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Composition, Physicochemical, and Physical Properties of Rolled Oats Snack Bars Formulated with Green Banana Flour

[1]*Norhidayah Che Dahri,* [1]*Lee-Hoon Ho,* [2]*Thuan-Chew Tan and* [1]*Kamarul 'Ain Mustafa*

[1]Department of Food Industry, Faculty of Bioresources and Food Industry,
Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu, Malaysia
[2]Food Technology Division, School of Industrial Technology,
Universiti Sains Malaysia, 11800 USM, Penang, Malaysia

Abstract: The objective of this study was to compare rolled oats-based snack bars made with different levels of green banana flour (GBF). GBF was incorporated in proportions of 5, 10, 15 and 20% on rolled oats basis in snack bar. Compositions, physicochemical and physical properties of snack bars were assessed. The increase in the addition of GBF significantly decreased (P<0.05) the moisture and crude protein contents, but significantly increased (P<0.05) the ash, crude fiber, crude fat and carbohydrate contents, as well as the calorie values. The pH, total soluble solids and total sugars content were found to increase significantly (P<0.05), while the water activity decrease significantly (P<0.05), with increasing substitution level of GBF for rolled oats. Higher substitution level of GBF in snack bars had significantly increased (P<0.05) the amount of total phenolic content, total flavonoids and total antioxidant values than that of control (snack bar without GBF). Texture profile analysis indicated that all the prepared samples were significantly different (P<0.05) from each other in terms of hardness and cohesiveness. The addition of GBF significantly reduced (P<0.05) the lightness (L^*) and significantly increased (P<0.05) the yellowness (b^*) of snack bars. The findings from this study showed that GBF has the potential to be incorporated into snack barsto improve its properties, especially in nutrition and functional aspects.

Key words: Green Banana Flour · Rolled Oats · Snack Bars · Chemical Composition · Antioxidant Properties · Texture Profile

INTRODUCTION

The demands for safe and nutritious food is growing worldwide, since eating a balanced diet is the recommended way to prevent health problems, *e.g.* malnutrition, obesity, heart disease, diabetes and other ailments [1]. Survey done in 2010 by World Health Organization (WHO) ranked Malaysia as sixth in Asia with the highest adult obesity rate and tops the list in South-East Asia for both obesity and diabetes [2]. The Malaysian government is concerned on the health effects, productivity and the health care cost implications of an obesity epidemic in the country. Snack bars, a popular and convenient ready-to-eat snack is continued to grow in sales [3]. However, most of the snack bars available in the market are of high sugar and glycemic index that cause powerful spikes in blood sugar for energy supplied. This subsequently leading to an increased risk for obesity, Type 2 diabetes, cardiovascular disease and other diseases associated with ageing.

Fruit and vegetables have abundant of polyphenol compounds and wide variety of antioxidant compounds. These constituents of fruit and vegetables are very important for maintaining human health by protecting from life-style related diseases, such as obesity, Type 2 diabetes and cardiovascular disease. Therefore, regular intake of fruits could promote desirable health benefits. However, one of the main constraints in increasing fruit and vegetables consumption is time required to prepare them [4]. Thus, fruits transformed into more convenient

Corresponding Author: Lee-Hoon Ho, Department of Food Industry, Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu, Malaysia. Tel: +60 9699 3605.

ready-to-eat food such as snack bar would be an ideal food format to eat as part of a meal. Snack bar would be a convenience food assortment to benefit from the health benefits of fruits by increasing the consumption of fruit especially among the young [5].

Banana is widely produced in tropical and subtropical regions and it is one of the most highly consumed fruits in the world. The world production of banana (*Musa* spp.) in 2014 was 114 million MT, of which approximately 31 million MT was plantains [6]. Banana (*Musa paradisiaca* var. Awak) belongs to a type of plantain is abundantly planted in Malaysia. Green bananas are getting interest in its nutritional value due to a significantly high in proportion of indigestible compounds, such as resistant starch (42%), dietary fiber (14.5%) and others indigestible fractions (43.5%), that may be beneficial for intestinal health [7, 8]. Foods rich in fiber are recommended to individuals suffering from impaired glucose tolerance as these foods are capable of reducing the glycemic response, consequently minimizing the need for insulin. Fiber acts by protecting the starch granules from the physical action inside the human stomach. In addition, fiber plays a pivotal role in reducing microbial activity in the large intestine. Apart from dietary fiber, bananas also contain high amounts of essential minerals, such as potassium and various vitamins, such as A, B_1, B_2 and C [9]. Furthermore, green bananas also contain high antioxidant compounds, including polyphenols, catecholamines and carotenoids, which show strong protective effects against certain diseases, *i.e.*, rheumatoid arthritis, cancer and cardiovascular disease [8, 9].

Improper handling of green bananas during pre- and post- harvesting causes it to deteriorate and leading to huge losses. According to Cordenunsi and Lajolo [10], approximately 20% of all bananas harvested end up as waste and are normally disposed improperly. Hence, a better strategy to solve this problem by processing this waste into the flour and transform into various innovative products to encourage consumption of banana and thus contribute to health benefits for humans is worth pursuing. Drying or dehydration is one of the oldest methods and commonly applied in food processing for food preservation, minimizing packaging requirement and also reducing shipping weights [11].

