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Reformulation of Le'Natura® Biscuit: Effects on Textural, Sensorial, Nutritional and Glycemic Index Values

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ABSTRACT:

Introduction: The purpose of this study was to reformulate Le'Natura® biscuit for textural, sensorial, nutritional and glycemic index properties improvement. The original biscuit had a brittle and coarse texture with a bitter after-taste. It also contained high carbohydrate which made the biscuit unsuitable for diabetic patients and less desirable to the health-conscious consumers.

Methods and Results: Several ingredients from the original formulation were either eliminated, reduced or substituted in order to modify the texture and taste, to obtain a low glycemic index (GI) value and to increase acceptability. The ingredients involved in reformulation were wheat flour, milk powder, maltodextrin, atta flour, green bean flour, polydextrose, palm oil, and leavening agents. The final reformulated biscuit showed improvements in thickness, spread ratio, fracturability and firmness properties. The improved biscuit also scored higher acceptability for appearance, texture, sweetness, after-taste and overall acceptability attributes. The in vivo GI measured indicates that the improved biscuit was in the low GI range of 44.7±4.7 compared to the original biscuit (63.5±7.7, moderate GI). The nutrients composition of total energy, fat, protein, dietary fiber, iron, and calcium content were increased while total carbohydrate and sodium levels were decreased.

Conclusions: With the improvements, Le'Natura® biscuit is expected to capture the functional food market segment more competitively.

Keywords: functional food; biscuit; glycemic index; high fiber

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1. Introduction

Foods or their components which provide health benefits beyond basic nutrition and play a role in minimising the risk of certain diseases and other health conditions is known as functional foods [1]. This food contains bioactive components such as phytochemicals, polyphenolic compounds and antioxidants which contribute to its health benefits [2]. In most cases, developing a functional food requires substitution or removal of the main ingredients that pose the risk of diseases with other alternative ingredients. The challenge for the food industry is finding the substitute without compromising the product quality, in particular, the taste and texture.

High fiber Le'Natura® wholesome biscuit produced by Nourish Care Sdn. Bhd., is one of many functional food products currently available in the market targeted for health-conscious and diabetic consumers. The functional ingredients in the biscuit are noni fruit (*Morinda citrifolia* L.) extract, oat and stevia. The noni fruit extract boosts immunity, prevents the formation and proliferation of tumours, relieves arthritis, helps manage diabetes and relieves inflammation; β-glucan in oat helps lower blood cholesterol while the dietary fibre in oat prevents constipation [3,4]. The brittleness, coarse texture and detectable after-taste of Le'Natura® biscuit due to the presence of these functional ingredients did not go well with consumers. Carbohydrate-containing foods showed major influence on blood glucose levels

over a period of time. Replacement of sugar with stevia reduces the simple carbohydrates but creates an apparent after-taste which is disliked by consumers, while the incorporation of oat in high amount in the formulation made the texture unpalatable. The objective of this study was to change the formulation by reducing, adding or substituting certain ingredients to improve the textural, sensorial and nutrient qualities also lowering the GI value to meet the needs of diabetic consumers.

2. Materials & Methods

2.1. Formulation of the original Le'Natura® biscuit

A non-disclosure agreement was signed between the researchers and the company (Nourish Care Sdn Bhd) in order to protect the original formulation (trade secret) of the biscuit. Although the actual ingredients used were stated but the quantity of each ingredient was not disclosed. Table 1 shows the biscuit reformulation conducted in this study.

2.2. Preparation of biscuit

Firstly, palm oil, stevia and salt were thoroughly mixed in a bowl mixer (Chef Classic, Kenwood, UK) for 15 minutes. Milk powder, noni extract, vanilla, leavening agents and water were added and mixed for another 20 minutes.
The remaining ingredients were added and mixed at high speed until a homogenous dough was obtained. The dough was molded (round shape, 5 cm diameter) and baked at 180°C for 40 minutes using an electrical deck oven (Revent International, Sweden). After baking, the cookies were allowed to cool at room temperature for 3 hours prior to analyses.

2.3. Experimental workflow

The study was conducted in two stages; firstly, the improvement of textural and sensorial qualities. The best reformulated biscuit was then chosen to proceed to the second stage in which glycemic index and nutrient compositions were analyzed.

