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FORMULATION OF A LOW GLYCEMIC BINDER FORTIFIED WITH PALM VITAMIN E (tocotrienol-rich fraction) FOR FUNCTIONAL GRANOLA BARS

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ABSTRACT

A granola bar is the combination of dry ingredients and a wet binder compressed into a bar form and is an excellent vehicle for delivering bioactive compounds to consumers. Sugar is one of the main components in granola bar binder, and it provides the sticky property and flavour to the granola bar. However, high sugar consumption can cause complications and health problems. This study focuses on the use of low glycemic natural sweeteners in the formulation of a granola bar binder and palm vitamin E (tocotrienol-rich fraction, TRF) as a potential fortifier to enhance the functionality of the granola bar while promoting health benefits, including cardioprotection, neuroprotection, as well as hypocholesterolemic, anti-cancer and antioxidant properties. An augmented simplex lattice design was used to develop the granola binder with natural low glycemic sweeteners (in response to °Brix), namely honey, date paste and coconut sugar. The desired °Brix was 80 to 85. The optimal range of sweeteners blend with the desired °Brix was 31.18% to 38.4% of honey, 7.25% to 9.43% of date paste and 24.65% to 32.63% of coconut sugar. Granola bars were prepared using three different sweetener formulations. Palm TRF was added to the selected binder formulation to enrich the vitamin E content in the finished product (granola bar). Honey and coconut sugar were responsible for the effect on °Brix of the binder, while date paste was the limiting factor that constrained °Brix. Granola bar with 15.22% honey, 4.71% date paste and 16.31% coconut sugar received sensory scoring which was significantly higher than for a commercial bar. The formulated granola bar which was enriched with 3.23 mg g^{-1} vitamin E had a proximate composition and caloric value comparable to that of the commercial granola bar.

Keywords: low glycemic binder formulation, granola bar, palm vitamin E, palm tocotrienol-rich fraction (TRF).

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INTRODUCTION

Functional foods can be defined and easily understood as foods with functions. They are foods that are enriched or fortified with nutrients to deliver certain functions beyond their conventional nutritional value. People consume functional foods to achieve the goals of self-medication, disease prevention and health management (Hasler, 2002). Packed functional foods allow consumers to enjoy foods conveniently, without sacrificing their nutritional value. Palm-based vitamin E, also known as palm tocotrienol-rich fraction (TRF) due to its high content of tocotrienols, is derived from the palm oil by-product and palm fatty acid

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distillate (Top *et al.*, 1993). Palm TRF which contains other phytonutrients such as carotene and squalene is obtained as a co-product in palm biodiesel production (Zou *et al.*, 2012). In comparison with the common form of vitamin E available, which is predominantly α-tocopherol, palm TRF consists of 75% tocotrienols and 25% tocopherol isomers. Its high tocotrienols content distinguishes palm TRF from other sources of vitamin E that normally contain tocopherols solely. Tocotrienols are proven to outperform tocopherols in terms of their biological functions. Additionally, tocotrienols have some biological functions that are not expressed by tocopherol, for instance, hypocholesterolemic and anti-cancer effects, neuroprotective, cardioprotective, gastroprotective and bone-protective properties (Chin and Ima-Nirwana, 2015; Trias and Tan, 2012). Therefore, palm TRF has potential as a fortifier to be incorporated into conventional food products to impart functions that will enhance well-being.

The rise of ageing population, escalating medical costs and increasing health awareness among consumers have caused the expansion of the health and wellness industry. Nowadays, foods are not only intended to satisfy one's hunger but also to assist in diet-related disease prevention. Functional foods have the largest market in the health and wellness industry, accounting for USD 159 billion in 2016, with a 23% increment to the global market revenue, compared to its worth of USD 129.39 billion in 2015. The change in eating habits and consumer expectations towards food products in the market has given a positive impact on the global demand for functional foods. This growing demand is projected to expand the functional food market to USD 255.1 billion in 2024. Vitamins are common fortifiers used in the food industry and represent the leading key products in the functional food market. Functional foods fortified with vitamins are expected to contribute about USD 85 billion in the functional food market in 2024, followed by fortification with minerals and dietary fibre (Research and Market, 2016).

Palm oil is one of the major export commodities of Malaysia and serves as an engine driving Malaysia's economy. The export value of palm oil products in 2016 was RM 64.58 billion (Kushairi *et al.*, 2017) and amounted to RM 77.8 billion in 2017. Expanding downstream activities, such as developing palm oil derivative products, is crucial to support the sustained development of the oil palm industry. Hence, incorporation of palm TRF into food products to fulfill the demand of the functional food market is one of the ways to promote the oil palm industry.

