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Original Article

Production and Nutritional Evaluation of Protein Enriched Cookies Incorporated with Winged Beans (*Psophocarpus tetragonolobus)*

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ABSTRACT

Processed wheat flour products have higher demand in the market while other pulse-based products have lower market demand. However, a greater nutritive value of bakery products can be obtained by mixing pulse flours with wheat flour and corn flour. The method involved four-component mixture design that generated four composite flours. Composite flours formulated with winged bean seed flour (25 to 40%), winged bean tuber flour (10 to 25%) and corn flour (20 to 40%) along with 100% wheat flour as control. Further, produced cookies were evaluated for physical parameters, proximate analysis, and energy value. The sensory evaluation for different treatments was carried out using 9-point hedonic scale testing for taste, texture, color, aroma, appearance, and overall acceptability. The results showed that there were significant differences (p<0.05) observed between different treatments for moisture, fiber, ash, protein-energy value, and sensory attributes. The physical parameters like thickness, volume, and density showed significant differences (p<0.05) among the treatments. The moisture content of cookies varies between 0.8 to 2.05% while fiber content ranged from 5.88 to 29.11%. The protein content of composite cookies was range between 10.48 to 23.36% and mineral content varied between 4.19 to 6.17%. The energy value of the cookies around 510.22 to 602.47 Kcal/100g. According to the nutritional values, T_2 selected as best treatment. The sensory analysis also exhibits that composite cookies were preferred over traditional cookies. The outcome of this research can be useful for the development of protein-enriched cookies with underutilized plant-based products.

Introduction

Nowadays foods are formulated not only to fulfil hunger but also to provide essential nutrients to improve the physical and behavioural well-being of individuals by preventing nutrition-related diseases. (Nöthlings et al., 2007; Takachi et al., 2008). Professionals are constantly investigating the capabilities of various food ingredients in order to produce functional foods (Ganorkar and Jain, 2014). The winged bean *(Psophocarpus tetragonolobus)* is enriched with the nutritional composition of proteins, vitamins, and minerals. The tubers of winged bean (WB) are starchy with a high percentage of proteins (17-20%) compared to other vegetables, the seeds are very nutritious with 32-37% of proteins on a weight basis. It contains 23-40% carbohydrates and vitamins such as B1, B2, B3, B6, B9, C, A, and E. The mature seeds include 14-25% fats, of which 94% are in a free form, while the rest are complexed with carbohydrates and proteins (Bassal et al., 2020).

The baking industry is one of every of the biggest food industries all over the globe. Ultimately, biscuits and cookies are popular baked products due to their simplicity, ready-to-eat nature, precise taste, easy availability at an inexpensive fee, and long shelf life (Ashraf et al., 2015). Increased urbanization is a major driver of changing people's eating preferences, and foods like cookies, bread, biscuits, and other baked goods are often substituted. The ability of bakery items to be fortified with grains, millets, or other functional

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ingredients is their primary benefit (Ganorkar and Jain, 2014). Bakery products are crafted from distinctive sorts of flours and people made the usage of composite flour have many fold advantages and they are seemed upon as providers of important nutrients (Ashraf et al., 2015).

Further, wheat is mainly used in bakery products. Wheat flour is the fundamental structural factor of maximum batter and dough products. The gluten is responsible for textural functions, which permit expansion of air cells and offer pressure after baking. On the other hand, wheat protein is deficient in some quintessential critical amino acids and it has decrease protein in evaluation with oilseeds and pulses (Peter et al, 2012). Also, Corn flour can be used as an inexpensive, nutritious, and tasty additive in baked goods. Leucine, the basic amino acid in corn, is important in the prevention of pellagra disease. Corn flour has a yellow color and gives baked goods a rich appearance when blended with wheat flour. For the enrichment and diversification of cookies, cornflour, soy flour, cotton-seed flour, legume flour, and protein isolates can be used (Bilgiçli et al., 2006). The protein and dietary fibre content of commercially available cookies are especially low. The WB contains a wealth of nutrients and nutraceuticals that have been shown to improve human health. Despite the fact that WB has a lot of potential as a functional ingredient, its use in food products is still limited. Therefore, the aim of this study was to produce protein-enriched cookies that were incorporated with wing beans.

