Optimisation and Characterisation of Gluten-Free Gram Cookies for Attention Deficit Hyperactivity Disorder children

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Abstract

Attention-deficit hyperactivity disorder (ADHD) is a disorder that involves a child's academic, social, and family functioning. The prevalence of the disorder is approximately 5.3% worldwide and occurs mainly in boys. Research has indicated that diet or nutritional intervention may decrease the rate of conduct and personality disorders. The present study was carried out with the aim of formulating and evaluating gluten-free Gram based cookies. The formulated cookies were analysed and compared based on nutritional, sensory, physical, and textural indices. On the basis of sensory evaluation, the overall acceptability of gluten-free Gram cookies was found to be 4.80±0.41, and that of control cookies was 4.13±0.76. The parameters considered for sensory evaluation were appearance, colour, flavour, taste and texture. Gram Cookies recorded the highest values in protein, moisture, ash, dietary fibre, energy and omega-3 fatty acids: 14.60g, 0.65%, 1.43%, 11.58g, 538.52Kcal, and 6.64g. A significant difference ($p < 0.05$) in calcium, iron, Phosphorus, Magnesium and Zinc and Vitamin B_6 and Vitamin C composition of Gram Cookies and control cookies was observed. Hence, it can be suggested that value-added cookies is beneficial for ADHD children for enhancing their cognitive functions and nutritional status.

Index Terms: Cookies, Gram, Analysis, Gluten-free, ADHD

I. . Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is among the most prominent behavioural disorders of children worldwide, occurring in 5.3% of children. ADHD manifests itself through excessive impulsivity, inattention, hyperactivity, and long-term emotional, mental, and academic difficulties. A high prevalence and incidence of

psychological disorders may be related to nutritional status, brain growth, and cognitive functioning. Children with ADHD must follow a healthy diet regimen. Evidence suggested that nutritional value, eating patterns, and other behaviour features can impact neuropsychiatric disorders, along with ADHD. Dietary combinations containing micronutrients such as vitamins, minerals and polyunsaturated fats are suggested as being supportive in treating ADHD (Lange, 2020) [1]

Among the bakery products, cookies are essential food products used as snacks by children (Pal et al., 2018) [2]. The low moisture content of cookies makes them immune from microbial spoilage and ensures to retain their quality for more extended periods, such as bread and cakes (Kurniadi *et al*.,2018) [3]. It is possible to manufacture and distribute large quantities of cookies due to the long shelf life. Fortification and other improvements to their nutritional quality make them an attractive food choice, provide some nutrients to people at risk for nutritional insufficiency, enhance the nutritional content value of food, and provide certain technological functionality in food processing. (Rani *et al*., 2020)[4]. In the present study, wheat was replaced by horse and black grams flour to prepare gluten-free Gram cookies.

Wheat contains gluten, such as in rye, wheat, and barley, which causes Gluten sensitivity (NIDDK, 2008). It is markedly more frequent among children presenting with ADHD. Interestingly, Celiac disease may show symptoms similar to those of ADHD in a significant percentage of children before collecting the start of a gluten-free diet. Therefore, despite the different views on this topic, some scientists advised screening for this disease in studying children with suspected ADHD. Celiac disease manifestations of other neurological and psychiatric include peripheral neuropathy, ataxia, seizures, migraine, depression, autism spectrum disorders, anxiety disorders and schizophrenia. It is a gluten-free diet for ADHD, as it reduces the child's abnormal behaviour. (Niederhofer *et al*., 2011) [5]. A child usually recovers faster than an adult does. In addition to reducing the risk of long-term complications caused by untreated ADHD symptoms, having a gluten-free diet decreases the chances of suffering from these complications. The study is a sequence of those steps and purposeful to prepare Gram-based cookies. According to the current study, horse gram and black gram flour is used to replace wheat flour. Horse and black grams are highly nutritious and rich in fibre, protein, unsaturated fats, squalene, zinc, phenolic compounds, flavonoids, vitamins, and minerals. It provides many health benefits outside of its nutritional value, which allows it to be classified as a "functional food."