A granola bar is composed of dry ingredients, such as oats, wheat, grain, seeds, nuts or dried fruits, mixed with a binder to form a compressed bar form. It is readily accepted by consumers as a nutritive snack or quick meal due to its balanced nutritional value (da Silva *et al.*, 2013). The physical and sensorial characteristics of a granola bar, such as texture and taste, can greatly influence consumer preference for the product (Kim *et al.*, 2009). Granola bar is an excellent vehicle for delivering essential nutrient to people who lack the time or resources to extensive meal planning due to its convenience (Silva *et al.*, 2016). Binder, a blend of sweeteners and fatty materials is used to agglomerate the dry ingredients and allow them to be compressed into a bar form. The sugar content in the binder especially from high glycemic sweeteners is always a concern to health-conscious consumers and diabetic patients. According to Jenkins *et al.* (1981), food materials with a glycemic index below or equal to 55 are considered as low glycemic and prevents sudden elevated blood glucose levels and keeps blood glucose at a steady level (Radulian *et al.*, 2009). A low glycemic diet reduces the risk of chronic diseases, for example, type 2 diabetes and cardiovascular disease, and also good for weight management. Hence, the formulation of a binder with natural low glycemic sweeteners will be useful in meeting healthy claims.

Honey is an ancient sweetener which delivers a wide range of health benefits that can boost well-being. Honey is well-known for its anti-microbial effects (Al-Waili and Haq, 2004), and reported glycemic index at 55 by averaging over 11 types of honey (Foster-Powell *et al.*, 2002). Date fruit is another ancient staple food originates from the Arab world. Date fruit has a glycemic index of 51.4 (an average of five different varieties), and caused no significant elevation in blood glucose level of diabetic subjects after consumption (Alkaabi *et al.*, 2011). Besides its appealing low glycemic effect, date fruit is a good source of fibre (8% to 20%), mainly in the form of dietary fibre. The high dietary fibre content is good for regulating cholesterol level (Alsaif *et al.*, 2007) and reducing the risk of diabetes (by managing insulin level) and other related metabolic syndromes (Weickert and Pfeiffer, 2008). Coconut sugar is another low glycemic sweetener with a glycemic index of 35, as well as high in mineral, micronutrient and inulin content (Trinidad, 2003) that can promote well-being.

Honey, date paste and coconut sugar with their low glycemic indices and high nutritive values have potential as alternative sweeteners to be incorporated into a granola bar binder. Granola bar using a low glycemic binder will be appealing to health-conscious consumers and diabetic patients. Fortification of the binder with palm TRF further enhances the nutritive value of the granola bar. In this study, a low glycemic granola bar binder fortified with palm TRF was formulated using three low glycemic sweeteners, namely honey, date paste and coconut sugar. A sensory analysis was conducted to evaluate the intensity of liking for the finished products. The nutritional value of the selected product was analysed together with its vitamin E content.

MATERIALS AND METHODS

Materials

All the food ingredients were obtained from the local market. Palm TRF (Gold Tri.E Batch No. SB16121670) was obtained from Sime Darby Berhad, Selangor, Malaysia. All solvents used in the vitamin E analysis were of HPLC grade.

Experimental Design

The augmented simplex-lattice design for mixtures was used to study the effect of interactions between the three sweeteners on the quality of the binder. The basic composition of the binder formulation is shown in *Table 1*. The study variable was the concentration of the sweeteners, namely honey, date paste and coconut sugar. The response variable was the degree of Brix (°Brix) of the binder.

TABLE 1. BASIC COMPOSITION FOR GRANOLA BAR BINDER FORMULATION

Ingredient	Percentage
Honey, date paste and coconut sugar	72.5
Peanut butter	25.0
Palm-based fat	2.5

The maximum level (component proportion = 1) of each variable was 72.5% (relating to the total formulation) of the corresponding sweetener. A total of 14 runs with four replication points (three vertexes, one centre of edge) were generated (*Table 2*). The points of replication were used to calculate the experimental error and fit of the model. The order of the trials was randomised, and the Scheffé canonical model for the three components was used to fit a polynomial equation to the response by estimating the coefficients of determination (Equation 1).

Equation1. Scheffe canonic equation

$$Y = \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{23}X_2X_3 + \beta_{123}X_1X_2X_3$$

where Y = dependent variable; β = estimated coefficient of each linear component and its interactions to develop the predictive model; X = independent variable.

Modelling was based on °Brix of the binder by sweetener blends, and their compositions were determined using statistical criteria. The simplex lattice design used allowed the evaluation of models for sweetener blends having binary and ternary interactions. The quality of the model was judged by analysis of variance (ANOVA) of the regression results. Based on the regression model significance, a contour plot was produced to determine the optimal blend region. Overall desirability (D) of the blend was determined by monitoring °Brix of binder within the range through applying the desirability function (d_i) developed by Derringer and Suich (1980) (Equation 2). The lower boundary was set at 80 °Brix, the upper boundary at 85 °Brix, and the targeted region was at the mid-point between the lower and upper boundaries which was 82.5 °Brix. The weight (r) was set at 1 to create a linear progression towards the goal set. Overall desirability (D) was calculated by averaging the d_i values (Equation 3). Design-Expert 7.0.0 was used to select the experimental design and for data analysis as well as graph construction.

Equation 2: The desirability function, d_i

$$d_i = \begin{Bmatrix} 0 \\ \left[\dfrac{Y_i - Y_{i_*}}{Y_{i^*} - Y_{i_*}}\right]^r \\ 1 \end{Bmatrix} \begin{matrix} Y_i \leq Y_{i_*} \\ Y_{i_*} \leq Y_i \leq Y_{i^*} \\ Y_i \geq Y_{i^*} \end{matrix}$$

Equation 3: Overall desirability, D

$$D = (d_1 \times d_2 \times \cdots \times d_k)^{1/k}$$

where Y_i = °Brix; Y_{i^*} = upper boundary; Y_{i_*} = lower boundary; r = weight.