Materials and Methods

Study area

The research was carried out at the Food Science and Technology Laboratory, Faculty of Technology, South Eastern University of Sri Lanka.

Collection of materials

WB (*Psophocarpus tetragonolobus* var. Krishna) seeds and tubers were collected from the home gardens of weboda, Sri Lanka. While, ingredients to prepare the composite cookies were purchased from the local markets of Weboda, Sri Lanka.

Preparation of winged bean seeds and tubers flour

The tubers and seeds of WB were washed using potable water and peeled. The tubers were cut into small pieces. Afterward, tubers and seeds were boiled and sundried (30±5 °C, RH, 67±5 %) until the pieces were completely dried (until seeds and tubers turn into light brown color). The dried seeds and tubers were ground using a grinder (Twister DLX 750, India) and passed through a series of sieves up to 250 µ to obtain flour of uniform size. The flour was then sealed in an airtight container and stored in an airtight container until further usage.

Experimental design

Five composite cookies were prepared by replacing part of the wheat flour, cornflour with WB seed flour, and tuber flour. The treatments were followed as;

T_0; 100% wheat flour (control)
T_1; 20% wheat flour, 40% WB seed flour, 20% WB tuber flour, and 20% cornflour
T_2; 40% wheat flour, 30% WB seed flour, 10% WB tuber flour, and 20% cornflour
T_3; 25% wheat flour, 25% WB seed flour, 25% WB tuber flour, and 25% cornflour
T_4;10% wheat flour, 30% WB seed flour, 20% WB tuber flour, and 40% cornflour.

Development of cookies

The cookies of all formulations were prepared based on the treatments. The WB seed and tuber flour, wheat flour, cornflour, powdered sugar, butter, baking powder, cardamom powder, cinnamon powder, vanilla, and salt were added together and mixed for 7-10 min. Afterward, the batter was divided into 5g small balls and moulded into a round shape (42mm diameter, 0.6mm thickness). The cookies were placed on a greased tray and put into a refrigerator for half an hour. The baking oven (TLPPL 131, India) was preheated at 170 °C and the cookies were baked at the set temperature for 15 min. Baked cookies were then cooled for 1-2 min and stored at room temperature in an air-tight container for further analysis.

Physical characteristics of formulated cookies

Cookie thickness and diameter were measured using a vernier calliper. The thickness was measured from three places of cookies and the diameters were obtained by measuring in different 90º angles. The arithmetic means were measured and results are reported in mm. The spread ratio was obtained following equation,

$$\text{Spread Ratio} = \frac{\text{Diameter}}{\text{Thickness}}$$

Volume was determined by using the rapeseed displacement method (Sudha et al., 2007). Weight was determined by digital weighing balance (AS 220.R2, Poland). Density was determined by using the following equation.

$$\text{Density (g/cm3)} = \frac{\text{mass } (g)}{\text{volume}(cm3)}$$

Proximate analysis

The moisture, ash, and protein content were analysed according to the AACC methods, (2000). Nitrogen content was estimated by the semi-micro Kjeldahl method and was converted to protein using factor 5.7. The dietary fibre content was determined using the described method of the A.O.A.C. (2005).

Energy value

In a crucible, 1g of dried sample was obtained, and cotton thread was attached to the fuse wire that was in contact with the dried sample. The sample-loaded crucible was placed inside the bomb, along with 15ml of distilled water. The bomb was then placed inside the bomb calorimeter (IKA C6000, India). Following that, a bomb calorimeter started the operation by selecting appropriate set orders. The results were obtained from the calorimeter as Kcal/100g values.

Sensory evaluation

The four composite cookies samples and the control were presented for evaluation and attributes assessed were flavour, texture, appearance, mouthfeel, aroma, and overall acceptability. The panellists were asked to score their preference and general acceptability based on a 9-point hedonic scale.

Statistical analysis

The results were submitted to analysis of variance (ANOVA) and means were compared by the test of Tukey's HSD at p = 0.05 using SPSS statistical package (SPSS 20.0, IBM, New York, NY, USA).

