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NUTRITIONAL, ANTIOXIDANT, SENSORIAL ATTRIBUTES OF MORINGA OLEIFERA LEAF POWDER SUPPLEMENTED WHEAT BREAD AND ITS SUBSEQUENT EFFECT ON THE GLYCEMIC REGULATION AMONG HEALTHY ADULTS: AN IN VIVO STUDY

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ABSTRACT

INTRODUCTION: Functional foods have gained attention for their potential health benefits and nutritional enhancement. *Moringa oleifera* also known as the "miracle tree," is particularly noted for its high nutrient density and health benefits. Incorporating *Moringa oleifera* leaf powder (MOLP) into staple foods like bread could offer a potential practical approach to enhance its nutritional value and health benefits.

OBJECTIVES: This study aimed to evaluate the impact of incorporating *Moringa oleifera* leaf powder (MOLP) into wheat-based bread on (i) sensory qualities, nutritional composition, and antioxidant potential as compared to regular wheat bread. (ii) To evaluate the MOLP based wheat bread on the glycemic responses among healthy adults.

METHODOLOGY: *Moringa oleifera* leaves were processed into powder and the powder was used to supplement wheat flour at a ratio of 150 g wheat flour to 15 g MOLP. Sensory evaluation was performed on 9- point Hedonic Scale through 15 trained panelists. Chemical analysis of both the MOLP-enriched bread and control bread was performed to determine macronutrient, minerals, and antioxidant potentials as per standard procedures. Glycemic responses were determined for the breads at 30, 60, 120, 180 & 240 minutes following standard protocols.

RESULTS: MOLP-enriched bread showed significant increases in protein, ash, crude fat, and crude fiber 10.76 ± 0.20, to 3.23 ± 0.25, 2.20 ± 0.15 and 3.00 ± 0.30 as compared to the control bread at p value $\leq$ 0.05. The enhanced bread also had higher levels of essential minerals, including calcium magnesium and iron, and zinc. Results showed that moringa fortified wheat bread have highest amount of calcium (207 ± 1.00) and magnesium (212 ± 5.95) while being a rich source of iron and zinc as well. Cadmium content was lower in the MOLP-enriched bread (0.036 ± 0.041) compared to the control (28.1 ± 0.23, p = 0.000). Sensory evaluation revealed that while the control bread was preferred overall, the MOLP-enriched bread was deemed acceptable due to its improved nutritional profile. Sensory evaluation showed that the control bread was preferred by 53.3% having the highest scores the MOLP-enriched bread was still acceptable by 10% for higher acceptability. However overall low scores might have been due to the higher MOLP ratios and either reduced ratio or addition of some natural flavors to the breads will help improve acceptability for taste and texture. Results of the glycemic responses indicated a persistent low blood glucose value specifically at 60 min is indicative of the utility of *Moringa oleifera* as hypoglycemic herb in the commercial bakery products. **CONCLUSION:** The study is concluded on the facts that addition of *Moringa oleifera* Leaf Powder is an effective way of improving the nutritional, antioxidant value of the staple wheat bread and can be a better way of regulating glycemic indices among healthy adults however, these hypoglycemic effects shall be evaluated through long term trials.

Key Words: *Moringa Oleifera* Leaf Powder (MOLP), Sensory Evaluation, Nutrient Composition, Antioxidant properties, Glycemic Regulation, Wheat Bread

