this study were sweet corn (*Zea mays Saccharata*) and red bean (*Vigna angularis*). The sweet corn chosen for this research is a variety called exotic sweet corn. Exotic sweet corn was chosen because it is widely available on the market. Indonesian people mostly consume sweet corn. National demand for sweet corn in 2015 reached 8.6 million tons per year (Kemenperin, 2016). Corn was also predicted to have low glycemic index (Afandi *et al.,* 2021). Exotic sweet corn has yellow seeds with 14–16 rows. The cob is 17–21 cm long and 4.6–5.4 cm in diameter. Fruit weight per cob 250–400 g. Exotic sweet corn was obtained from the Kemang Traditional Market in Tanah Sareal, Bogor. Red bean has a pod length of about 12 cm and can contain 1–12 seeds. The red bean was obtained from the Agro Lestari Store in Dramaga, Bogor. The reference food for the glycemic index analysis used is glucose (Dextrose Monohydrate, PT Brataco, Indonesia).

Preparation of raw materials

Sweet corn was prepared by peeling the wrapping leaves, washing, cutting every 5 cm, steaming every 2 kg of sweet corn with 1 L of water for 15 min, and then shelling. Red beans, which were then combined with sweet corn for making flakes product, were pre-pared by washing in three times, soaking for 7 h, washing in three times, and steaming for 45 min with 2 L water that was heated before for 15 min.

Proximate analysis of sweet corn

Water, ash, and fat contents were performed according to Indonesian National Standard (SNI) methods (BSN, 1992), whereas crude protein content and total dietary fiber (TDF) were performed according to the Association of Official Analytical Chemists (AOAC) official methods (AOAC, 2010; AOAC, 2005). The result of this will be used to determine the portion of test food for glycemic index analysis.

Glycemic index analysis

The GI test of the sweet corn was carried out with ISO 26642:2010E (ISO, 2010). Firstly, the application for an Ethics Permit was carried out by making a research protocol accompanied by an informed consent form and an explanatory text for respondents to the Human Ethics Commission of IPB University. This research was conducted in accordance with the ISO (2010) protocol, and was approved by the Human Ethics Commission of IPB University (protocol code: 893/IT3.KEPMSM-IPB/SK/2023). This research had a total of ten individual participants. The inclusion criteria set for the subjects in this study were subjects aged 22–50 years and in healthy condition. Subjects were given a preliminary explanation of the research and if they agreed to become panelists, they signed an informed consent. There were two categories of samples for glycemic index analysis, which was reference food (glucose) and test food (sweet corn), both had portion equivalent to 25 g of available carbohydrates. The test was carried out with 2 replicates for the reference food and 1 test for the test food. The calculation of available carbohydrates was based on carbohydrate content by difference (% w/w) subtracted by total dietary fiber content (McCleary *et al.,* 2020). A glucometer from the One Touch Ultra Lifescan was used to measure blood glucose levels. Blood was drawn through the capillaries found on the fingertips of the subject. Capillary blood vessels were chosen because based on research (Lee *et al.,* 2018), blood drawn from capillaries had a smaller variation in blood glucose concentrations in subjects than blood drawn from veins.

All subjects had fasting blood glucose levels and 2 h postprandial within normal limits. The normal level of blood glucose after fasting is <125 mg/dL and the normal level of blood glucose 2 h postprandial is <180 mg/dL (Hammer *et al.,* 2019). The GI of each participant was calculated by comparing the incremental area under the curve (IAUC) of the test food with the reference food. The GI value of the test food was calculated by calculating and averaging the glycemic index value of each participant. Finally, blood glucose response curves were made based on blood glucose levels during fasting (0 min), 15, 30, 45, 60, 90, and 120 min following the consumption of glucose or the test food. The glycemic response was expressed as a geometrically computed incremental area under the curve (IAUC) that ignored the area under baseline glucose. The mean, standard deviation (SD), and coefficient of variation (CV= 100xSD/mean) of IAUC of the two glucose tests and the test meal were determined for each participant. The test food's GI value was represented in terms of the average GI of all individuals. The following formula was used to calculate the GI of each test meal in each subject. The CV value was used to examine intra-subject variance from the two reference meal tests.

$$\text{Subject GI} = \frac{\text{Average IAUC test food}}{\text{Average IAUC glucose}} \times 100\% \;\ldots\ldots\; (1)$$