Gram cookies substituting wheat cookies are not available commercially. Products (cookies, biscuits, bread) baked with Horse gram and black gram flour for fibre or other purposes, but within specific ranges combined with

various kinds of flour. Therefore, this study was conducted with the following objectives: To formulate gluten-free cookies for ADHD children and assess the horse and black grams as the major ingredients of the cookies by substituting wheat flour with gram flour. The purpose is to standardise the recipe for Gram cookies and evaluate the nutritional, sensory, and textural qualities of cookies.

II. Materials and methods

A. Raw material selection

Fresh Horse gram and black Gram were procured from the local grocery stores, cleaned, rinsed, and sundried and were milled into flour. Other ingredients namely butter, jaggery, salt and egg were purchased from local stores.

B. Baking Of Cookies

Control cookies

Biscuits are commonly made from wheat, the most common cereal used in their production. Gluten is considered crucial in making cookies, (Omeire *et al*.,2010) [6]. Generally, low gluten levels and weak gluten strength are desirable for a superior sugar-snap cookie. The preparation of control cookies involved sieving the wheat flour with baking powder, then blending the fat with powdered sugar, adding milk to prepare the dough soft and kneading the dough if necessary. The dough was made into balls and rolled it out. After cutting the cookies, greased the tray with butter and placed them in it. Preheated the oven for 10 minutes. The rolls were baked between 12 and 15 minutes at 200°C. Once baked, removed them and cooled on a cooling rack. As with the control cookies, the same measuring equipment, blender, and electric mixers were used to prepare the Gram cookies. The composition of the cookies prepared using the standard method (control cookies) is listed in **Table 1.**

Gram cookies

Gram cookies were made from sieved horse gram and black gram flour, rich in Zinc and Omega-3fatty acids.

The preparation of Gram cookies involved weighing the ingredients using a weighing balance. Butter, jaggery, egg, horse gram and black gram flour were mixed. After resting for 20 minutes, the dough was baked. The cookies were shaped into small portions of equal weight, arranged on a baking tray and baked at 180*C for 15 minutes after baking. The cookies were cooled to room temperature before being used. The proportion between control cookies and Gram-formulated cookies is given in **Table 1.**

Table 1 Proportion of Control cookies and formulated Gram cookies

CONTROL COOKIES		FORMULATED GRAM COOKIES	
Raw materials	**Quantity**	**Raw materials**	**Quantity**
Wheat flour	225 g	Horse gram &black gram flour	200 g
Baking powder	2.50 g	Egg	50 g
Sugar	130 g	Jaggery	75 g
Milk	60 ml	Butter	100g
Salt	2.16 g	Salt	as pinch

C. Sensory Evaluation of Cookies

A semi-trained panel of 30 members rated the cookies based on their sensory characteristics. A list of terms identifying sensory characteristics was provided to the panel members. Scoring procedures evaluated typical quality attributes selected by Chopra N *et al*. (2018) [7]. A score list with a 5-point hedonic scale was applied.

D. Determination of physical characteristics of the cookies

Weight

The weight of each cookie was determined using the method of (Ikuomola 2017) [8]. After the cookies had cooled, weighing balances were used to determine the weights.

Diameter

The diameter was determined by placing cookies side by side. Cookies were measured by measuring their diameters along the ruler. An angle of 90° was used for duplicate measurements. The diameter was repeated, and the average value is given in millimetres (AACC, 2000) [9]

Thickness

The thickness was determined by stacking cookies on top of one another. The height of the total object was measured in millimetres using a ruler. Measurements were repeated three times to obtain an average value. The results are given in millimetres. (AACC, 2000). [9]

Spread ratio

A spread ratio was determined by setting up pairs of equal-sized cookies and measuring their height. The diameters of each of them were measured after they were placed edge-to-edge. With the following formula, the spread ratio was calculated as diameter/height, SF=*10. Cf is a correction factor at constant atmospheric pressure, whereas D and T are diameter and thickness. It has a value of 1.0 in this case. (AACC, 2000)[9]

E. Texture analysis of cookies

A textural analysis was conducted on the cookies using a Texture Analyser (TA-XT2). Cookie hardness is measured by the maximum force that a cookie can withstand (gm, kg, N) before it breaks. In order to measure the hardness of cookies, a probe was used with an HDP/BSK blade set. In the application guide of the texture analyser, it was mentioned that the texture analyser was switched to ON', and then settings for hardness measurement of cookies were adjusted. A calibration was performed on the probe, and then the sample was placed on the texture analyser platform by (Li, 2020) [10].