Wolfberry (*Lycium barbarum*) or common name known as Goji berry is a well-known herb in traditional Chinese medicine (The Pharmacopoeia of the People's Republic of China) [12]. Nowadays, wolfberry is widely used as a popular health food ingredient in various forms such as drinks, soups and a variety of solid foods [13, 14]. Several reports claim that wolfberry has beneficial effects in improving eye sight and blood circulation, enhancing immune system and to exhibit anti-carcinogenic properties [15-17]. In addition, it is also well-known in traditional Chinese herbal medicine for diabetes [18] due to its very low glycemic level, *i.e.* 29 [2]. However, no published work regarding the use of wolfberry and green banana flour in enhancing the bioactive nutrients of snack bar. Therefore, the objective of this study is to compare the composition, physicochemical and physical properties of rolled oats-based snack bars made with different levels of green banana flour. This innovated snack bars with health promoting properties is expected to be beneficial to consumers.

MATERIALS AND METHODS

Materials: All ingredients (*i.e.*, rolled oats, skimmed milk powder, goji berries, pumpkin seeds and sorbitol)with the exception of green banana flour for snack bars making were purchased in a local wet market, in Bachok, Kelantan, Malaysia('Jelawat' Wet Market). All the chemicals used in this work are of analytical reagent grade.

Methods

Green Banana Flour Preparation: Unripe green bananas(without yellow/brown spot) were used to produce green banana flour (GBF). The banana skin was peeled manually with a sterile knife. The pulps were then cut into small pieces prior to soaking in the sodium metabisulfite solution (1:1,000). Then, the pulps were sliced using the fruit slicer (Santos, Vegetable Slicer 48, Lyon, France) before drying in a ventilated dryer at 60°C (Tech-Lab, FDD-720, Selangor, Malaysia) for overnight. The dried slices were ground using laboratory mill (Panasonic, MX-801S, Selangor, Malaysia) to fine powder and kept in an airtight plastic container and stored in chiller prior to use.

Snack Bars Preparation: Snack bars were prepared according to the method as proposed by Silva *et al*. [1] with minor modifications on the size of prepared bar. Snack bars were prepared according to the formulation shown in Table 1. Toasted rolled oats were replaced by increasing amounts of GBF (5, 10, 15 and 20%) to prepared SBF5, SBF10, SBF15 and SBF20, respectively. Snack bar without GBF served as control. Dry ingredients, such as toasted rolled oats, GBF, skimmed milk powder, goji berries and pumpkin seeds, were mixed using blender

Table 1: Formulation of snack bar preparation

	Types of snack bar[1]				
Ingredients	SBF0	SBF5	SBF10	SBF15	SBF20
Rolled oats (g)	30	28.5	27	25.5	24
Green banana flour (g)	-	1.5	3.0	4.5	6
Skimmed milk powder (g)	20	20	20	20	20
Goji berry (g)	20	20	20	20	20
Pumpkin seeds (g)	10	10	10	10	10
Sorbitol (mL)	20	20	20	20	20

[1]SBF0 (control), SBF5, SBF10, SBF15 and SBF20 represent snack bars made from green banana flour replaced for toasted rolled oats at 0, 5, 10, 15 and 20% level, respectively.

(Waring Commercial Blender, 7011HS, Osaka, Japan). Sorbitol syrup was then added into the dry mixture and blended until a uniform mixture was obtained. The mixture was shaped into shapes of cuboid (3 cm ×9 cm ×0.8cm) prior todryingusing ventilated dryer (Tech-Lab, FDD-720, Selangor, Malaysia) at 40°C for 3 h. The snack bars were then packed in aluminium-coated cellophane and keptin airtight container at ambient temperature prior analysis.

Proximate Analysis: The proximate compositions of the samples were determined according to the official method as described by AOAC [19]. Oven drying (AOAC Official Method 977.11), Kjeldahl (AOAC Official Method 955.04), Soxhlet (AOAC Official Method 960.39), dry ashing (AOAC Official Method 923.03) and gravimetric methods (AOAC Official Method 991.43) was used to analyze moisture, crude protein, crude fat, ash and crude fibre contents, respectively.

Total Carbohydrate and Energy Estimation: The total carbohydrate content was estimated by difference [Total carbohydrate (% wet basis) = 100% –% (moisture + ash + crude protein + crude fat)] [20]. The energy of the sample was calculated by multiplied by the factor values; 1 g of crude protein or carbohydrate provides 4 kcal of energy and 1 g of crude fat provides 9 kcal of energy) [21].

Sample Extract Preparation: All the samples were extracted using methanol as described by Ho *et al.* [22]. Approximately 1 g of powdered sample was suspended in 100 mL of methanol. A solvent extraction was conducted using orbital shaker (Protech, 722-2T, Selangor, Malaysia) at 100 rpm at room temperature for 24 h. The supernatants we recollected by centrifugation (Sartorius Sigma/Sigma 3-K16, Northern Ireland, UK) at 3,000x*g* for 15 min and were used for the following analyses; total phenolic content, total flavonoid content and antioxidant properties (using 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical-scavenging assay and ferric-reducing antioxidant potential (FRAP) assay).