Binder Preparation

The ingredients for the granola binder included two major components: sweetener (a mixture of honey, date paste and coconut sugar) and fatty materials (peanut butter and palm-based fat). Binder of 50 g was prepared according to the basic formulation shown in *Table 1* with varying sweetener concentration according to *Table 2*. Coconut sugar was dissolved in water at a ratio of 1.4:1 (coconut sugar:water) prior to binder preparation to facilitate mixing of the binder ingredients. All the binder ingredients were mixed and cooked on a low heat stove with continuous stirring to prevent burning. The binder was cooked for 30 min. °Brix was measured using a digital pocket refractometer (PAL-BX/RI, Atago, Japan) and the data was recorded.

Granola Bar Preparation

Granola bars were prepared by mixing the binder with dry ingredients (rolled oats, rice puffs and walnut). The proportion of binder to dry

TABLE 2. COMPONENT PROPORTION OF SWEETENER BLENDS IN THE BINDER FORMULATION

Run	Component ratio		
	Honey	Date paste	Coconut sugar
1	0.00	0.50	0.50
2	0.50	0.00	0.50
3	0.50	0.50	0.00
4	0.00	1.00	0.00
5	0.00	0.00	1.00
6	0.00	1.00	0.00
7	1.00	0.00	0.00
8	0.00	0.00	1.00
9	0.67	0.17	0.17
10	0.17	0.17	0.67
11	1.00	0.00	0.00
12	0.50	0.50	0.00
13	0.17	0.67	0.17
14	0.33	0.33	0.33

ingredients was 1:1 (w/w). The final sweetener blend made up 36.3% in weight of the granola bar. The dry ingredients were toasted at 180°C for 10 min. The binder ingredients were cooked until they reached 80-85 °Brix. The 0.6% (w/w) palm TRF with 572.00 ± 1.07 mg g^{-1} of vitamin E (analysed to contain 137.30 ± 0.40 mg g^{-1} α-tocopherol, 155.40 ± 0.61 mg g^{-1} α-tocotrienol, 12.10 ± 0.04 mg g^{-1} β-tocotrienol, 170.80 ± 0.33 mg g^{-1} γ-tocotrienol and 96.4 ± 0.40 mg g^{-1} δ-tocotrienol) was added to the binder and mixed well. The binder was then added to the dry ingredients and mixed until all the dry ingredients were evenly covered with the binder and aggregated, to form a homogenous mixture. The mixture was then poured into a 30 cm x 30 cm baking tray. Pressure was applied to the surface using a roller to flatten the surface. The mixture was baked at 180°C for 15 min. The baked mixture was cut into bars of dimension 6 cm x 2 cm x 3 cm (length x width x thickness), with a weight of about 25 g per bar. The granola bars were packed in a three-sided sealed aluminum package, sealed and stored.

Sensory Evaluation

The samples were evaluated for sensory acceptance using a nine-point hedonic scale with anchor points, 1 (dislike extremely) and 9 (like extremely). A nine-point intensity scale was used to indicate overall liking in addition to liking, and perceived intensity levels for particular attributes. The sensory evaluation used 30 untrained panellists. The evaluation was conducted in individual sensory booths with white lighting. The granola bars were served in square pieces; 2 cm lenght x 2 cm width x 3 cm thickness on a plate labelled with a three-digit code. A commercial granola bar sample obtained from the market was used as a reference during the evaluation. For the evaluation, the panellists were given an evaluation questionnaire, and provided with water for palate cleansing between samples. The mean score for each sensory attribute was obtained using descriptive statistics to summarise the sensory scoring for each sample in the sensory evaluation.

Proximate Analysis and Caloric Value

Proximate analysis of samples of the granola bar selected by the sensory evaluation was performed, which included ash (AOAC 940.26 and 923.03, 2000), crude protein (MS 1194:1991 and Food Regulation, 1985), fat (AOAC 989.05, 2000 and 920.39, 1997) and dietary fibre (AOAC 955.29). Triplicate samples were used for all the analyses. Carbohydrates were quantified by difference, taking into consideration the total dietary fibre. The caloric value was calculated on the basis of the composition of the granola bars, using the Atwater conversion factor of 4 kcal g^{-1} for carbohydrates (17 kJ), 4 kcal g^{-1} for proteins (17 kJ), 9 kcal g^{-1} for fats (37 kJ) and 2 kcal g^{-1} for dietary fibre (8.5 kJ), according to Food Regulation, 1985 (Ministry of Health, 1985).

Moisture

The moisture content of the grounded granola bar sample was determined using a moisture analyser (MX-50, A&D, Japan) with the temperature set at 105°C. The heating process stopped when a constant sample weight was obtained, and the moisture content was recorded.