1. INTRODUCTION

There has been there has been a growing interest in functional foods in the recent years (Abou- Zaid et al., 2014). Functional foods and natural health products consist of a wide range of food and ingredients, with a variety of bioactive components responsible for their potential utility in health promotion and disease prevention (KC et al., 2023). Among the array of natural sources one such food that has gained attention is *Moringa oleifera*, often called as the "miracle tree" due to its exceptional nutrient density and wide range of health benefits (Leone et al., 2015). Among the different parts of Moringa tree available, leaf powder specifically is considered to be the most versatile and convenient option for incorporating into daily diets (Saras et al., 2023). *Moringa oleifera* leaves have been reported to contain protein, essential amino acids, iron, copper, calcium, Vitamin C and carotenoids and these leaves have been used as a nutritional supplement (Pandey et al., 2011). Traditionally, the fresh leaves of Moringa are consumed as a snack and by incorporating into salads and vegetable soups (Stevens et al., 2013, Babeyuju et al., 2014). Other promising ways of using the leaves are through the food enrichment and fortification of commonly consumed foods like bread (Chinma et al., 2014). A study by Hasaballa et al., (2017) reported that *Moringa* leaf contained the highest amount of calcium and iron compared to other parts. In addition to its natural polyphenols; *Moringa* also contribute sensory qualities of natural foods made with it (Ajibola et al., 2015). Many previous studies have explored the potential use of *Moringa oleifera* leaf powder into various food products in order to enhance their nutritional values (Sohay et al., 2017).

Wheat-based bread is a staple food in many diets around the world and represents an ideal medium for such an enhancement (Mohsen et al., 2009). In order to increase the nutritional composition of wheat bread, *Moringa oleifera* leaf powder (MOLP) can be used as it is rich in proteins and several micronutrients that are inherently deficient in wheat and wheat- based products such as bread (Govender et al., 2020). Globally, bread is considered to be the most affordable source of energy ,in the form of dietary starch source (Sensey et al., 2013) and, therefore, would be a suitable candidate for supplementation with MOLP (Kokoh et al., 2022). *Moringa oleifera* is a multi-purpose plant in itself due to its unique nutritional and chemical characteristics. It has various health benefits such as stabilizing the blood pressure, possess hypoglycemic effect in case of diabetes, used in diarrhea and bronchitis. However, studies on the hypoglycemic effects of MO leaves in humans are very limited and inconclusive. The current study investigated the impacts of incorporating *Moringa oleifera* leaf powder (MOLP) into wheat-based bread by comparing with the regular wheat bread focusing on both sensorial, chemical analyses and its effects on the postprandial glycemic regulation in young healthy adults.

2. MATERIAL AND METHODS

2.1: Procurement of Moringa Oleifera leaves

Fresh *Moringa oleifera* leaves were collected from Medicinal/ Botanical Centre of University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan.

2.2: Preparation of Moringa Oleifera Leaves Powder (MOLP):

Moringa leaves were washed using distilled water and dried in shade for about 7 days. The dried leaves were grinded in a lab electric grinder and then the powder was weighed on measuring scale and stored in air tight jars.

2.3: Preparation of the Test Breads (MOLP)

The flour mixtures used to produce MOLP supplemented Wheat bread and 100% regular wheat were prepared as per standard recipes and methods. sample ratio was as follow:

Code	Ingredients	Proportions use in grams
MOLP BREAD (15% W/W)	Brown sugar powdered+ Instant yeast+ All-purpose wheat flour +MOLP + Vegetable oil	15+7+250+38+2.5+05
100% WB	Brown sugar powdered+ Instant yeast+ All-purpose wheat flour+ Vegetable oil	15+7+250+2.5+05

2.4: Sensory Evaluation of the Breads

A panel of 15 trained panelists performed the sensory assessment. The degree of liking (DOL) for taste, look texture, odor and general acceptability were the sensory qualities that were assessed. A 09-point hedonic scale (1 being the most intense dislike, 5 being neither a like nor a dislike, and 10 being the most intense like) was used by all panelists to assess the two samples (breads).

2.5: Proximate Composition of the MOLP supplemented & Regular wheat Breads

The analysis of nutritional composition of test breads was done by AOAC method (2012) in triplicates.

2.5.1: Determination of Moisture Content

Determination of moisture content was done by drying a sample in an oven and calculating the moisture content using the weight difference between the dry and the moist material.