Determination of Total Phenolic Content (TPC): The Folin-Ciocalteau method was used to determine the TPC of the samples as describe by Ho *et al.* [22]. Different concentrations (20, 40, 60, 80 and 100 mg/L) of gallic acid standard were prepared for calibration curve. A 400 μL sample of the extracts was added to 2 mL of the Folin-Ciocalteau reagent (pre-diluted 10 times with distilled water) and rest for 5 min at room temperature. After 5 min, 1.6 mL of sodium carbonate (7.5%, w/v) solution was added. The solutions were mixed (vortex) and allowed to stand for 1 h at room temperature. Finally, the absorbance was measured at 765 nm using a UV-Vis spectrophotometer (Shimadzu, UV-1280, Kyoto, Japan) against a blank of methanol. TPC was expressed as mg of gallic acid equivalents per 100 g of sample (mg GAE/100 g of dry matter).

Determination of Total Flavonoid content (TFC): TFC was measured using the aluminium chloride colorimetric assay [22]. Different concentrations (20, 40, 60, 80 and 100 mg/L) of catechin (Cat No 219250; Calbiochem, Darmstadt, Germany) standards were prepared for calibration curve. One mL of the different concentrations prepared standard solution of catechin and extracts were added to 4 mL of distilled water and 300 μL of 5% (w/v)sodium nitrite. After 5 min, 300 μL of 10% (w/v)aluminium chloride were added. At the 6th min, 2 mL of 1 M sodium hydroxide and 2.4 mL distilled water were added. The solution was mixed well and the absorbance was measured against prepared reagent blank (*i.e.* methanol) at 510 nm using UV-1280 UV-Vis spectrophotometer. TFC was expressed as mg of catechin equivalents per 100 g of sample (mg CEQ/100 g of dry matter).

1,1-diphenyl-2-picrylhydrazyl (DPPH) Free Radical-Scavenging Assay: The determination of the free radical scavenging effect of samples on DPPH was determined based on the method described by Ho *et al.* [22]. One mL of trolox standard solution (concentrations: 20–200 µmol/L) was dissolved in methanol (as a negative control) and the sample (a positive control) were added to 6 mL of respective 100 µmol/L DPPH solution in methanol. The mixtures were thoroughly vortex-mixed and incubated at room temperature for 30 min. A decrease in the absorbance was determined at 517 nm against the blank using a UV-1280 UV-VIS spectrophotometer. Results were expressed as µmol of Trolox equivalents per 100 g of the sample (µmol TEAC/100 g of dry matter).

Ferric-Reducing Antioxidant Potential (FRAP) Assay: The ability of sample to reduce ferric ions was measured according to the method described by Ho *et al.* [22]. FRAP reagent were prepared using 300 mm sodium acetate buffer at pH 3.6, 20 mm iron chloride and 10 mm 2,4,6-tripyridyl-s-triazine dissolved in 40 mm hydrochloric acid at a ratio of 10:1:1 (v:v:v). The reagent were freshly prepared and pre-warmed at 37°C in a water bath (memmert WNB14, Schwabach, Germany). A calibration curve were prepared using different concentrations (100, 200, 400, 600, 800 and 1,000 µmol/L) of ferrous sulphate ($FeSO_4.7H_2O$) standard solutions. Approximately 100 µL of the extracts were added to 3 mL of FRAP reagent. The solutions were mixed well and then incubated at 37°C for 4 min. The reagent blank was a mixture of distilled water and FRAP reagent incubated at 37ºC for 1 h. The absorbance of the sample extract and the reagent blank was measured against a blank (distilled water) at 593 nm. Results were expressed as µmol of ferrous II equivalent per 100 g of sample (µmol Fe(II)/100 g of dry matter).

pH Measurement and Total Soluble Solids (TSS) Determination: Samples preparation for the analyses of pH and TSS were conducted according to the method of Adelekan and Oyewole [23]. Approximately 1 g of dried sample was added to 10 mL of distilled water and then stirred for 10 min. The mixture was then filtered for analyses. For pH measurement, the calibrated (with buffer solutions of pH 4.0 and 7.0) pH electrode was dipped in the filtrate. For TSS, ahand-held digital refractometer (Atago, 2383 MASTER-20M, Tokyo, Japan) was used and the results were expressed in °Brix.

Water Activity (a_w) Determination: The a_w of the samples was measured using an Aqualab Series 4 water activity meter (Aqualab dew point water activity meter 4TE, Washington, USA) at 25°C. Solid pieces of sample (about 2 g)were evenly placed on plastic cells and were allowed to equilibrate within the headspace of the sealed chamber. The reading was then recorded when equilibrium was achieved.

Total Sugar Determination: Total sugar content of the samples was evaluated based on phenol sulphuric acid method as described by Chow and Landhäusser [24]. A 50 mg of sample was extracted with 5 mL of 80% (v/v) ethanol by heating at 95°C in a water bath for 10 min. The supernatant was obtained by centrifuging at 2,500 rpm for 5 min. The extraction was repeated twice. To 0.5 mL of the ethanol extract, 1 mL of 2% phenol solution and 2 mL of concentrated sulphuric acid were added. The mixture was vortex mixed and incubated for 30 min in a water bath at 22°C. The mixture of the glucose, fructose and galactose was used a standard. The absorbance of the prepared standard and sample were measured at 490 nm using a UV-1280 UV- VIS spectrophotometer.

Color Measurement: The color of samples was determined according to *L** [Lightness (*L**=100; white and *L**=0; black), Chroma a* [green chromaticity (-60) to red (+60)] and Chroma b* [blue chromaticity (-60) to yellow (+60)] space value using a colorimeter (Konica Minolta, Chroma Meter CR-400, Tokyo, Japan).