Vitamin E Content

Vitamin E content (tocopherol and tocotrienol isomers) was analysed using an Agilent 1100 series high performance liquid chromotography (HPLC) system equipped with a quaternary pump (G1311A), fluorescence detector (G1321A), degasser (G1322A, serial number JP3021896), autosampler (G1313A), and *ChemStation* software. Chromatographic separations were performed using a Luna 5μ Silica 100A ODS (250 x 460 mm, 5 µm particle size) Hypersil column (Phenomenex, USA). The column was maintained at a pressure of 28 ± 1 bar and a temperature of 26°C. Samples were injected at a volume of 50 µl with a flow rate of 1 ml min^{-1} and a total run time of 30 min. The mobile phase was prepared using n-Hexane, 1,4-dioxine and 2-propanol (Merck, Darinstodt, Germany) at 97.5:2.0:0.5% (v/v/v), and degassed by sonication prior to use. Vitamin E isomers were detected using the fluorescence detector at an excitation wavelength of 295 nm and an emission wavelength of 325 nm.

An amount of 0.1 g finely ground sample was weighed, placed in a 15-ml centrifuge tube and spiked with 100 ppm internal standard 2,2,5,7,8-pentamethyl-6-chromanol (PMC) (Sigma

Aldrich, St Louis, USA). One ml of 0.9% sodium chloride (NaCl) was added, followed by 1 ml of ethanol. Next, 5 ml *n*-hexane was added, and the mixture was shaken for 1 hr at 1000-1500 amplitude, using a mini shaker (VIBRAX-VXR Basic, IKA, Germany). The mixture was centrifuged at 2500 rpm for 10 min at room temperature. The supernatant was collected and evaporated to dryness with nitrogen gas. The dried sample was reconstituted with 20 ml of the mobile phase prior to analysis.

Statistical Analyses

All analyses were conducted in triplicate. Analytical data were expressed as means with corresponding standard deviations. Sensory data were analysed using the General Linear Model (GLM) to determine any correlation between mean sensory score and formulation. Minitab 16 (Minitab Inc, State College, PA, USA) statistical software was used to conduct all the statistical analyses.

RESULTS AND DISCUSSION

Binder Formulation

The granola bar binder was formulated by blending three low glycemic natural sweeteners, namely honey, date paste and coconut sugar, to satisfy health aspects and to meet the needs of diabetic patients in the granola bar market. °Brix of the binder was measured as a baseline reference to ensure the consistency and quality of the binder. The sweetener proportions in the binder formulation were created by the augmented simplex lattice design for mixtures, and °Brix was measured for each of the formulations (*Table 3*).

TABLE 3. COMPONENT PROPORTIONS OF SWEETENER BLENDS IN BINDER FORMULATION AND CORRESPONDING °BRIX

Run	Component ratio			°Brix[a]
	Honey	Date paste	Coconut sugar	
1	0.00	0.50	0.50	66.30 ± 0.78
2	0.50	0.00	0.50	88.87 ± 0.06
3	0.50	0.50	0.00	68.97 ± 0.25
4	0.00	1.00	0.00	69.27 ± 0.06
5	0.00	0.00	1.00	82.20 ± 0.26
6	0.00	1.00	0.00	66.40 ± 0.10
7	1.00	0.00	0.00	84.30 ± 0.36
8	0.00	0.00	1.00	82.03 ± 0.15
9	0.67	0.17	0.17	81.00 ± 0.40
10	0.17	0.17	0.67	81.33 ± 0.15
11	1.00	0.00	0.00	85.00 ± 0.46
12	0.50	0.50	0.00	66.60 ± 0.89
13	0.17	0.67	0.17	68.50 ± 0.10
14	0.33	0.33	0.33	70.10 ± 0.26

Note: [a]Mean ± standard deviation (n = 3).

The results obtained were evaluated by ANOVA for model validation and significance of regression. A second-degree polynomial or quadratic model was used to fit the °Brix data collected from each blend of sweeteners for the binder formulation. A quadratic model was used to describe the results obtained, and the regression results are presented in *Table 4*. The calculated model F-value was 39.25, indicating the quadratic model in this mixture design was significant at $p<0.0001$. The lack of fit F-value of the model was 3.81, which implies that there was no significant lack of fit ($p>0.05$). In short, a quadratic model was suitable for this experimental design, while the insignificant lack of fit proved the fitness of the model. Besides that, the adjusted coefficient of determination (R^2_{adj}) and predicted coefficient of determination (R^2_{pred}) were 0.94 and 0.91, respectively. An R^2 value which comes closest to 1 is desired to provide a proper prediction by the equation generated from the model. The rule of thumb to follow is that the difference between the adjusted-R^2 and predicted-R^2 values should not be more than 0.2. Therefore, the quadratic model used for this study was suitable to be used for granola bar binder formulation.

An equation (Equation 4) and a contour plot (*Figure 1*) were generated using the quadratic model for the binder formulation. Equation 4 shows the effects of each sweetener on °Brix of the binder with binary interaction. Considering only a single sweetener, honey provided the highest °Brix, followed by coconut sugar and date paste, according to the descending order of the linear coefficient. The combination of date paste with honey, and date paste with coconut sugar had a binary antagonistic effect, which was verified by the negative binary coefficient value in both of the combinations. In other words, the addition of date paste into the binder would provide a lower average °Brix than expected from averaging °Brix of the respective single components. On the other hand, the combination of honey and coconut sugar had binary synergistic effects, whereby a higher average °Brix was obtained in the binary components than the averaged °Brix of the respective single components. In short, honey and coconut sugar produced a binder with high °Brix, while the addition of date paste resulted in a binder with lower °Brix.