Development of low glycemic index flakes

The method of making low-GI instant products in the form of flakes referred to the modified Riantiningtyas and Marliyati's (2017) study. The formula for making flakes with steamed sweet corn and steamed red bean can be seen in Table 1. The process of making flakes began with the preparation of raw materials. The use of fresh ingredients in the manufacture of flakes aimed to ensure that the glycemic index of the resulting product did not differ much from the raw materials used. Sweet corn was prepared by peeling the wrapping leaves, washing, cutting, steaming for 15 min, and then shelling. The red bean was prepared by washing it three times, soaking it for 7 h, washing it three times, and steaming it for 45 min. The two ingredients that have been cooked were then crushed and mixed with other food ingredients and food additives in a food processor. The resulting dough was stretched and flattened using a roller to form a sheet so that it did not differ in thickness which can result in uneven cooking. The dough sheet was then divided into small squares by cutting the sheet. Baking by oven was carried out for 45 min at a temperature of 150°C. Flakes were then ready to be served with milk. The processing step and equipment used were also simple for easy application by micro, small, and medium enterprises (MSMEs).

Characterization of low glycemic index flakes

The chemical characteristics of flakes were obtained by performing a proximate analysis. Moisture, ash, and fat contents were performed according to Indonesian National Standard (SNI) methods (BSN, 1992), whereas crude protein content and resistant starch (RS) were performed according to the Association of Official Analytical Chemists (AOAC) official methods (AOAC, 2010; AOAC, 2002). Physical characteristics were obtained through hardness analysis using the TA-XTplus Texture Analyzer from the United Kingdom, color analysis using the Konica Minolta Chromameter CR-400 from Japan, water absorption analysis using the method from Hildayanti (2012), and crispy resistance test in milk using the method from Papunas *et al*. (2013).

Analysis of water absorption of sweet corn-red bean flakes

According to method from Hildayanti (2012), a total of 5 g of a sample whose moisture content was known was put into boiling water for 4 min and then drained for 10 min. Subsequently, it was transferred to a cup whose weight was known and weighed (A). The cup and its contents were dried at 100°C for 3–5 h until the weight was constant. After that, it was cooled in a desiccator and weighed (B). The absorption capacity calculation is carried out as follows:

$$\text{Water Absorption} = \frac{(A - B) - (\text{sample moisture content x sample initial weight}}{\text{sample initial weight }(1 - \text{sample moisture content})} \times 100\% \;\ldots\ldots\; (2)$$

Crispy resistance of sweet corn-red bean flakes in milk

Test was conducted according to Papunas *et al*. (2013). The test aimed to determine the durability of the chips when served with milk but still quite crispy when consumed. Maintenance of resistance is carried out by pouring 1.5 g of flakes into a bowl and then pouring 70 mL of liquid milk at 29°C. The time for the flakes to remain floating on the surface until they are not crispy enough is counted as holding time in the milk.

Statistical analysis

The data were statistically evaluated using SPSS Software version 26 (IBM, USA). The analysis of variance (ANOVA) was carried out using a 95% confidence level. The results of statistical analysis could explain whether there were differences between data groups or not.

Table 1. Instant product formula of flakes

Ingredients	F1 (Red Bean:Sweet Corn) (30:70)		F2 (Red Bean:Sweet Corn) (70:30)	
	Weight (g)	%	Weight (g)	%
Red bean	60	17.91	140	41.79
Sweet corn	140	41.79	60	17.91
Tapioca flour	50	14.93	50	14.93
Skimmed milk powder	30	8.96	30	8.96
Sugar	50	14.93	50	14.93
Salt	5	1.49	5	1.49

RESULTS AND DISCUSSION

The glycemic index of sweet corn

Determination of the portion of the test food based on ISO (ISO, 2010) should be comparable to 50 or 25 g of available carbohydrates. Table 2 show the results of proximate analysis of the steamed sweet corn, while Table 3 shows the portion of steamed sweet corn to be tested on GI determination. The value of available carbohydrates was calculated by subtracting carbohydrate content from total dietary fiber. Analysis of carbohydrate content was carried out by difference, i.e. subtracting 100% by the moisture, ash, protein, and fat content. The carbohydrate content by difference in wet basis (wb) in this study for sweet corn was 19.10±0.07%. Determination of the portion equivalent to 25 g of available carbohydrates was done by calculating 25 divided by available carbohydrates multiplied by 100%.