Texture Profile Analysis (TPA): TPA was conducted using a texture analyzer (Stable Microsystem, TA–XT2i, Surrey, UK) with a load cell of 2 kg weight [25]. A bar size 3 cm × 9 cm × 0.8 cm was placed centrally beneath the three-point bending rig HDP/3PB blade to meet with a consistent flat surface at all the time. Before sample The instrument parameters were set; pre-test speed of the three point bend rig was 1.00 mm/s, the test speed was 5.0 mm/s and the post-test speed was 5.0 mm/s. The parameters of hardness, fracturability, adhesiveness, gumminess, chewiness, and cohesiveness were analyzed using Texture Expert Version 1.05 Software (Stable Micro System Ltd, Surrey, UK.).

Statistical Analyses: Statistical analyses were conducted using Statistical Package for the Social Sciences version 14.0 software (SPSS Inc., Chicago, IL, USA). The results obtained from the present study are represented as the mean values of three individual replicates±the standard deviation. Comparison between the mean values were determined using Duncan's multiple range tests at a significance level of $P<0.05$.

Table 2: Proximate composition analyses of rolled oat-based snack bars within various levels of green banana flour

	Types of snack bar[1]				
Proximate Composition	SBF0	SBF5	SBF10	SBF15	SBF20
Moisture (% wet basis)	13.91^{d}±0.54	12.92^{c}±0.18	12.42^{b}±0.11	11.66^{b}±0.05	11.23^{a}±0.07
Ash ((% wet basis)	3.45^{a}±0.01	3.54^{b}±0.01	3.56^{bc}±0.01	3.58^{c}±0.00	3.66^{d}±0.02
Crude protein (% wet basis)	19.00^{e}±0.11	18.78^{d}±0.05	17.81^{c}±0.16	16.85^{b}±0.06	16.39^{a}±0.05
Crude fat (% wet basis)	7.24^{a}±0.09	7.32^{a}±0.09	7.42^{ab}±0.08	7.56^{bc}±0.03	7.67^{c}±0.20
Crude fibre (% wet basis)	2.02^{a}±0.03	2.22^{b}±0.03	2.41^{c}±0.03	2.59^{d}±0.06	2.78^{e}±0.14
Total cabohydrate (% wet basis)	56.49^{a}±0.41	57.44^{b}±0.08	58.77^{c}±0.47	60.33^{d}±0.03	61.07^{e}±0.07
Energy (kcal/100 g of sample)	367.16^{a}±0.60	370.82^{b}±0.39	373.16^{c}±0.44	376.82^{d}±0.16	378.95^{e}±1.39

Data are mean±standard deviation (*n*=3). Values with different superscript letters within a row are significantly different (*P*<0.05).

[1]SBF0 (control), SBF5, SBF10, SBF15 and SBF20 represent snack bars made from green banana flour replaced for toasted rolled oats at 0, 5, 10, 15 and 20% level, respectively.

RESULTS AND DISCUSSION

Proximate Composition of Snack Bars: The effects of increasing levels (0% to 20%) of green banana flour (GBF) on the proximate compositions of the snack bars are presented in Table 2. The supplement of GBF reduced the moisture content progressively from 13.91 to 11.23 g/100g. The result for moisture content obtained in the present study is relatively close to those found by Mridula *et al.* [26] for snack bar made from flaxseed wherein ranging from 11.4 to 13.2 g/100g. In addition, a similar trend was observed by Ovando-Martinez *et al.* [8], who reported that moisture content decrease when substitution of green banana flour level in the product increased. Low moisture content is vital in food products because it greatly affects the textural quality, chemical and biochemical reactions and consequently influences their shelf life [27].

The ash content of the snack bars was significantly (*P*<0.05) affected with the substitution of GBF for rolled oats. The increase in GBF contents led to the gradual increase in ash contents of snack bars wherein increased from 3.45 to 3.66 g/100g (Table 2). According to Agbaje *et al.* [28], ash content can be correlated to the mineral content of the formulation ingredients. Thus, this finding indicates that GBF used in this present study had higher concentration of mineral contents than the rolled oats, which contributed to the significant higher (*P*<0.05) ash content in snack bars containing GBF than that of control, *i.e.* SBF0. In addition, Abbas *et al*. [29] reported that GBF has high content ofminerals, *i.e.* K, Mg, P, Ca, Mn and Zn. A similar trend was observed by Choo and Aziz [9], who reported that the substitution of wheat flour with banana flour resulted in significantly high ash content in yellow alkaline noodle.

The crude protein contents of the snack bars containing GBF(16.39–18.78 g/100g) were significantly lower (*P*<0.05) than that of control, *i.e.* SBF0 (19.00 g/100g) (Table 2). The crude protein content decreased progressively and uniformly with the increase in GBF levels in the snack bar formulations. This could be due to the GBF used in this study containing lower protein content, *i.e* 6.77% [30] compared to rolled oats, which has been reported to contain 11–15% of protein [31]. The result of crude protein obtained from the present study showed higher than those reported by Sun-Waterhouse *et al.* [32], who reported that the fruit-based functional snack bar possesses 1.07 to 2.74 g/100 g of crude protein.