Equation 4:

$$°Brix = 84.74X_1 + 68.0_3X2 + 82.42X_3 - 33.75X_1 + 23.57X_1X_3 - 32.69X_2X_3$$

where X_1 = honey; X_2 = date paste; X_3 = coconut sugar

°Brix is an important indicator for binder formulation, ensuring the quality and consistency

TABLE 4. ANOVA FOR THE REGRESSION RESULTS OF THE QUADRATIC MODEL FOR °BRIX OF THE BINDER FORMULATION

Variance parameter	Sum of squares	Degree of freedom	Mean squares	F-value	*p*-value[a]
Regression	867.35	5	173.47	39.25	<0.0001
Residual	35.36	8	4.42	-	-
Lack of fit	28.01	4	7.00	3.81	0.1117
Pure error	7.35	4	1.84	-	-

Note: [a]Significance probability level.
ANOVA - analysis of variance.

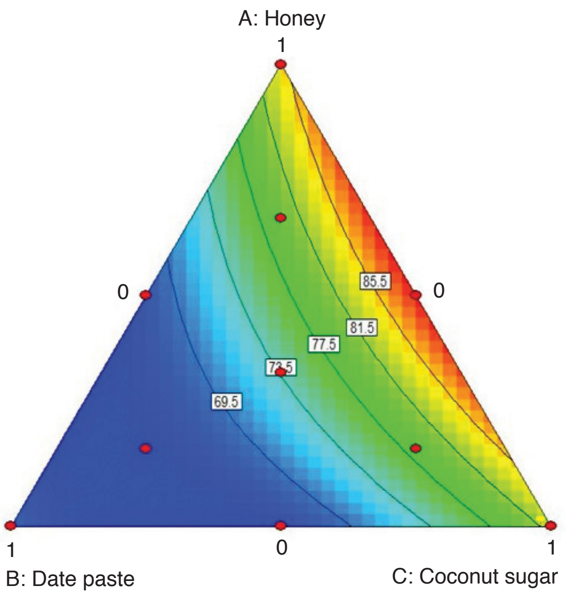

Figure 1. Contour plot for °Brix of binders with sweetener blends containing honey, date paste and coconut sugar.

of the binder. It measures the sucrose level or the soluble solids in the binder. The 1 °Brix represents 1 g of sucrose or soluble solids in 100 g of the solution, herein referring to the binder. The binder plays an important role in granola bar production, acting as glue to agglutinate all the ingredients and shape the mixture of ingredients into a bar form. The binder is also the major component contributing to the taste of the granola bar. A binder containing sweeteners and fatty materials provides the taste of sweetness and flavour to the granola bar, which directly affects consumer preference at the point of purchase. Therefore, the quality of a binder is maintained by monitoring °Brix. According to Bartkowska and Towell (2012), °Brix for a binder syrup should have a range between 70 and 90 °Brix, more preferably ranging from 75 to 85 °Brix, and most preferably from 78 to 83 °Brix. A binder syrup which is used for coating or binding purposes with too high °Brix, exceeding the range limit, is not desirable because the binder may become overly sticky and thus the product is not suitable to be hand-held by the consumer. Moreover, a sticky binder in a granola bar creates problems during the packaging process, because the binder may adhere to the packaging surface and distorts the shape of the granola bar. Conversely, low °Brix, beneath the lower limit, causes the binder to become brittle and dry, making it less flexible and cohesive when binding the dry ingredients. Granola bars formed by using a binder with low °Brix are unable to hold their shape due to the poor agglutination ability of the binder to stick all the ingredients together and keep the moulded shape intact. Therefore, in this study, optimisation of the binder formulation was done by setting the lower and upper limits from 80 to 85 °Brix, with a targeted value in the mid-point between the two limits, which was 82.5 °Brix. The optimisation range set was in line with the work conducted by Duffy and Matasovsky (2015); Bartkowska and Towell (2012) and Malecha *et al.* (2004), who used binders with 70 to 90 °Brix to form cereal products such as granola clusters or granola bars. The binder with °Brix falling within this range possessed a consistency that is appropriate for the formation of granola products. The potential binder formulation with 80 to 85 °Brix was 0% - 100% honey, 0% - 100% coconut sugar and 0% to 100% coconut sugar and 0% - 12.86% date paste (*Figure 2*). A desirability function analysis, with limits set as mentioned in the experimental design, was conducted by considering the valid predictors of °Brix using the quadratic model. The

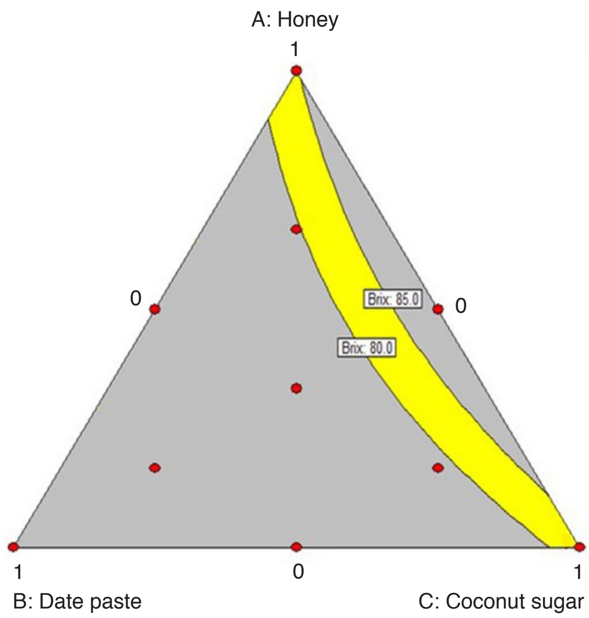

Figure 2. Overlay plot of sweetener blends containing honey, date paste and coconut sugar with 80 to 85 °Brix.