2.4. Physical and textural analysis

Diameter and thickness of the biscuits were measured using a digital Vernier caliper (Mitutoyo Corp., Japan). The spread ratio was calculated by dividing the diameter of biscuits with the thickness of biscuit [5].
Fracturability and firmness of the biscuits were analyzed using a texture analyzer (TA.XTplus, Stable Micro Systems, UK). Crisp fracture rig (HDP/CFS) with 0.55 diameter ball probe and 10 kg load cell was used. The test speed was 1.0 mm/s, with a travel distance of 10 mm. Fracturability (g) was obtained from the force of the first significant break and its hardness (g/cm^2) was the maximum force divided by area of the peak.

2.5. Sensory evaluation

Sensory evaluation was conducted by 32 untrained panelists consisting of staff and students of UiTM Shah Alam under laboratory conditions. Panelist preferences were assessed using a 7-point hedonic scale with scale 1 corresponding to "dislike extremely" and 7 "like extremely". Attributes of appearance, texture, sweetness, after taste and overall acceptability of the biscuits were assessed. Water at room temperature was used as a neutralizer between different samples.

2.6. Nutrient composition analysis

Total fat was analyzed using Soxhlet extraction method 963.15 [6], protein using Kjedhal method 991.20 [6], total dietary fiber using enzymatic-gravimetric method 985.25 [6] and total carbohydrate [7]. Mineral contents (Fe, Ca and Na) were measured using ICP-OES instrument based on method 975.03 [6]. Total energy was calculated by multiplication of 9 kcal/g for fat and 4 kcal/g for both protein and carbohydrate.

Table 1: Biscuit Reformulations

Abbreviation	Description	Purpose of reduction/substitution/addition
OF	Original formulation (wheat flour, vegetable oil, oat, wheat bran, sorbitol, polydextrose, atta flour, water, full cream milk powder, ammonium bicarbonate, salt, sodium bicarbonate, stevia, Noni fruit extract, vanilla, sodium acid pyrophosphate (SAPP).	
RF1	10% reduction of NH_4HCO_3 and SAPP each	To reduce after-taste, improve taste and reduce brittleness
RF2	15% reduction of palm oil	To reduce fat content and to reduce brittleness
RF3	15% reduction of polydextrose	To improve texture and lower GI value
RF4	15% substitution of wheat flour with maltodextrin	To improve texture and lower GI value
RF5	15% substitution of wheat flour with green bean flour	To improve taste, texture and lower GI value
RF6	15% substitution of wheat flour with atta flour	To improve taste, texture and lower GI value
RF7	15% reduction of milk powder	To improve taste, texture and lower GI value
RF8	15% addition of milk powder	To improve taste, texture and lower GI value

Note: OF: Original formulation; RF: Reformulation; GI: Glycemic index

2.7. In vivo glycemic index assessment

Eleven healthy adults comprising of males, 27.3% and females, 72.7% within the age group of 20-60 years old with normal glucose level and no medical history of diabetes mellitus in which their fasting blood glucose levels were less than 5.6 mmol/L [8] were used in this study. The subjects were 54.5% within normal body mass index (BMI) while 9.1% were categorized as underweight, 27.3% pre-obese and 9.1% obese grade 1.

All subjects involved were required to go through the study protocol on four separate occasions in a randomized order of one test of the final reformulated biscuit and three repeated tests of reference food (glucose powder dissolved in 500 ml water). After 10-12 hours of overnight fasting, the subject was given 25 g available carbohydrate portions of the test food or glucose drink (reference food). Fasting blood sample was taken prior to the consumption of test biscuit or reference food. Further blood glucose samples were taken at 15, 30, 45, 60, 90 and 120 minutes after the initial food intake. Blood samples were obtained by finger prick and assayed using the glucose oxidase method by an automatic glucose analyzer (Betacheck G5, National Diagnostic Products, Australia).

Calculations of blood glucose incremental area under the curve (iAUC) for reference food and test food were performed using Microsoft Excel with the principle of the total surface area of triangle and trapezoid, ignoring the area beneath the baseline for each test individually [9]. The area under the GI response curve for test food is expressed as the percent of the mean response to the reference food taken by the same subject, and the resulting values were then averaged to obtain the GI value for the biscuit. GI classification is referred to as low GI <55, moderate GI range from 55 to 69 and high GI ≥70 [10].