With regard to crude fat contents, a significantly increased (*P*<0.05) in the crude fat content was observed in the snack bar supplemented with 15 and 20% level of GBF (*i.e.* SBF15 and SBF20) (Table 2). According to Baiyeri *et al.* [33], banana at the unripe stage has relatively higher in fat content. The results obtained in the present study was in agreement with studies accomplished by Juarez-Garcia *et al.* [7], whereby the use of banana flour in bread making results in increased crude fat content of the end product. Garcia *et al.* [34] worked on cereal bars containing different levels of toasted rice bran and reported that the crude fat content to vary between 7.43 and 9.57%. Similarly, Sun-Waterhouse *et al.* [32] worked on fruit-based functional snack bars and reported that the crude fat to range from 8.48 to 9.97%. Both of these studies are in line the findings from this study.

Crude fiber content of supplemented snack bars ranged from 2.22 to 2.78 g/100g, which was significantly higher (*P*<0.05) than the crude fiber of the control, *i.e.* SBF0 (2.02 g/100g) (Table 2). This could be attributed to the high fiber content in GBF. According to Asif-Ul-Alam *et al.* [35], crude fiber content in GBF ranged from 4.2 to 4.9 g/100g. The present obtained results are in the accordance to the results found by Choo and Aziz [9]. The authors reported that yellow alkaline noodles containing green banana flour has higher crude fiber content than that of control. In addition, according to

Table 3: Total phenolic content, total flavonoid content and antioxidant properties of rolled oat-based snack bars within various levels of green banana flour

Types of snack bar[1]	TPC[2]	TFC[3]	DPPH[4]	FRAP[5]
SBF0	152.04^{a}±0.48	106.18^{a}±0.44	2761.26^{a}±1.25	2483.33^{a}±0.49
SBF5	166.76^{b}±0.82	111.48^{b}±1.13	3040.03^{b}±0.78	2651.31^{b}±1.36
SBF10	180.00^{c}±1.58	116.15^{c}±0.44	3158.98^{c}±0.38	2828.25^{c}±0.67
SBF15	194.03^{d}±0.97	120.22^{d}±0.96	3441.56^{d}±1.35	2939.61^{d}±1.17
SBF20	207.21^{e}±0.59	125.92^{e}±0.88	3721.67^{e}±1.05	3050.56^{e}±0.96

Data are mean±standard deviation (*n*=3). Values with different superscript letters within a column are significantly different (P<0.05).

[1]SBF0 (control), SBF5, SBF10, SBF15 and SBF20 represent snack bars made from green banana flour replaced for toasted rolled oats at 0, 5, 10, 15 and 20% level, respectively.

[2]TPC represents total phenolics content (mg GAE/100g of dry matter)

[3]TFC represents total flavonoids content (mg CEQ/100g of dry matter)

[4]DPPH represents 1,1-diphenyl-2-picrylhydrazyl (µmol TEAC/100g of dry matter)

[5]FRAP represents ferric-reducing antioxidant potential (µmol Fe(II)/100 g of dry matter)

Mota *et al*. [36], GBF was found to be abundant in insoluble dietary fiber and hemicelluloses. The presence of dietary fiber in food is of great interest in health, as numerous studies have linked their role in the reduction of the risk of some diseases, such as colon cancer, obesity, heart problems and diabetes [37].

The total carbohydrate content increased when GBF content increased in the snack bar formulation with significant differences (P<0.05) between the control (56.49 g/100 g) and samples containing GBF (SBF5, SBF10, SBF15 and SBF20; 57.44, 58.77, 60.33 and 61.07 g/100 g, respectively) (Table 2). This could be due to the high accumulation of starch, the predominant component of carbohydrate in banana fruits during immature stage, which contributed to the high content of carbohydrate in GBF. The results in this study is comparable to the results obtained by Agbaje *et al.* [28], who reported that the carbohydrate contents obtained in their study for cereal bars were ranged between 58.31 and 73.35%. Taking into consideration that the produced snack bar is categorized as a nutrition and 'energy' bar, the increase observed in the crude ash, crude fat, crude fiber and total carbohydrate contents would be foreseen as a great effect. The energy of the produced snack bars containing GBF were found to be increased as the level of GBF (370.82–378.98 kcal/100 g) increased (Table 2). The results obtained in this present work are similar to that reported by Agbaje *et al.* [28] and Shaheen *et al.* [38] for cereal bars (322.06–379.80 kcal/100 g) and fruit bars (325.46–386.96 kcal/100 g), respectively. Therefore, all snack bars produced in this study could be considered as high caloric value snack bars.

Total Phenolic Content (TPC), Total Flavonoid Content (TFC) and Antioxidant Properties of Snack Bars: Significantly higher (P<0.05) TPC were observed with the incorporation of GBF into the snack bar formulation (Table 3). This could be due to the high phenolics content (746 mg GAE/100g of dry matter) and various flavonoids (*i.e.*, catechin, epicatechin, gallocatechin, dopamine and tannin) found in green banana [30, 46]. A similar trend was found by Ovando-Martinez *et al.* [8], whereby the banana flour-added spaghetti has higher polyphenols content than that of control. Furthermore, according to the authors, high polyphenolic compounds in the product can be correlated to the high level of condensed tannins. Fruits are usually abundance in polyphenols, such as anthocyanins and proanthocyanidins or condensed tannins. The GBF used to develop the snack bars in this study was obtained from green bananas. According to Ovando-Martinez *et al.* [8], bananas at their immature stage possesses an astringent flavor, which is due to the presence of condensed tannins or proanthocyanidins.