F. Colour attributes of cookies

A Hunter Lab Colorimeter (D-25, Hunter Associated Laboratory, USA) was used to determine the colour of baked cookies. As described, Hunter lab colourimetry was evaluated using Hunter colour standards before reading cookies samples (kuchtova, 2017) [11].

G. Nutrient Analysis

Each cookie sample was analysed by standard methods (Association of Official Analytical Chemists) to determine its moisture, ash, protein, fat, and carbohydrate content within 100 grams. The samples were dried at 105°C until they reached a constant weight, at which point the moisture content was estimated with the gravimetric method. Using the bomb calorimeter method, energy was measured, and carbohydrate was measured by the anthrone method. To calculate crude protein from total nitrogen, the Kjeldahl method was applied. Calculating the nitrogen to crude protein ratio involves a conversion factor of 6.25%. To measure ash content, weighing the samples was done in a 550°C Muffle furnace until a constant weight was obtained. Socs

Plus was used to extract crude fat, and Fibra Plus was used for acid and alkali washing of crude fibre. Total dietary fibre as measured by Method 985.29 plus low molecular weight resistant maltodextrin (AOAC). Vitamin B_6 and C were assessed using a titrimetric method (AOAC) [12], and an atomic absorption spectrometer determined minerals (calcium, magnesium, phosphorus, iron, and zinc).

H. Statistical analysis

The statistical analysis was performed by Systat 14.5 software. Data are presented as Mean + Standard Deviation. Using One way ANOVA and 'F' values were calculated to determine whether the means of the two groups differed significantly. The Kruskal-Wallis test was used to analyse data with non-parametric distributions. Also, the frequency distributions of the two groups were compared by a T-test. The significance of p-values below 0.05 was regarded as statistically significant.

III. Results

A. Physical Analysis of cookies

Table 2: Physical Analysis of cookies

Variable	Cookies	Mean±SD	t-value	p-value
Weight	Control Cookies	13.09±0.54	-17.323	.000*
	Gram Cookies	10.760.10		
Diameter	Control Cookies	17.27±0.02	-16.956	.000*
	Gram Cookies	17.15±0.01		
Thickness	Control Cookies	9.45±0.35	14.659	.000*
	Gram Cookies	6.85±0.21		
Spread Ratio	Control Cookies	5.12±0.33	13.215	.001*
	Gram Cookies	6.09±0.09		

***= Significant at 1% level**

As shown in the above table, the significance value for the independent t-test is 0.000, 0.000, 0.000, and 0.001. The difference between Control Cookies and Gram Cookies was statistically significant ($p<0.05$). Duncan's multiple range tests determined that various weights, diameters, and thicknesses were significant. Hence, the result showed that the two cookies differed in weight, diameter, consistency, and spread ratio (Ho et al., 2016). [13].

B. Texture Analysis of cookies:

Table 3: Texture analysis of cookies

Variable	Cookies	Mean±SD	t-value	p-value
Hardness	Control Cookies	1.40±0.71	5.645	.004*
	Gram Cookies	1.67±0.22		

***= Significant at 1% level**

A cookie's texture plays an essential role in comparing the cookies, as it can influence customer satisfaction of the product (Omran *et al*., 2016) [14]. Gluten-free cookies should provide consumers with a pleasant taste. It is determined whether a cookie is of high quality through an objective and instrumental method. The hardness of the sample was measured with a texture analyser as the maximum peak force (gm/cm2) required to rupture it. Researchers found that control cookies were less complex or softer than Gram cookies. For control cookies, the hardness was 1.40±0.71, but for Gram Cookies, it was 1.67±0.22. Based on the independent t-test results, the hardness difference between Control Cookies and Gram Cookies is statistically significant ($p<0.05$). Thus, the result shows that two cookies varies in hardness. The development of a gluten network is the cause of cookie hardness, where gluten attracts water molecules to promote network development, as stated by (Kulthe et al.,2017) [15]. In the present study, the use of horse gram and black gram flour to prepare cookies could have contributed to the minor development of the gluten network.