desirability analysis was evaluated based on the *D* value, which could range from 0 to 1, with the value coming closest to 1 being considered as more desirable. An optimal range of binder formulation was obtained with *D* = 1, as shown in *Table 5*. From the optimal range obtained, date paste constituted the least portion of the sweetener incorporated into the binder due to its antagonistic effect with the other sweeteners on °Brix. Thus, less date paste was used in the formulation to reach the preferred high °Brix.

Three binder formulations were selected for granola bar production and proceeded for sensory evaluation to investigate consumer acceptance. All the binders were fortified with 3.57 mg g^{-1} (0.6%, w/w) palm TRF. The granola bar formulations are shown in *Table 6*. The dry ingredients:binder ratio was fixed at 1:1. The amount of date paste in the selected binders was fixed at a maximum level with the intention of introducing its health benefits into the binder, such as high dietary fibre content to improve bowel movement, control cholesterol level (Alsaif *et al*., 2007) and reduce the risk of diabetes (Weickert and Pfeiffer, 2008). Honey and coconut sugar were incorporated into the binder to provide additional health benefits, such as antioxidant effect contributed by honey which is rich in phenolic compounds and flavonoids (Khalil and Sulaiman, 2010). At the same time, coconut sugar rich in inulin, a dietary soluble fibre, facilitates the mucosal build up in the intestine, reduces the absorption of glucose (Kim and Shin, 1996) and makes the granola bar diabetic patients friendly. The amount of honey and coconut sugar was varied (F1: low honey to coconut sugar ratio; F2: intermediate honey to coconut sugar ratio; F3: high honey to coconut sugar ratio).

TABLE 5. OPTIMAL RANGE OF THE BINDER FORMULATION WITH DESIRABILITY, *D* = 1

Ingredient	Percentage
Honey	31.18-38.43
Date paste	7.25 - 9.43
Coconut sugar	24.65 - 32.63
Peanut butter	25.00
Palm-based fat	2.50

TABLE 6. COMPOSITION OF GRANOLA BARS WITH SELECTED BINDER BLENDS FORTIFIED WITH 3.57 mg g^{-1} PALM-BASED VITAMIN E

Ingredient	Percentage		
	F1	F2	F3
Dry ingredients			
Rolled oat	31.00	31.00	31.00
Rice puff	12.00	12.00	12.00
Walnut	7.00	7.00	7.00
Wet ingredients			
Honey	9.79	15.22	22.11
Date paste	4.71	4.71	4.71
Coconut sugar	21.75	16.31	9.42
Peanut butter	12.50	12.50	12.50
Palm-based fat	1.25	1.25	1.25

Sensory Evaluation

The sensory scores for five sensory attributes given by the 30 panellists for the experimental granola bar formulations, evaluated together with a commercial bar purchased from a local pharmacy as a reference, are shown in *Figure 3*. There were no significant differences (p>0.05) between the formulations (F1, F2 and F3) and the commercial granola bar in appearance, aroma and taste. Regardless of the insignificant difference in the scores, the commercial bar constantly received the lowest score for all these attributes. The coconut sugar used as one of the binder components in the formulated F1, F2 and F3 granola bars provided a malty and caramelised flavour after baking which was appealing to the panellists. According to Waldrop and Ross (2014), consumers have a high acceptance of granola bars made with coconut sugar due to the unique flavours brought out by this ingredient. On the other hand, the F1, F2 and F3 granola bars received significantly (p<0.05) higher score on the acceptance for texture than the commercial granola bar, with the highest scores given to F2 and F3. Texture is one of the important sensory attributes assessed by the consumers and subsequently influences the intensity of liking towards the product (Kim *et al*., 2009). At the same time, the formulated bars outperformed the commercial bar in all the sensory attributes, with F2, had the best acceptance from the panellists, as reflected by its highest overall acceptance score. Incorporation of low glycemic sweeteners in the

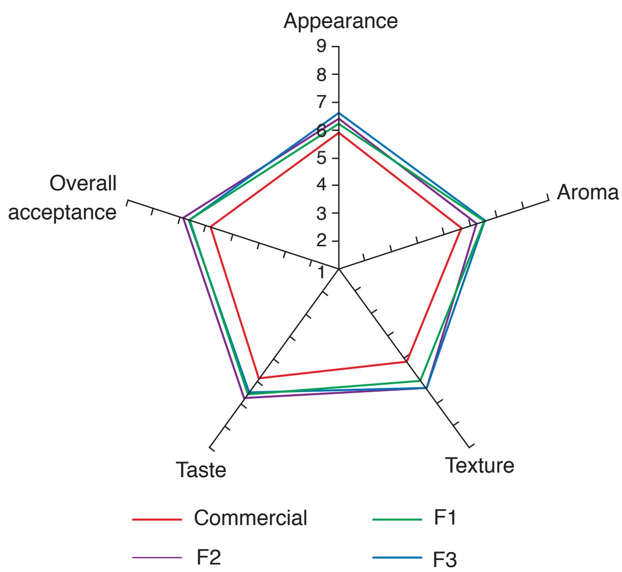

Figure 3. Sensory mean scores (n=30) of experimental granola bar formulations and a commercial granola bar.

granola bar binder not only improved the health aspects of the granola bar, but the mixture of natural low glycemic sweeteners also enhanced the sensory characteristics of the bar and outperformed the commercial bar used in this sensory study.