Snack bars containing GBF had significantly higher (P<0.05) TFC (111.48–125.92 mg CEQ/100 g of dry matter) than that of control (106.18 mg CEQ/100 g of dry matter) (Table 3). A steady increase in the TFC of the snack bars with the increase of GBF content was associated to the flavonoids content in the GBF. According to Rosell [47], the TFC is a potent antioxidant that effectively acts in the extinction of free radicals to prevent premature aging. Bananas are rich in polyphenolic compounds, vitamin and flavonoids, which play a vital role in the scavenging of free radicals.

The antioxidant properties of the snack bars were determined based on the scavenging activity of free radicals in DPPH and FRAP assays. It was found that the incorporation of GBF into snack bars increased the antioxidant activity when compared with control (Table 3). The supplemented snack bars showed significant higher (P<0.05) inhibition of DPPH (3,040.03–3,721.67 µmol TEAC/100 g of dry matter) than that of control (2,761.26 µmol TEAC/100 g of dry matter). Results from the FRAP assay showed that the ability of snack bars containing

Table 4: pH value, water activity, total soluble solid and total sugar content of rolled oat-based snack bars within various levels of green banana flour

Types of snack bar[1]	pH	Water activity	Total soluble solid (°Brix)	Total sugar (% w/v)
[i]SBF0	$5.36^{a}\pm0.15$	$0.54^{c}\pm0.00$	$4.50^{a}\pm0.20$	$19.10^{a}\pm0.34$
[ii]SBF5	$5.41^{b}\pm0.02$	$0.53^{c}\pm0.00$	$4.67^{ab}\pm0.15$	$27.66^{b}\pm0.61$
[iii]SBF10	$5.44^{bc}\pm0.02$	$0.52^{b}\pm0.00$	$4.97^{b}\pm0.15$	$32.25^{c}\pm0.68$
[iv]SBF15	$5.46^{cd}\pm0.03$	$0.51^{ab}\pm0.00$	$5.50^{c}\pm0.20$	$35.03^{d}\pm0.57$
[v]SBF20	$5.50^{d}\pm0.02$	$0.50^{ab}\pm0.00$	$5.60^{c}\pm0.10$	$39.98^{e}\pm0.73$

Data are mean±standard deviation (*n*=3). Values with different superscript letters within a column are significantly different (*P*<0.05).

[1]SBF0 (control), SBF5, SBF10, SBF15 and SBF20 represent snack bars made from green banana flour replaced for toasted rolled oats at 0, 5, 10, 15 and 20% level, respectively.

GBF to reduce ferric ions (2,651.31–3,050.56 µmol Fe(II)/100 g of dry matter) was significantly greater (*P*<0.05) than that of control (2,483.33 µmol Fe(II)/100 g of dry matter). According to Parn *et al.* [48], phenolic compounds can contribute significantly to the total antioxidant activities. This could be explained through the results recorded in Table 3, whereby the values of DPPH and FRAP scavenging activities were consistent with the TPC analysis. Moreover, according to Alothman *et al.* [49], the antioxidant activity is depended whether on the available concentration of an individual antioxidant compound or on the potential synergistic interaction that occurs in various constituents of plants. Among the antioxidant compounds, gallocatechin and dopamine are most abundant in green banana pulp [9, 46]. Moreover, Kondo *et al.* [50] reported that compounds, such as ascorbic acid, β-carotene, α-carotene and various xanthophylls, are presence abundantly in banana pulp and may contribute to the antioxidant activity in composite products. A similar trend was reported by Ovando-Martinez *et al.* [8], Choo and Aziz [9] and Wang *et al.* [51], whereby the incorporation of green or immature banana flour in spaghetti, noodles and crackers formulations, respectively, improved the antioxidant activities of the food products.

pH Value, Water Activity, Total Soluble Solids and: The pH value of snack bars containing GBF indicates increased gradually on increasing the level of GBF substitution compared to the control (Table 4). The presence of GBF in snack bars resulted in significant increased (*P*<0.05) in pH; from 5.36 (SBF0) to 5.41–5.50 (SBF5–SBF20). However, the pH value for all snack bars were fell into category of acidic food. This was attributed to the utilized of fruit (*i.e.* wolfberry) and fruit flour (*i.e.* green banana flour) in the formulation, which arecommonly reported to be acidic in its nature. Aurore *et al*. [27] reported that green banana flour has pH 5, which indicates acidic flour. According to Suntharalingam and Ravindran [39], the acidity of the banana flour is due to the presence of various oxo-acids such as citric, oxalic and malic. Different behaviour was observed by Silva *et al*. [40] for snack bar added with jerivá flour which reduced from pH 6.92 to 6.78 and can be considered as slightly acidic food.

The a_w is an important measurement help to predict food mechanical properties, stability and shelf life of the food product. It may influence the microbial spoilage, as well as chemical reactivity and enzymatic reaction of the food product [41]. The changes in a_w are responsible for the mechanical properties of snack bars, which probably associated with the differences in a product microstructure and chemical composition [42]. The a_w of snack bar containing GBF was found to be decreased significantly (*P*<0.05) with incorporation of GBF at 5 to 20% levels (0.50–0.53) to the snack bars (Table 4). Since a_w of 0.6 is theminimum value required for microbiological growth [43],all the snack bars produced in this study (a_w lower than 0.6) had a low risk of microbial proliferation and pathogenic spoilage. Therefore, it should be expected long shelf life for control (*i.e.* SBF0) and even longer in snack bars containing GBF. A similar trend was reported by Silva *et al*. [40], they reported that snack bar added with jerivá flour decreased the a_w of snack bars (a_w ranging between 0.55 to 0.53) compared to control (a_w of 0.56).