2.8. Statistical analysis

Statistical analysis was conducted using IBM Statistical Package for the Social Science (SPSS) program (Version 19.0). Significant differences ($p \leq 0.05$) between means were evaluated by one-way analysis of variance (ANOVA) and Tukey's comparison of the means.

3. Results and Discussion

3.1. Physical and textural quality

For snack foods such as biscuits, physical and textural measurements of the end-product are an important quality control parameter. Table 2 shows the results of thickness, diameter, spread ratio, fracturability and firmness of reformulated biscuits (RF) and the original formulated biscuit (OF). When compared to OF, RF1 showed an increase in diameter while RF8 showed a decrease in biscuit diameter. Other reformulated samples showed no significant diameter difference with OF. For thickness, no significant difference was observed between OF with RF2, RF3, RF4, RF6 and RF8 biscuits. There was no significant difference observed in the spread ratio between OF and reformulated biscuits except for RF1. An increase in diameter causes a decrease in the thickness of biscuit. This, in turn, increases the spread ratio value of the biscuit.

Physical and textural attributes of biscuits such as height, diameter, spread ratio, hardness and brittleness are also contributed by the use of leavening agent [11]. The changes in these qualities are observed in RF1 biscuit. The lesser number of leavening agents used contributed to an increase in diameter, spread ratio, fracturability and firmness while the thickness of biscuit decreased. Fat is one of the principal ingredients that influence overall food texture. Biscuits with low fat levels are higher in their breaking strength and hardness [12]. In this study, sample RF2 had 15% less vegetable oil thus increasing the biscuit fracturability and firmness compared to OF. Mamat *et al.* [13] showed that a reduction in fat content significantly increases the force to break the sample of commercial semi-sweet biscuits. However, ingredient information alone cannot explain the perceived hardness of some of the biscuits studied. Sudha *et al.* [14] observed that the force required for breaking biscuits containing 70% less fat was almost three times more than that required to break the control biscuit. This is due to sugar crystallization and the formation of a glassy solid after baking which influences the hardness of biscuits [15-17].

Table 2. Physical and Textural Properties of Biscuit.

Sample	Diameter (cm)	Thickness (cm)	Spread ratio	Fracturability (g)	Firmness (g/cm^2)
OF	5.3^{b}	1.4^{a}	3.8^{c}	490.8^{c}	2929.1^{c}
RF1	5.8^{a}	1.0^{c}	5.7^{a}	684.5^{a}	5516.9^{a}
RF2	5.2^{bc}	1.3^{ab}	4.0^{bc}	582.7^{b}	4093.2^{b}
RF3	5.3^{b}	1.4^{a}	3.8^{c}	578.8^{b}	3513.6^{bc}
RF4	5.4^{b}	1.4^{a}	3.8^{c}	574.7^{b}	3640.1^{bc}
RF5	5.2^{bc}	1.2^{bc}	3.8^{c}	569.7^{b}	4014.9^{b}
RF6	5.3^{b}	1.3^{ab}	4.1^{bc}	682.7^{a}	3553.6^{bc}
RF7	5.4^{b}	1.2^{b}	4.3^{bc}	574.8^{b}	2640.1^{c}
RF8	5.1^{c}	1.3^{ab}	3.9^{c}	578.8^{b}	5093.2^{ab}

Note: OF: Original formulation; RF: Reformulation; Mean values followed by different superscript letters in a column are significantly ($p<0.05$) different from each other.

Table 3. Sensory Acceptability of OR and RF Biscuit

Sample	Appearance	Texture	Sweetness	After taste	Overall acceptability
OR	5.50^{a}	4.17^{b}	5.92^{a}	3.51^{c}	4.95^{bc}
RF1	2.92^{c}	2.15^{c}	5.05^{b}	5.46^{a}	4.05^{c}
RF2	5.82^{a}	5.33^{a}	4.75^{b}	5.15^{ab}	5.17^{b}
RF3	5.83^{a}	4.85^{ab}	4.98^{b}	4.72^{b}	5.08^{b}
RF4	5.17^{ab}	4.50^{b}	5.22^{b}	5.41^{a}	5.33^{b}
RF5	5.96^{a}	5.92^{a}	6.04^{a}	5.50^{a}	5.87^{a}
RF6	4.97^{ab}	2.43^{c}	5.93^{a}	5.83^{a}	5.63^{a}
RF7	4.33^{b}	4.63^{b}	5.93^{a}	5.13^{a}	5.03^{ab}
RF8	4.63^{b}	4.90^{ab}	4.47^{b}	4.80^{b}	4.97^{ab}

Note: OF: Original formulation; RF: Reformulation; Mean values followed by different superscript letters in a column are significantly (p<0.05) different from each other.