Table 2. Chemical composition of steamed exotic sweet corn samples

Component	Basis (%)	
	Wet	Dry
Water content	74.11±0.01	74.11±0.01
Ash content	0.81±0.01	3.14±0.06
Protein content	1.81±0.01	6.97±0.04
Fat content	4.17±0.01	16.11±0.04
Carbohydrate *by difference*	19.10±0.03	73.78±0.06

Table 3. Determination of the portion of the test food (steamed sweet corn)

Component	Content
Carbohydrate (%wb)	19.10
Total dietary fiber (%)	3.53
Available carbohydrate (%)	15.57
Servings equivalent to 25 available carbohydrates (g)	160.55

Figure 1 depicts the blood glucose response curve to the sweet corn sample in comparison to the pure glucose (dextrose monohydrate). This can indicate the value of the GI of sweet corn is below 100 (pure glucose). Corn products have dietary fiber that can affect blood glucose response. Dietary fiber in corn products can affect blood glucose responses because, in the digestive system, soluble dietary fiber will form a gel that can inhibit digestive enzymes in breaking down starch and cause the starch digestion process to be slower (McRorie and McKeown, 2017). The difference in metabolic processes caused the blood glucose response of sweet corn under the pure glucose response.

Blood glucose levels after consuming the reference food reached their highest peak in the 30th min after consuming dextrose monohydrate (glucose), while blood glucose levels after consuming the sweet corn test food reached their highest peak at the 15th min. Blood glucose levels after 2 h tend to have almost the same value both after consuming the test and reference food. The description of the blood sugar response was obtained on average from the glycemic response of all subjects. According to this study's findings, the glycemic index of steamed sweet corn is 36. Foods are classified into three groups depending on their glycemic index: low (GI<55), medium (GI 55–70), and high (GI>70) (ISO, 2010).

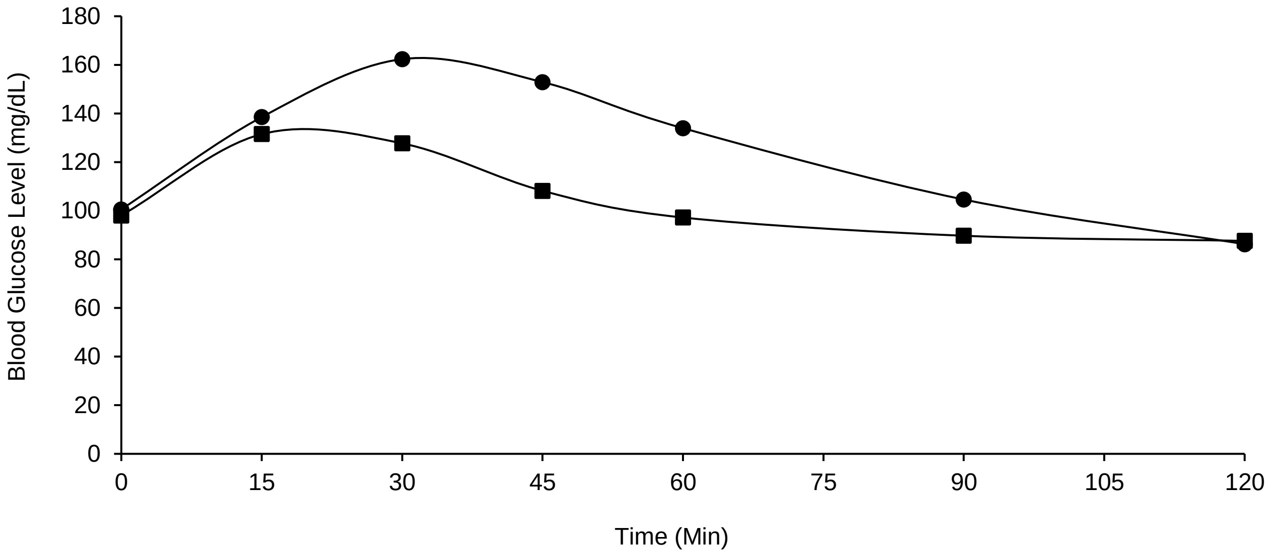
Based on previous research (Afandi *et al*., 2021), sweet corn has a low glycemic index. Compared to the results of the study, the GI of steamed sweet corn is correctly classified as a low-GI food. The results of previous studies showed that the consumption of low glycemic index carbohydrates had a significant negative relationship with the risk of diabetes, in other words, it could be a solution or alternative to maintain the glucose level of the body (Vlachos *et al.,* 2020). Therefore, the consideration based on the glycemic index value can be used for the selection of alternative foods. In this case, sweet corn was found to have a low GI, hence can be used as an ingredient for low-GI food products.