C. Colour Attributes of cookies:

Table 4: Colour attributes of cookies

Variable	Cookies	Mean±SD	F-value	p-value
L*	Control Cookies	43.73±7.67	21.586	.000*

	Gram Cookies	28.50±4.14		
a*	Control Cookies	4.52±0.30	16.258	.001*
	Gram Cookies	7.43±1.09		
b*	Control Cookies	20.65±1.89	7.562	.006**
	Gram Cookies	41.21±0.11		

***= Significant at 1% level, **= Significant at 5% level,**

Table 4 shows the colour characteristics of cookies (Control cookies and Gram Cookies). The colour of each cookie was determined by measuring its lightness (L*), redness (a*), and yellowness (b*). The table above shows the output of the One-way ANOVA. There is a statistically significant difference ($p< 0.05$) in lightness (L*) and redness (a*) between Control Cookies and Gram Cookies, and there is a difference in yellowness (b*) at the 5% level ($p< 0.05$). Thus, the results indicate that the two cookies differ in their lightness (L*), redness (a*), and yellowness (b*). In baking at high temperatures, browning is caused by the Maillard reaction. It was found that the darker surface of cookies resulted from the incorporation of Horse Gram and Black Gram flour (Borrelli et al.,2013) [16].

. *D. Sensory Analysis of the cookies*

Table5: Sensory Analysis of the cookies

Variable	Cookies	Mean±SD	K-W Value	p-value
Appearance	Control Cookies	3.86±0.77	10.412	.016**
	Gram Cookies	4.60±0.50		
Colour	Control Cookies	4.25±0.44	20.978	.000*
	Gram Cookies	4.40±0.68		
Flavour	Control Cookies	3.93±0.82	8.945	.023**
	Gram Cookies	4.85±0.36		

Taste	Control Cookies	4.33±0.88	7.894	.020**
	Gram Cookies	4.75±0.44		
Texture	Control Cookies	3.46±0.77	20.512	.000*
	Gram Cookies	4.30±0.47		
Overall acceptance	Control Cookies	4.13±0.76	19.926	.001*
	Gram Cookies	4.80±0.41		

***- Significant at 1% level, **-Significant at 5% level**

A panel of judges evaluated sensory parameters such as appearance, taste, colour, texture, flavor, and overall acceptability. The developed Gram cookies were generally well expected, and scores across all parameters were more significant than the minimum acceptable level of the five-point hedonic scale. A Kruskal-Wallis H test indicated that there was a statistically significant difference in appearance, colour, flavour, taste, texture and total acceptability between the two Cookies, $\chi 2$ (2) = 10.412, 20.978, 8.945, 7.894, 20.512 and 19.926, p = 0.016, 0.000, 0.023, 0.020, 0.000 and 0.001. Thus, the result shows a difference between cookies in all these parameters. The results of (Pestoric et al., 2017) [17] also indicated that altered the acceptability of composite cookies by partially replacing wheat flour with black Gram and horse gram flour.

E. Nutrient Analysis of Cookies

The cookies were analysed for their nutritional content, and cookies made from refined wheat flour served as the control sample. Control cookies were made using standard recipes, and Gram cookies were standardised through trial and error. Table 6 shows the results of the nutrient analysis of cookies

Table 6: Nutrient analysis of cookies

Nutrients	Cookies	Mean	SD	t-value	p-value
Moisture	Control Cookies	4.81	0.19	36.976	.000*