Brittle and crunchy foods are known to have irregular and irreproducible force-deformation relationships caused by the non-uniformity of internal structure and surface characteristics of the product [18]. In this study, the reformulated Le'Natura® biscuit showed improvement in brittleness, dryness and its coarse texture compared to OF. The OF sample showed the lowest fracturability and firmness values, this confirmed the problem faced by the company. Brittle biscuits will easily break during handling, packaging and transportation activities. Increase in fracturability was observed for all reformulated biscuits compared to the original biscuit. There was no significant difference in the firmness of RF3, RF4, RF6 and RF7. This indicates that the reformulated samples were still as brittle as the original biscuit. Higher firmness was shown by RF1, RF2, RF5 and RF8 compared to OF.

3.2. Sensory acceptability

The sensory scores of the original and reformulated biscuits are presented in Table 3. The results showed no significant difference in appearance was obtained between the original biscuit with RF2, RF3, RF4, RF5 and RF6. However, RF1 showed the lowest acceptability for appearance due to its lack of expansion because of the reduction of leavening agents in the formulation. This reduction was done to eliminate after-taste that was contributed by the unpleasant ammonia flavor of the agents. Even though there was an improvement in taste, it did not produce the desired outcome for other sensory attributes.

For preference of sweetness, no significant difference was observed for RF5, RF6 and RF7 reformulated biscuits with the original. Improvement in texture is reflected in higher preference score compared to OF sample is shown by RF2 and RF5. All reformulated biscuits showed improvements in the after-taste attribute. Overall, RF5 and RF6 were well accepted by the panelists with RF5 obtaining the highest score of acceptance for all sensory attributes compared to the other reformulated biscuits. Therefore, RF5 with 15% wheat flour substitution with green bean flour was selected as the best reformulated sample.

3.3. Glycemic index and nutrient composition

Comparison of the GI values and nutrient compositions between OF and the selected reformulated (RF5) biscuit is shown in Table 4. The substitution of 15% wheat flour with green bean flour had greatly affected the GI value of the biscuit. The GI value of the original biscuit was successfully reduced to a low GI value. Although many factors could affect the GI value, the properties of carbohydrates present in food prominently influence the pattern of blood glucose levels. Based on the results obtained, RF5 contained 7.6% less total carbohydrate content than OF biscuit.

Higher total fat in RF5 directly increases the total energy value. RF5 also showed increased in protein by 17%, total dietary fiber increased by 5%, iron increased by 55.6% and calcium increased by 25.5%. Reduction in sodium content (27%) was another added value obtained for the selected reformulated biscuit.

Table 4. Glycemic Index and Nutrient Composition of Biscuits.

	OF	RF5
Glycemic index	63.5±7.7 (Moderate)	44.7±4.7 (Low)
Total energy (kcal/100g)	420	528
Total fat (g/100g)	25.0	29.0
Protein (g/100g)	7.9	9.25
Total dietary fiber (g/100g)	18.3	19.2
Total carbohydrate (g/100g)	62.2	57.5
Mineral content		
Fe (mg/100g)	1.8	2.8
Ca (mg/100g)	20.0	25.1
Na (mg/100g)	200	146

Note: OF: Original formulation; RF: Reformulation.

4. Conclusion

The reformulated biscuits had shown changes in their physical and textural properties also influenced the acceptability of the new biscuits. Using green bean flour to substitute wheat flour gave higher sensory scores with the improved textural quality compared to the original biscuit. The reduction in carbohydrate and sodium contents, low GI value with increased total energy and nutrients are new value-added features of Le'Natura® biscuits. The improvements will enable the company to have the competitive edge they need in the functional foods market for diabetic and health-conscious consumers.

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Conflict of interest

None.

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