Chemical composition of low glycemic index flakes

Table 4 shows the nutritional composition of the flakes as a result of the study. Based on the analysis, both had similar ash content. The formula 1 (F1) had a higher fat, carbohydrate, and total starch contents. Formula 2 (F2) had higher moisture, protein, and RS contents.

The amylose content of food products impacts the RS content. The double helical structure of retrograded amylose losses its water binding capacity and does not fit into the binding site of amylase, thus resisting digestion (Birt *et al.,* 2013). Thus, higher amylose leads to a higher content of RS, due to more amylose chains that associate with each other to form more compact crystalline structures so that they are more resistant to digestive enzymes (Bajaj *et al.,* 2018). Based on these results, F2 had a higher level of resistant starch. This is due to the larger part of the red bean in the formulation. Red bean has higher amylose content (~50%) (Bajaj *et al*., 2018) than corn (~25%) (Lopez-Silva *et al.,* 2019).

The total starch content of formula F1 flakes was higher than formula F2. Total starch consists of resistant starch and digestible starch. Since F2 had higher resistant starch, then F1 had more digestible starch. Starch will affect the glycemic index value. Resistant starch will cause the digestibility of starch to decrease, thus causing a slow increase in blood glucose levels (Robertson *et al.,* 2021) and the glycemic index will be slower. Therefore, F2 is predicted to have a lower glycemic index than F1. The flakes' structure is influenced by starch. Starch that binds to water and undergoes high-temperature treatment will be gelatinized and result in the formation of cavities in the product structure (Amagliani *et al.,* 2016). The more cavities formed due to gelatinization, the more water will be trapped in the flakes so that the rehydration level will increase (Digaitis *et al.,* 2022).



Note: Black dots= Blood glucose after consumption of glucose; Black rectangles= Blood glucose after consumption of sweet corn

Figure 1. Average blood glucose response of respondents to sweet corn

Table 4. Chemical composition of flakes

Content	Sample	
	F1 (Red Bean:Sweet Corn) (30:70)	F2 (Red Bean:Sweet Corn) (70:30)
Water (%, wb)	2.59±0.06[a]	3.56±0.07[b]
Ash (%, wb)	5.02±0.02[a]	4.99±0.01[a]
Ash (%, db)	5.17±0.01[a]	5.17±0.01[a]
Protein (%, wb)	9.35±0.11[a]	11.18±0.10[b]
Protein (%, db)	9.78±0.15[a]	11.60±0.11[b]
Fat (%, wb)	1.66±0.04[a]	1.26±0.0005[b]
Fat (%, db)	1.70±0.04[a]	1.30±0.0004[b]
Carbohydrate *by difference* (%, wb)	81.19±0.12[a]	79.02±0.16[b]
Carbohydrate *by difference* (%, db)	83.35±0.0017[a]	81.93±0.001[b]
Resistance starch (%, wb)	1.60±0.01[a]	1.77±0.01[b]
Resistance starch (%, db)	1.64±0.01[a]	1.83±0.01[b]
Total starch (%, wb)	41.97±0.17[a]	31.64±0.18[b]
Total starch (%, db)	43.09±0.18[a]	38.82±0.19[b]

Note: wb= Wet basis; db= Dry basis; Values are expressed as mean ± standard deviation; Values[ab] in the same row, followed by the same superscript letter indicate no significant difference (*p*>0.05), according to ANOVA with significancy level at 5% and Duncan's Posthoc-test

Color profile of low glycemic index flakes

Color is a very important component for recognizing, assessing, and determining the quality of food. Food that has an unattractive or deviant color will affect consumer perceptions. Color is used to determine the quality of food since it is the first thing that the consumer notices (Petrescu *et al.,* 2020). The results of measuring the color of flakes can be seen in Table 5.