The correlation of mean sensory score with formulation was further evaluated using GLM and was expressed in F- and *p*-values, which both represent the significance level of a correlation, using $p<0.05$ to indicate a significant correlation between formulation and response (a sensory attribute's mean score). The correlation values are presented in *Table 7*. All of the sensory attributes were highly associated with the formulation, suggesting that any variations in the granola bar composition affected the sensory characteristics of the product and subsequently influenced the consumer's preferences.

Proximate Analysis and Caloric Value

The proximate composition and caloric value of the most preferred granola bar (F2) are shown in *Table 8*. Its formulation was comparable to the granola bar composition reported by Aigster *et al.* (2011), who developed granola bar supplemented with resistant starch, as well as to the commercial granola bar purchased from a local pharmacy. The slightly higher fat content of the F2 granola bar was probably due to the presence of walnut. Gharibzahedi *et al.* (2014) reported that walnut contains about 65% fat, mainly comprising polyunsaturated linoleic acid (C18:2) (50.67%) and monounsaturated oleic acid (C18:1) (24.27%). This unique fatty acid profile, with high polyunsaturated and monounsaturated fatty acids, seemed to be able to lower the cholesterol level and moderate the risk factors of cardiovascular diseases (Banel and Hu, 2009). Fat is one of the key components of a granola bar, acting as a source of energy needed for biological system as well as improving the palatability of the product (Nadeem *et al.*, 2012). The F2 granola bar has a fair amount of protein comparable to snack bars supplemented with whey protein concentrate and vetch protein isolate, a protein isolated from Indian vetch (*Lathyrus sativus* L.), which comprises 7.41% to 14.96% protein as reported by Nadeem *et al*. (2012). The protein content of the F2 granola bar is attributed to the presence of peanut butter and walnuts, which contains 24% (Settaluri *et al.*, 2012) and 15% (Gharibzahedi *et al.*, 2014) protein, respectively. Peanut is a vital protein source, having all the essential amino acids required in a daily diet to maintain a normal metabolic system (Settaluri *et al.*, 2012). The F2 granola bar is also a good source of dietary fibre. According to Food Regulation 1985, food containing more than 3 g fibre per 100 g solid matter can be claimed as a source of fibre. The high dietary fibre content of F2 is credited to the presence of date paste in the binder. Dates are a good source of fibre as they contain about 8% to 20% fibre on a dry weight basis; furthermore, about 91% to 94% of this fibre is dietary fibre (Borchani *et al.*, 2010). A diet with high dietary fibre is recommended to reduce the risk of some diet-related diseases, such as diabetes (by regulating insulin sensitivity in diabetics) and other metabolic syndromes (Weickert and Pfeiffer, 2008).

The caloric value of the F2 granola bar was comparable with that of the commercial granola bar, and is thus suitable to be used as an energy source for people who requires high energy intakes, such as athletes and sportspersons. Almost half

TABLE 7. CORRELATION OF MEAN SCORE OF SENSORY ATTRIBUTES WITH GRANOLA BAR FORMULATION

Sensory attribute	F-value	*p*-value
Appearance	3.32	0.02
Aroma	3.36	0.02
Texture	9.78	0.00
Taste	5.61	0.00
Overall preference	7.37	0.00

TABLE 8. PROXIMATE COMPOSITION AND CALORIC VALUE OF EXPERIMENTAL (F2) AND COMMERCIAL GRANOLA BARS

Constituent	g/100 g wt[a]		% Daily value (DV)[d]	
	F2	Commercial	F2	Commercial
Ash	1.20 ± 0.00	-	-	-
Moisture	5.57 ± 0.07	-	-	-
Fat	21.53 ± 0.15	12.50-19.00	8.28	4.82-7.31
Crude protein	9.10 ± 0.10	8.30-9.50	4.56	4.16-4.76
Total dietary fibre	4.77 ± 0.15	4.20-4.80	9.56	4.20-4.8
Carbohydrates[b]	57.83 ± 0.10	66.70-70.80	4.82	5.56-5.90
Total calories[c] (kcal)	471.07 ± 1.24	400-500	5.89	5.00-5.95

Note: [a]Mean ± standard deviation (n = 3). Data expressed as g/100 g wet weight basis (wt).
[b]Calculated by difference.
[c]Mean ± standard deviation (n = 3). Data expressed as kilocalories per 100 g wt (kcal/100 g wt).
[d]Percent daily value are based on a 2000 calorie diet, with recommended intake of fat less than 65 g; protein at 50 g; carbohydrate at 300 g and dietary fibre at 25 g.

of the caloric value comes from the low glycemic sweeteners used in the binder, and the rest is from the fat, protein and dietary fibre.