Results and Discussion

The formulated cookies had a diameter ranging from 4.15 to 4.23 cm. There was an increase in the diameter of cookies with a decrease in WB seed and tuber flour. The control treatment with 100% wheat flour had the highest mean cookie diameter. The highest level of mean had composite flours in T1 cookies. This could be due to the higher water holding capacity of WB flour (Kantha and Erdman, 1984). There was no significant difference (p>0.05) observed for diameter among the treatments. The means values of thicknesses ranged between 0.06 and 0.07 cm with significant deference within treatments (p<0.05). The T2 recorded higher means (0.07 cm) than the others while T0 obtained lower mean thickness (0.06 cm) (Table 1).

Table 1. Physical parameters of the cookies

Treatment	Diameter (cm)	Thickness (cm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Spread Ratio
T0	4.23± 0.01^a	0.06± 0.002^a	4.10± 0.04^a	3.17± 0.07^a	1.30± 0.03^a	72.72± 2.68^a
T1	4.19± 0.08^a	0.06± 0.003^{ab}	4.31± 0.15^a	3.38± 0.07^{ab}	1.28± 0.06^a	68.53± 4.87^a
T2	4.11± 0.06^a	0.07± 0.001^b	4.25± 0.18^a	3.68± 0.09^b	1.16± 0.06^a	59.28± 1.84^a
T3	4.16± 0.09^a	0.06±0.001^{ab}	4.53± 0.02^a	3.41± 0.17^{ab}	1.34± 0.07^a	66.76± 2.40^a
T4	4.15± 0.03^a	0.07± 0.001^{ab}	4.39± 0.25^a	3.68± 0.11^b	1.19± 0.06^a	61.19± 1.369^a

The values are means of replicates ± standard error. Within a column, means followed by the same superscripted letter are not significantly different by Tukey's HSD at p=0.05

The formulated cookies had a weight ranging from 4.10 to 4.53 g. The higher value was observed in T3 composite flours cookies. The control sample)T0(had the least weight)4.10 g(. The findings contradicted the findings of researchers who reported significant weight reductions in cookies made from soya bean supplemented with wheat flour, millet-sesame flour respectively)Ikuomola et al., 2017(.

The formulated cookies had a volume ranging from 3.17 to 3.68 cm^3)Table 2(. There was an increase in the volume of cookies in contrast to the control sample. The control treatment with 100% wheat flour had the lowest mean cookie volume. The highest level of mean had composite flours in T2 cookies. A similar finding for volume was reported by Egwujeh et al., (2018(for cookies produced from blends of wheat flour and cricket flours.

The formulated cookies had a density ranging from 1.16 to 1.34 g/cm^3)Table 2(. The T3 treatment had the highest mean cookie density)1.336 g/cm^3) while the lowest density was recorded from T2 cookies)1.16 g/cm^3). A similar finding was reported by Egwujeh et al., (2018(for cookies produced from blends of wheat flour and cricket flours.

The formulated cookies had a spread ratio ranging from 61.19 to 72.72 with a significant difference among the treatments)p<0.05( )Table 2(. The control treatment with 100% wheat flour had the highest mean cookie spread ratio)72.72(. The highest level of mean had observed in composite cookies of T1)68.534). The control treatment containing 100% wheat flour had the highest mean cookie spread ratio while the lowest was recorded from T2)59.28). A similar finding for spread ratio was reported by Jemziya and Mahendran, (2015) for cookies produced from blends of sweet potato and

wheat flour. The changes in spread ratio of cookies containing varying proportions of WB flour may be related to variances in swelling patterns and rheological characteristics. This might be owing to the greater fibre and protein content, as well as the WB flour's high water holding ability)Kantha and Erdman, 1984(.

Proximate analysis of the cookies and energy values

The moisture content)%(of the cookies ranged between 0.8 and 2.05. The reference sample)T0(had the least value (0.8%) while the T2 cookie had the highest value of 2.05%. However, increased substitution levels with WB flour and wheat flour caused a significant)p<0.05(increased in the moisture content values. Sahe, (2016(reported the same findings of the moisture contents for Cassava, Ackee Fruit, and Groundnut incorporated Cookies. The moisture content of the cookies was low enough (10%) to decrease the possibility of deterioration by microorganisms and, as a result, to provide high storage stability)Ayo et al., 2007(. On the contrary, Gernah et al. (2010) reported that cookies prepared using wheat-brewers spent grain flour blends have a greater moisture level (5.20-9.30 %). According to Adebowale et al. (2012), baked foods: Cake, cookies, and bread with high moisture content promote bacterial, yeast, and mold growth, which can lead to spoiling.