Table 5. Flakes color

Color	Sample	
	F1 (Red Bean: Sweet Corn) (30:70)	F2 (Red Bean: Sweet Corn) (70:30)
L*	59.23±1.08[a]	57.06±2.16[a]
a*	10.67±3.13[a]	13.42±0.23[a]
b*	26.44±0.98[a]	26.21±1.37[a]
Chroma	28.56±2.08[a]	29.44±1.32[a]
°Hue	68.21±5.08[a]	62.86±0.82[a]

Note: wb= Wet basis; db= Dry basis; Values are expressed as mean ± standard deviation; Values[ab] in the same row, followed by the same superscript letter indicate no significant difference (p>0.05), according to ANOVA with significancy level at 5% and Duncan's Posthoc-test

There are several parameters to describe color, such as Hunter parameters, namely L*, a*, and b*; then also the Munsell system parameters, namely Chroma and °Hue. The L* value indicates the brightness of the sample, and the scale used is from 0 to 100. A value of 0 indicates the sample is very dark (black) and 100 indicates the sample is very light (white). In the F1 flakes sample, the L* value was 59.23 ± 1.08; Meanwhile, in the F2 flakes sample, the L* value was 57.06±2.16. It can be seen that both samples show bright colors. The a* (redness) value has a range of (-80) ± (+100) indicating from green to red. The a* value for the F1 flakes sample is 10.67± 3.13 and for the F2 sample, it is 13.42±0.23, which means the color is more red and less green. The notation b* (yellowness) with a value range of (-70) ± (+70) indicates from blue to yellow (Brühl and Unbehend, 2021). The b* value obtained for the F1 flakes sample was 26.44±0.98 and for F2 13.42± 0.23, which means it is more yellow and less blue.

Measurements based on the Munsell system include measurements of color intensity (chroma) and chromatic color (Hue). The chroma value (C) is a value that shows the color intensity of the sample. The higher the C value, the darker the color will look because the intensity increases. The C value for F2 formula flakes was 29.44±1.32, while F1 formula flakes were 28.56±2.08. The °Hue value shows the position of the sample color in the Munsell imaginary color diagram and objective color data will be obtained to show the color range that is close to the actual color. Based on research, it can be seen in Table 5 that the F1 formula flakes sample has a °Hue of 68.21±5.08 (Yellow chromatic color area) and the F2 formula flakes have a °Hue of 62.86±0.82 (Yellow chromatic color area). This is in accordance with the visual appearance of the flakes which are brownish yellow. All color test parameters of the two samples showed no significant differences between the two samples. The flakes' visual appearance can be seen in Figure 2.

A

B

Note: photos taken with Iphone 12 camera on normal zoom. F1 Formula flakes (A), F2 Formula flakes (B)

Figure 2. Flakes product

Other physical characteristics

The texture is an important parameter that also affects consumer perception. One way to judge texture can be through its hardness or crispness. The texture is a sensation that may be felt with the fingers or tongue (when something is bit, chewed, and swallowed) (Liu *et al.,* 2017). Analysis of water absorption aims to determine the change in the shape of flakes when soaked in milk. For flakes derived from cereals such as wheat and corn, the higher the water absorption value, the more destroyed the product is because it is very easy to soften in water (Susanti *et al.,* 2017). The resistance test for flakes' crispness in milk is usually carried out on breakfast cereal products to determine the resistance of flakes when served with milk while they are still quite crispy when consumed. (Papunas *et al.,* 2013). Table 6 displays the data from the study's measurements of the flakes' hardness value and other physical attributes. In the analysis of water absorption capacity, formula F2 flakes had water absorption capacity (531.03±1.41%) which was greater than the water absorption capacity of formula F1 flakes (124.58±1.52%). Water absorption is influenced by amylose content (Robertson *et al.,* 2021). As previously stated, the amylose content in corn was ~25% (Lopez-Silva *et al.,* 2019), lower than the amylose content in red beans at ~50% (Bajaj *et al.,* 2018). Water absorption can also be caused by the raw material for flakes formula F2, which was mainly red bean. F2 had a lower water content than the main raw material for flakes formula F1, namely sweet corn, so it was able to absorb large amounts of water. Gelatinized dry starch can absorb water (rehydration) easily (Petrescu *et al.,* 2020).