(%)	Gram Cookies	0.65	0.06		
Ash	Control Cookies	0.96	0.04	-16.734	.000*
(%)	Gram Cookies	1.43	0.03		
Fat	Control Cookies	25.26	0.23	51.962	.000*
(g)	Gram Cookies	17.48	0.13		
Omega3Fatty	Control Cookies	2.55	0.43	-11.543	.000*
Acids(g)	Gram Cookies	6.64	0.44		
Protein	Control Cookies	6.67	0.40	-23.359	.001*
(g)	Gram Cookies	14.60	0.43		
Crude Fibre	Control Cookies	0.26	0.12	-22.312	.002*
(g)	Gram Cookies	5.30	0.35		
Dietary Fibre	Control Cookies	9.41	0.28	-7.316	.003*.
(g)	Gram Cookies	11.58	0.43		
Energy	Control Cookies	514.36	0.31	-79.164	.000*
(Kcal)	Gram Cookies	538.52	0.43		
Carbohydrate	Control Cookies	62.68	0.34	4.091	.015**
(g)	Gram Cookies	61.58	0.32		

***= Significant at 1% level, NS = Not Significant, **-Significant at 5% level**

The nutritional compositions of cookies are given in Table 6. As indicated by the moisture content, Gram cookies were significantly reduced ($p<0.05$) when Gram cookies were substituted for Control cookies above the 5% level. Bertagnolli et al. (2014) suggest that cookies containing low moisture are more shelf-stable when properly packaged and stored. (e.g. packaging that protects from moisture, gases, and light). Therefore, the use of

horse gram and black gram flour during baking cookies will lead to longer-lasting products since horse gram and black gram flour contain less moisture. [18]

Among cookies with an ash content of 5%, a significant difference was observed ($p < 0.05$) (Table 6). Ash value of 1.43±0.03 was observed in Gram cookies, while the ash content was 0.96±0.04 for Control Cookies. There was a high level of mineral content in the composite cookie samples based on the high ash content. It indicates that cookies made with horse gram and black gram flour mixes contain more minerals than those made with regular flour (Omeire,2010) [6].

The protein content of Gram cookies had the highest range, 14.60±0.43, while the control cookies had the lowest, 6.67±0.40. A significant difference in the protein amount of the cookies was at a 5% level ($p < 0.05$). According to the results, the protein content of cookies made with Horse Gram and Black Gram flours tended to be increasing, almost in line with the findings of (Adebowale et al.,2012) [19].

The difference in fat between Control Cookies and Gram Cookies was not significant ($p > 0.05$). The Gram Cookies had the lowest fat content, 17.48±0.13, while the Control cookies had the highest fat content, 25.26±0.23. The fat content gives the cookies a high kilocalorie value and serves as a lubricant to enhance the taste and texture of the product. It is also a rich source of calories. It serves as a transporter for lipid-soluble vitamins, such as A, D, E and K. In addition, fat content in foodstuffs should not exceed 25% because it can cause deterioration and the formation of unhealthy and toxic chemicals. (Ikuomola,2017) [8]. The presence of Omega3 fatty acids in the prepared cookies can be linked to Gram cookies concentrate, which had the maximum value of 6.64 and the lowest value of 2.55. These fatty acids can help promote genes involved in stimulating neuronal activity and enhancing cognitive functioning in humans. (Lange, 2020) [1]

The crude fibre and dietary fibre content of cookies produced from Gram Cookies had the highest values, 5.30±0.35 and 11.58±0.43, while the Control Cookies had the lowest values, 0.26±0.12 and 9.41±0.28. There was a statistically significant difference in Crude Fibre and Dietary Fibre between Control Cookies and Gram Cookies ($p < 0.05$). The results obtained for the cookie samples are justified because horse gram and black gram flour have a higher crude fibre and dietary fibre content than wheat flour. The high fibre content in food products is critical since it facilitates bowel movements (peristalsis), bulks up food, and prevents many gastrointestinal conditions in humans (Ajila et al., 2008)[20]

Carbohydrates present in Gram Cookies had the lowest carbohydrate content, 61.58±0.32, whereas Standard Cookies had the highest value, 62.68±0.34. It was not observed a significant difference between Control

Cookies and Gram Cookies (p >0.05). The low glycemic index of the composite cookies and their high fibre content makes them healthy. It promotes digestion and reduces constipation, often caused by foods made from whole pulse flours.(Kuchtova *et al.*, 2018) [11].