Table 2. Nutritional properties and energy values of protein-enriched cookies

Treatment	Moisture (%)	Ash (%)	Protein (%)	Fibre (%)	Calories (Kcal/100g)
T0	0.8± 0.21^{a}	5.01± 0.37^{ab}	10.48± 0.37^{a}	5.88± 0.22^{a}	510.22± 0.14^{a}
T1	1.58± 0.17^{ab}	6.17± 0.49^{b}	23.36± 0.22^{d}	29.11± 0.04^{e}	602.47± 0.10^{d}
T2	2.05± 0.29^{b}	4.37± 0.02^{a}	16.39± 0.58^{b}	23.70± 0.02^{c}	586.52± 0.61^{b}
T3	1.96± 0.33^{ab}	5.00± 0.01^{ab}	20.45± 0.07^{c}	21.32±0.20^{b}	585.40± 0.01^{b}
T4	0.90± 0.22^{ab}	4.19± 0.48^{a}	17.11± 0.06^{b}	25.28±0.24^{d}	594.26± 0.15^{c}

The values are means of replicates ± standard error. Within a column, means followed by the same superscripted letter are not significantly different by Tukey's HSD at p=0.05

Cookie ash contents varied between 4.19 to 6.17%. Samples T1 had higher ash contents (6.17%) than the remaining ones. Control T0 had 5.01% of ash content on a weight basis. The lowest ash content was that of T4, 4.185%. Ubbor and Akobundu, (2009) recorded 4.66% ash for 100% wheat flour cookies. Sahe (2016) reported similar findings of the ash contents in cassava, ackee fruit, and groundnut incorporated Cookies. Adegboyega et al. (2020) reported the ash content of the different varieties of WBs flours, In the processed seeds, the values of ash ranged from 4.45 to 4.93% for unprocessed flour but in processed flour, it ranges from 4.45 to 4.93%. In the tubers, it ranged between 1.1 to 3.31%. Therefore, by referring to these values, ash contents recorded in the study were within common ranges.

The protein content of the cookies ranged from 10.48 to 23.36%. The T1 cookie sample had the higher protein content (23.36%) while the reference sample (T0) had the lowest (10.48%). There was a significant difference (p<0.05) was observed for protein content among the treatments. The addition of WB flour caused an increment in the protein content of the cookies. The findings of Omeire and Ohambele, (2010) confirm that, the increasing amount of protein content (8.54–17.72%) observed in the produced cookies with increased proportion of defatted cashew nut flour blends. Olaoye et al. (2006) also observed an increase in protein content with a commensurate rise in the amount of soy flour supplementation in bread made from wheat, plantain, and soybean composite flour. The findings agreed with Adebowale et al., 2012 report who observed an increasing trend in the protein content (7.06-11.84%) of cookies made from sorghum-wheat flour blends. In general, the protein contents of the composite cookies were significantly greater than that of the control.

The presence of high fibre in food items is crucial due to its capacity to stimulate bowel movement (peristalsis), give bulk to meals, and prevent numerous gastrointestinal disorders in humans (Satinder et al., 2011). And fibre intake is necessary because of its health benefits such as preventing constipation and reducing the risks of chronic diseases, diabetes, obesity, etc (Marlett et al., 2002). The crude fibre content of cookies produced from WB flour blends ranged from 5.88 to 29.11 %. The T1 cookie sample had the highest value (29.11%) while the reference sample (T0) had the lowest value (5.88%). There was a significant difference was observed for fiber content among the treatments (p<0.05). WB has relatively higher crude fibre content than wheat and this justify the results obtained for the cookie samples. Gernah et al. (2010) discovered that the increasing trend in the crude fibre (1.32–10.82%) contents of cookies made from wheat-brewers spent grain flour composites.

The protein, and carbohydrate are the main constituents of the blend cookies contributed to the energy value of the cookies. Energy levels were

between 510.22 to 602.47 Kcal/100g. All the composite cookies had higher energy levels than the control (510.22 Kcal/100g) with significant differences(p<0.05) between them. Sample T1 had the highest energy level (602.47 Kcal /100g) among all the composite cookies. According to the Sriwichai et al. (2021), WB tuber recorded up to 16,264 J/g energy value. The WB seeds had an energy value of 5670 gcal/g in dry matter basis (Mnembuka, and Eggum, 1995).