Table 6. Hardness value, water absorption, and resistance test of flakes crispness

Characteristics	Sample	
	F1 (Red Bean: Sweet Corn) (30:70)	F2 (Red Bean: Sweet Corn) (70:30)
Hardness (gf)	553±5.09[a]	519.05±6.86[b]
Water absorption (%)	124.58±1.52[a]	531.03±1.41[b]
Resistance test of flakes crispness in milk (min)	2.2850±0.0212[a]	1.4450±0.0212[b]

Note: wb= Wet basis; db= Dry basis; Values are expressed as mean ± standard deviation; Values[ab] in the same row, followed by the same superscript letter indicate no significant difference (*p*>0.05), according to ANOVA with significancy level at 5% and Duncan's Posthoc-test

The hardness value is obtained from the highest peak in the texture analysis graph using a texture analyzer (Rivera *et al.,* 2021). The compression force is needed to determine the deformation that occurs in the product during texture analysis to get the hardness value of the product (Ansari *et al.,* 2014). The hardness value is directly proportional to the force required for product deformation, where the force required increases with increasing hardness values. A product's lower crispness rating corresponds to its greater hardness value, and vice versa (Paula and Conti-Silva, 2014). Formula F1 flakes have a hardness value of 553±5.09 g force, while formula F2 has a hardness value of 519.05±6.86 g force. The product of flakes formula F2 had a lower hardness value, so it can be concluded that it was crispier. This can be caused by the raw material of the flakes, the main component of which was steamed red bean which had a lower water content than steamed sweet corn. Steamed red bean had a moisture content of 55.31±2.19% (Afandi *et al.,* 2021), while the moisture content of steamed sweet corn in this study was 74.11±0.01%.

Flakes are a type of ready-to-eat cereal product, therefore in serving flakes, must be able to maintain crispness. Good breakfast cereal products should be able to maintain their crispness for more than two min in a bowl of milk (Gandhi and Wenk, 2014). The durability of the flakes in F1 milk is 2.29 min and the durability of the flakes in F2 milk is 1.45 min. The crispness of formula F1 was appropriate while F2 was slightly lower than the literature. Large starch granules have greater resistance to heat and water treatment than smaller starch granules (Cornejo-Ramírez *et al.,* 2018). Corn starch has a fairly large and inhomogeneous granule size, ranging from 1 to 20 μm (Cornejo-Ramírez *et al.,* 2018). The size of red bean starch granules is relatively small, *i.e.* 3.8–13.5 μm. Corn starch granule size is larger than red bean starch granule size. This caused flakes made from a higher content of sweet corn to be last longer in milk. Carbohydrate content also determines the resistance of crispness in milk. Carbohydrates include starch and fiber. The properties of fiber and starch to water are different, where starch is more resistant to water, while fiber is absorbing water.

The amount of fiber in a substance has determines how resistant it is to crispness. The more fiber contains in a material, the more water it will absorb, and the faster the resultant flakes will collapse in milk (Papunas *et al.,* 2013). Many studies classify resistant starch as a dietary fiber. Flakes made with the main ingredient of red bean (F2) which had a lower total starch, but had a higher content of resistant starch (dietary fiber) were easily absorbed in water so they tend to be broken down faster in milk.

CONCLUSIONS

Research has been carried out on the glycemic index value of steamed sweet corn, and it has a low glycemic index of 36. Sweet corn is then combined with red beans which have a low glycemic index of 26 (Afandi *et al.,* 2021). In this study, two formulas based on the proportion of red beans to sweet corn, F1 (30:70) and F2 (70:30), were used to develop the flakes product. These formulas were based on the ratio of red bean to sweet corn. The findings demonstrated that F1 flakes had greater fat (db), carbohydrate (db), and total starch (db) contents than F2 flakes. Water, protein (db), and resistant starch (db) contents were all greater in F2 flakes than in F1 flakes. Physical parameters studied from this research were color, hardness, and water absorption. The outcomes demonstrated that both of them already have qualities that were consistent with the traits of flakes in general, namely a crispy texture and a yellow hue. The color of the two flakes were not significantly different, the texture of the F2 was crispier than F1, but the F2 flakes had a water absorption capacity that was too high. F2 is recommendded for further development because F2 has higher resistant starch, so it is predicted to have a lower glycemic index. Glycemic index analysis is recommended for further confirmation of the flakes' products.

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