The TSS present in the snack bars with or without GBF were 4.50–5.60 °Brix (Table 4). The results onTSS showed that snack bars containing GBF had significantly higher (*P*<0.05) TSS (4.67, 4.97, 5.50 and 5.60 °Brix for SBF5, SBF10, SBF15 and SBF20, respectively) than that of the control, *i.e.* SBF0 (4.50 °Brix). The TSS in snack bars containing GBF increased gradually on increasing the level of substitution could be attributed to GBF used, which has been reported by Suntharalingam and Ravindran [39] to be rich in carbohydrate compositions. According to Ho *et al*. [44], the TSS which include the soluble sugars, such as glucose, sucrose and fructose, are correlated with the starch content. Starch is the major component in green banana flour,where it has approximately 68.8 to 70.5% of starch [39].

Table 5: Color values of of rolled oat-based snack bars within various levels of green banana flour

Types of snack bar[1]	Lightness, L^*	Redness, a^*	Yellowness, b^*
SBF0	89.47^e±1.01	6.12^a±1.10	18.22^a±0.94
SBF5	80.31^d±0.71	6.13^a±1.30	21.02^b±1.20
SBF10	78.51^c±0.90	6.13^a±0.88	22.86^c±1.12
SBF15	72.55^b±0.90	6.14^a±1.40	24.94^d±0.91
SBF20	68.25^a±0.55	6.15^a±1.30	27.62^e±1.47

Data are mean±standard deviation (n=3). Values with different superscript letters within a column are significantly different (P<0.05).

[1]SBF0 (control), SBF5, SBF10, SBF15 and SBF20 represent snack bars made from green banana flour replaced for toasted rolled oats at 0, 5, 10, 15 and 20% level, respectively.

The control snack bar (*i.e.* SBF0) contained 19.10% w/v of total sugars, which was significantly lower (P<0.05) than those snack bars containing GBF (27.66, 32.25, 35.03 and 39.98% w/v for SBF5, SBF10, SBF15 and SBF20, respectively) (Table 4). The total sugar results are in the accordance to the TSS results. The slight increase in sugar content in snack bars containing GBFcould be attributed to the presence of GBF in snack bar. According to Suntharalingam and Ravindran [39], green banana flour has total sugar content of averaged 2.7–2.9%, which is higher than that of oats (0.9–1.3%) [45].

Color Characteristics of Snack Bars: Color is one of an important attribute due to its contribution to consumer preference. Consumers judge the visual quality, *i.e.* surface color and acceptability of a snack bar via color. The color analysis results indicated that the snack bars containing GBF (SBF5, SBF10, SBF15 and SBF20) had a significantly lower (P<0.05) in lightness (L^*) (80.31, 78.51, 72.55 and 68.25, respectively) than that of control, *i.e.* SBF0 (89.47) (Table 5). It was found that the presence of GBF made the snack bars appeared to be darker color, whereby the surface of the snack bars changed from white to brownish color. In addition, the color changed could also be associated with Maillard reactions (non-enzymatic browning), which could have occurred during heating between protein and reducing sugars presence in the snack bar. According to Hathorn *et al.* [52], L* value of approximately 50 is classified as 'dark', 60 as 'optimum' and 70 as 'light' in color. Therefore, all the produced snack bars categorized as light color, with the exception of snack bar incorporated with 20% level of GBF (optimum color).

The redness (a*) of all the formulated snack bars was positive, indicating that red hues was present in all the snack bars. All snack bars showed insignificant different (P>0.05) from each other (Table 5). The reddish color of the snack bars was resulted from the goji berries, a red fruit used in the formulations. According to Hidalgo and Almajano [53], red fruits are rich in anthocyanins, which are water-soluble plant pigments responsible for the blue, purple and red color of many plant tissues. The results of color obtained in this study also suggested that the incorporation of GBF into snack bars did not affect the reddish color of the end products.

Concerning the level of GBF incorporated, a steady increase in the yellowness (b*) was observed with the raise of the flour level, which indicated snack bars to lean more towards yellowish color (Table 5). The b* increased in the order of SBF0 (control) <SBF5<SBF10<SBF15<SBF20 (18.22<21.02<22.86<24.94 <27.62, respectively). This suggests that the yellowness color of the snack bars occurred when it was incorporated with GBF. Choo and Aziz [9] and Kondo *et al.* [50] reported that GBF contains high concentration of flavonoids (yellow pigments), which can be explained for the more yellowish colour of the snack bars as the GBF substitution level increased from 5% to 20%. A similar trend was reported by Chong and Aziah [54] and Mohamed *et al*. [55] for doughnut and bread incorporated with GBF, respectively.