Results of sensory evaluation

The mean scores for consumer preference in terms of flavour, texture, appearance, mouthfeel, aroma, and overall acceptability are presented below with significant differences (p<0.05) among the cookie samples.

Table 3. The sensory attributes of protein-enriched cookies

Treatment	Flavour	Texture	Appearance	Mouth Feel	Aroma	Overall Acceptability
T0	6.55^{ab}	6.40^{a}	6.55^{a}	6.45^{ab}	6.55^{ab}	6.55^{ab}
T1	6.00^{a}	6.05^{a}	6.65^{a}	6.50^{ab}	5.95^{a}	5.95^{a}
T2	7.45^{b}	7.10^{a}	6.95^{a}	7.25^{b}	7.25^{b}	7.25^{b}
T3	7.20^{ab}	6.30^{a}	6.50^{a}	6.95^{ab}	6.70^{ab}	6.70^{ab}
T4	6.60^{ab}	6.05^{a}	6.30^{a}	6.00^{a}	5.95^{a}	5.95^{ab}

The values are means of replicates (n=20). Within a column, means followed by the same superscripted letter are not significantly different by Tukey's HSD at p=0.05

Flavour is the main criterion that makes the product to be liked or disliked. The mean score for the flavour of the cookies revealed that the flavour of the cookies varied significantly (p<0.05) among different treatments. The mean scores for all samples ranged between 6.0 and 7.45. among the cookies, T2 scored a high mean. The texture is the measurement of properties related to how a food feels in the mouth (Jemziya and Mahendran, 2015). There was no significant difference (p>0.05) between the texture of cookies. The T2 showed that the highest score for texture (7.1) while T1 showed the least mean value for texture (6.05). The effect of gluten on cookies texture and other baked goods is well known (Lazaridou and Biliaderis, 2009).

Appearance is an important sensory attribute of any food because of its influence on acceptability (Ubbor and Akobundu, 2009). The cookies scored between 6.3 and 6.95 on the 9 point-hedonic scales and no significant difference was observed (p>0.05). Mouth feel is a desirable quality of cookies. it is the primary factor that determines the acceptability of any product, which has the highest impact as far as the market success of the product is concerned. The preference means scores of mouthfeels ranged between 6.0 and 7.25 with significant differences (p<0.05). The T2 recorded higher means (7.25) than the others while sample T5 obtained lower mean scores (6).

The mean scores for the aroma of all samples ranged between 5.95 and 7.25 with significant differences (p<0.05). Among all cookies, T2 scored high mean scores (7.25) and the lowest values of mean scores were recorded for T1 and T4 (5.95) (Table 3). This indicates that the smells of all the samples did attract the liking of the panellists with mean scores above 5. Indeed, the liking or preference in aroma attributes of cookies describes how much or less the smell was appreciated by the panellists. The overall acceptability means scores recorded by the samples ranged between 5.95 and 7.25 with significant differences (p<0.05). T1 and T4 having the lowest mean (5.95) while T2 had the highest value (7.25). Overall acceptability may look different from preference because of a given product (Sahe, 2016). According to Handoyo (2019), The addition of winged bean flour will increase the panellist's preference for cookies, but if too much winged bean flour is added, the panellist's preference for the resulting cookies will decrease. This is due to the winged bean having a strong unpleasant taste and aroma that can affect the level of preference panellists for cookies produced.

Conclusion

This study showed that the nutrition parameters and energy value of the composite cookies were higher than the values obtained from wheat flour cookies. Among the treatments, T_2 secured higher nutritional composition wich formulated with 40% WB seed flour, 20% WB tuber flour, and 20% cornflour. The sensory analysis also exhibits that WB seed and tuber flour incorporated cookies obtained preference over traditional cookies. Therefore, the current work efficiently combined local raw materials such as WB seed and tuber flour to develop cookies which constitute a fine and delicate commercial potential baked food.

Author Contribution

Gajanayaka performed lab analysis and data analysis. Fathima Jemziya supervised the experiment and review the manuscript. Ahamed Rifath wrote of manuscript.

Competing Interest

The authors have declared that no competing interests exist.

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