Gram Cookies had the highest energy value, 538.52±0.43, while the Control Cookies had the lowest, 514.36±0.31. Compared with the Control cookies, the composite cookies had no significantly different energy values (p >0.05). The blend's protein, fat, and carbohydrate constituents contributed to the cookies energy value. Cookies are an energy-giving food that is primarily eaten between meals by children and adults alike. The consumption of horse and black gram flour could contribute to higher levels of protein and fibre in cookies (Adeola,2018)[21].

F. Vitamin and Mineral Analysis:

Cookies can provide minerals and vitamins to ADHD children with their needs. Since 100 g of the Gram cookies provided from calcium (67.38mg), iron (6.44mg), phosphorus (280.51mg), magnesium (96.40mg) and zinc (16.08mg), respectively from daily requirement compared with the control cookies calcium (21.30mg), iron (2.17mg), phosphorus (178.62 mg), magnesium (31.24mg), and zinc (4.36mg). The calcium, magnesium, and zinc levels in Control Cookies and Gram Cookies were significantly different (p <0.05). Kapil and Bhavna have reported the association between micronutrients and brain function. Pollitt suggests that iron deficiency anaemia is associated with low educational achievement among children. Lack of minerals is related to low absorption of minerals during childhood development or the poor retention of minerals from eating habits. Many nutrition survey data illustrated that the children do not get their minerals and vitamins to improve brain health and educational performance. (Swaminathan,2013) [22]. Gram cookies contain vitamin B_6 and Vitamin C due to the presence of horse and black Gram, which includes 0.59 and 4.26, while the control cookies had the lowest values, 0.01 and 2.00. In terms of Vitamin B6 and Vitamin C, a significant difference (p< 0.05) was observed between Control Cookies and Gram Cookies. Vitamin B6 & C are essential for proper brain development and function (Jannusch,2017) [23].

Table 7: Vitamins and Mineral content of cookies

Constituents	Cookies	Mean	SD	t-value	Sig

Calcium (mg)	Control Cookies	21.30	0.35	-186.338	. 000*
	Gram Cookies	67.38	0.24		
Iron (mg)	Control Cookies	2.17	0.43	-13.618	.000*
	Gram Cookies	6.44	0.33		
Phosphorus (mg)	Control Cookies	178.62	0.38	-289.228	.000*
	Gram Cookies	280.51	0.48		
Magnesium (mg)	Control Cookies	31.24	0.23	-252.545	.000*
	Gram Cookies	96.40	0.39		
Zinc (mg)	Control Cookies	4.36	0.33	-42.862	.000*
	Gram Cookies	16.08	0.34		
Vitamin B6 (mg)	Control Cookies	0.10	0.17	-18.719	.001*
	Gram Cookies	2.06	0.06		
Vitamin C (mg)	Control Cookies	2.05	0.17	-57.658	.000*
	Gram Cookies	9.15	0.14		

***= Significant at 1% level, **-Significant at 5% level**

IV. Conclusion

This study was designed to assess the nutrient content of Gram Cookies which was formulated for ADHD children. The health status of ADHD children claims that the nutrient content is significantly higher in protein, fibre, and vitamin and mineral content. The nutrient content of these cookies is in accordance with the ICMR guidelines. The recommended dietary allowances per day will give one-third of nutrition to ADHD children. It will maintain the health status by promoting the supply of neurotransmitters. This study helps to assess ADHD children and their caregivers, which helps to understand the benefits of nutrition on their health. It was suggested that the prepared snack, in the form of baked cookies, could be safely served as a snack for ADHD children by providing

them with the required macro and micronutrients that reduce the symptoms and improve brain function and educational achievement.

ETHICAL APPROVAL

The research design and the protocols used in the study were approved by the Institutional Ethical Committee and Ethical Clearance with a certification AUW/IHEC/FSN-20-21/XPD-27.

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