Textural Parameters of Snack Bars: The substitution of GBF for rolled oats at 5% level in the composite snack bar (SBF5) did not affect the hardness (7.37 g) of the snack bar compared to control, *i.e.* SBF0 (7.26 g) (Table 6). However, the hardness value was significantly increased (P<0.05) to 7.98, 8.81 and 8.92 g for SBF10, SBF15 and SBF20, respectively. According to Garcia *et al.* [34], the greater the amount of fiber in the snack bars, the higher the hardness values of the bars and subsequently required high force to compress the bars. This high crude fiber content of snack bars containing GBF is in the accordance to the results summarized in Table 2. The results obtained in the present study also can be explained by the compactness of the bars as a result of the presence of fiber component, *i.e.* GBF, which reduce the amounts of some of the constituents responsible for generating empty spaces in snack bars. In addition, the different granulometry values of the dry

Table 6: Textural parameters of rolled oat-based snack bars within various levels of green banana flour

	Types of snack bar				
Texture Profile Analysis Parameter	SBF0	SBF5	SBF10	SBF15	SBF20
Hardness (g)	$7.26^{a}\pm0.94$	$7.37^{a}\pm0.64$	$7.98^{b}\pm0.57$	$8.81^{b}\pm0.10$	$8.92^{b}\pm0.70$
Fracturability (g)	$7.44^{a}\pm0.29$	$7.49^{a}\pm0.45$	$7.56^{a}\pm0.55$	$7.61^{a}\pm0.80$	$7.66^{a}\pm0.62$
Adhesiveness (g/sec)	$-6.04^{a}\pm0.86$	$-5.69^{a}\pm0.43$	$-6.18^{a}\pm0.89$	$-6.75^{a}\pm0.50$	$-7.15^{a}\pm0.88$
Gumminess	$0.90^{a}\pm0.49$	$1.10^{a}\pm0.54$	$1.14^{a}\pm0.45$	$1.16^{a}\pm0.40$	$1.22^{a}\pm0.49$
Chewiness	$0.33^{a}\pm0.91$	$0.34^{a}\pm0.11$	$0.40^{a}\pm0.44$	$0.43^{a}\pm0.11$	$0.44^{a}\pm0.08$
Cohesiveness	$0.08^{a}\pm0.02$	$0.09^{b}\pm0.01$	$0.13^{c}\pm0.02$	$0.15^{d}\pm0.02$	$0.16^{e}\pm0.01$

Data are mean±standard deviation (*n*=3). Values with different superscript letters within a row are significantly different (*P*<0.05).

[1]SBF0 (control), SBF5, SBF10, SBF15 and SBF20 represent snack bars made from green banana flour replaced for toasted rolled oats at 0, 5, 10, 15 and 20% level, respectively.

constituents, *i.e.* GBF has higher bulk density than rolled oats, might also influence the hardness of the end products. In addition, the increased hardness of the snack bars containing GBF was proportional to the moisture content (Table 2). According to Eliasson and Larsson [56], water plays an important role in determining the conformational state of biopolymers, as well as influencing the nature of interactions between the various constituents of the formulation. Therefore, the low proportion of water availability will lead to the increase in hardness of the snack bars.

No significant difference (*P*>0.05) was found between snack bars containing GBF (*i.e.* SBF5, SBF10, SBF15 and SBF20) and control (*i.e.* SBF0) on fracturability, adhesiveness, gumminess and chewiness properties of snack bars. The fracturability values ranged between 7.44 and 7.66 g. This suggests that the force required to break the snack bars into pieces when it is bitten using the incisors of teeth were similar. With regard to adhesiveness, all snack bars presented the negative values (Table 6), which indicated that the snack bars were very adhesive or were sticky. Similar results have been previously reported by Parn *et al.* [48], fruit bars made from date paste are in ranging -733 to -793 g/s. For gumminess attribute, all snack bars produced demonstrated no significant difference (*P*>0.05) among the samples (Table 6). This shows that the energy required to break down the snack bars into a state of 'ready to swallow" were similar.

All snack bars had low cohesiveness values ranging between 0.08 and 0.16 (Table 6). Snack bars containing GBF had significantly higher (*P*<0.05) cohesiveness values which ranged between 0.09 and 0.16 than that of control, *i.e.* SBF0 (0.08). Cohesiveness reflects to the ability of the foodstuff to hold together against compressed between the teeth before it breaks. This indicates that snack bars containing GBF were harder to chewed, owing to their high cohesiveness. This result was in accordance to the hardness results as shown in Table 6. However, this did not influence the chewiness values, whereby no significant differences (*P*>0.05)were found among all the produced snack bars. This suggests that time duration to masticate the snack bars containing GBF before 'ready-to-swallow' state, when a constant rate force is applied were similar to the control snack bar.

CONCLUSION

Snack bars incorporated with GBF at levels of 5–20% influences the chemical composition and physicochemical properties. Incorporation of GBF in snack bars preparation improved the nutritional quality, which provide substantial amount of ash, crude fiber, crude fat, carbohydrate and energy, as well as lower water activity, which indicates a more shelf stable snack bars can be developed through incorporation of GBF. Moreover, an increase in TPC, TFC and antioxidant activities (FRAP and DPPH free radical-scavenging assays) were observed in snack bars with incorporation of GBF. The developed snack bars containing GBFexhibited darker/brownish and more yellowish color than that of control, *i.e.* SBF0. The substitution of GBF for rolled oats in snack bars preparation increased the hardness and cohesiveness values. However, other texture attributes, such as fracturability, adhesiveness, gumminess and chewiness, were not adversely affected. The incorporation of GBF in a new food products, such as snack bars, is feasible and could be considered as a new highly nutritional ingredient for the food industry and could offer various types of healthy snack bars for consumers.

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