Besides considering the nutritional balance of the product, it should be noted that the F2 granola bar was fortified with palm TRF to provide additional health functions to the product. No vitamin E was detected in the granola bar prior to enrichment with palm TRF. The amount of palm TRF incorporated into the F2 granola bar was quantified as vitamin E content using HPLC method, and the vitamin E content is shown in *Figure 4*. A total of 3.23 ± 0.07 mg g^{-1} of vitamin E, with 23% α-tocopherol, 26% α-tocotrienol, 2% β-tocotrienols, 31% γ-tocotrienol and 17% δ-tocotrienols were detected. The unique vitamin E composition, with 77% tocotrienols and 23% tocopherols, is attributed to the presence of palm TRF in the bar and parallels the findings reported by Zou *et al.* (2012) and Choo *et al.* (2005). Vitamin E derived from palm oil contains a high amount of tocotrienols, which is exclusive, unlike most of the other natural sources of vitamin E which comprise solely or mainly tocopherols. Enrichment of the granola bar with 0.6% (w/w) liquid palm TRF or 3.57 mg g^{-1} vitamin E showed about 10% loss in vitamin E after the baking process, and this made up the final vitamin E content of 3.23 mg g^{-1}. According to the Institute of Medicine (IOM) and the Food Nutrition Board (FNB) (2000), the recommended dietary allowance (RDA) of vitamin E for both adult women and men aged above 14 years is 15 mg per day, with a tolerable upper level (UL) estimated at 1000 mg per day. The F2 granola bar at a serving size of 25 g contains approximately 80 mg of vitamin E per bar, which is about five times the RDA value, but 12.5 times lower than UL to avoid the risk of a hemorrhagic event (Schürks *et al.*, 2010). Incorporation of high fraction of tocotrienols in a diet is favourable due to their better performance in enhancing certain biological functions, such as an antioxidant (Wong and Radhakrishnan, 2012), hypocholesterolemic effects (Qureshi *et al.*, 2002), anti-cancer property (Shibata *et al.*, 2010), neuroprotection (Grimm *et al.*, 2016) and cardioprotection (Noguchi *et al.*, 2003), compared with tocopherols. Hence, the F2 granola bar incorporated with palm TRF has great potential in enriching nutritive value as well as providing potential health benefits offered by tocotrienols.

CONCLUSION

A low glycemic granola bar binder was successfully developed using a combination of three natural low glycemic sweeteners, namely honey, date paste and coconut sugar. Optimisation of the binder formulation was done using the augmented simplex lattice design for mixtures, with °Brix as the response. An equation generated using a quadratic model showed that honey and coconut sugar were responsible for °Brix of the binder, whereas date paste caused an opposing effect on °Brix. Only a limited amount of date paste was incorporated into the sweetener blend of the binder to retain °Brix of the binder at a certain level. Sensory evaluation showed that the granola bar prepared with a binder containing 15.2% honey, 4.7% date paste and 16.3% coconut sugar was most preferred by the panellists, which was reflected by its highest overall sensory mean score. GLM analysis confirmed that the panellists' liking intensity was solely dependent on the formulation. The granola bar prepared using the selected low glycemic binder formulation and fortified with palm TRF had a proximate composition and caloric content comparable to the commercial product used as a reference. Addition of palm TRF improved functionality to the granola bar and may enable it to outperform other products in the health and wellness market.

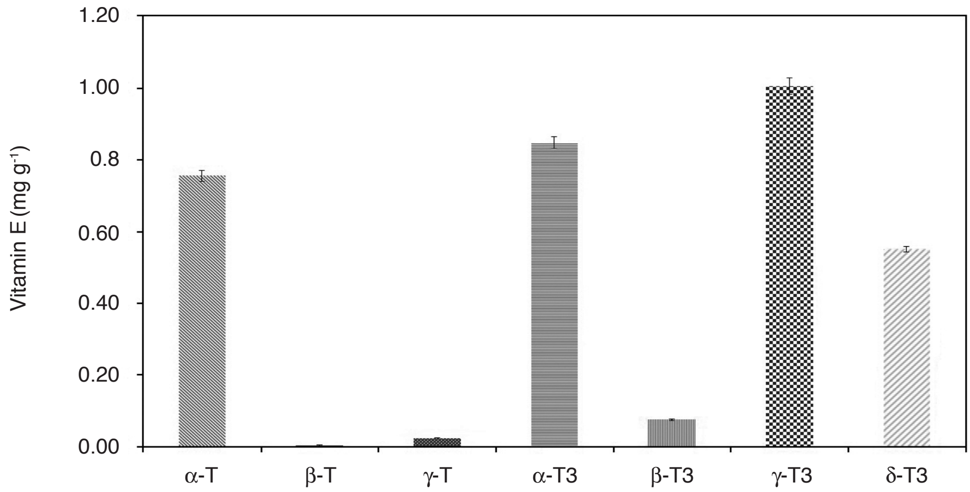

Figure 4. Vitamin E composition of F2 granola bar fortified with palm tocotrienols-rich fraction [mean ± standard deviation (n = 3)].
T - tocopherols; T3 - tocotrienols.

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