Moisture Content% = 100 (B- A) – (C- A) / (B – A)

Where:

A = weight of clean, dry scale pan(g)

B = weight of scale pan + wet sample (g)

C = weight of scale pan + dry sample (g)

2.5.2: Determination of Ash Content

The weighed sample was kept at 1000 °C degree in a moisture extraction oven before being transported to a muffle furnace and heated to 5500 °C, till it become white and carbon free. The sample was taken out of the oven, brought to room temperature in desiccator and immediately weighed. The residual Percent ash was calculated as:

Percent Ash = weight of ash / weight of original sample x 100

2.5.3: Determination of Crude Protein Content

The sample was analyzed using Kjeldhal’s method, which determined the samples total nitrogen concentration once it has been digested in sulphuric acid using a catalyst made of mercury or selenium. The percent crude protein was calculated in two steps as:

$$\text{Nitrogen in sample \%} = \frac{100(\text{ A x B})}{\text{C}} 0.014$$

Crude Protein % = Nitrogen in sample x 6.25

Where:

A = hydrochloric acid used in titration (ml)

B = normality of standard acid
C = weight of sample (g)

2.5.4: Determination of Crude Fat Content

The fat content was extracted from the sample by Soxhlet method with petroleum ether and evaluated as a percentage of the weight before the solvent is evaporated.
The weight of the crude content by a formula:

$$\text{Crude lipid content \%} = \frac{100(B-A)}{C}$$

Where;
A = weight of clean dry flask (g)
B = weight of flask with fat (g)
C = weight of sample (g)

2.5.5: Determination of Crude Fiber Content

Crude fiber content of dry sample was determined by using AOAC, 2005 method. The sample was allowed to boil with diluted H_2SO_4, washed with water, further boiled with dilute sodium hydroxide and the remaining residue after digestion was taken as crude fiber. The percent crude fiber was calculated as:

$$\text{Crude lipid content \%} = \frac{100(A-B)}{C}$$

Where;
A = weight of the crucible with dry residue (g)
B = weight of crucible with ash (g)
C = weight of the sample (g)

2.5.6: Determination of Carbohydrate Content

The percent carbohydrate was calculated as weight by difference between 100 and the summation of other proximate parameters as Nitrogen free Extract (NFE). Carbohydrate content was calculated by subtraction according to the following equation: Carbohydrate % = (100 - Moisture% +ash% +fat% +crude protein% +crude fiber%) as per A.O.A.C (2012) was method.

2.6: Determination of Mineral Content

Mineral content including calcium, iron, zinc, magnesium and cadmium of Moringa oleifera and control breads were performed through Atomic Absorption Spectrophotometer (AA) through standard procedures of AOAC (2012).

2.7: Determination of Total Phenolic Content

The total phenolic content of the 100 % MOLP, 15% MOLP supplemented wheat bread, and 100% wheat bread was performed as per standard procedure of Siddhuraju and Becker (2003). Folin-Ciocalteu reagent was used for estimating the total phenolic content. About 20 µg of the powdered leaf sample was taken separately into a test tube and made up to 1 mL with distilled water. To this, diluted Folins-phenol reagent in a ratio of 1:1 with water and 20% of 2.5 mL of sodium carbonate Na_2CO_3 were added. The mixture was adequately mixed and shaken and was then incubated in the dark for 40 min to allow the development of colour. The absorbance of the mixture was measured at 725 nm. A calibration curve using gallic acid with linearity obtained within 10–50 µg/mL was used to obtain the total phenolic content. The total phenolic content of the samples was expressed as mg GAE/g extract (mg of gallic acid equivalent).

2.8: DPPH Radical Scavenging Activity

The antioxidant potential of the 100% MOLP and 15% supplemented MOLP wheat bread was determined through the modified method of Mensor et al. of the 2,2- diphenyl-2-picrylhydrazyl (DPPH) assay system was used for the DPPH radical scavenging activity. One milliliter of a 0.3 mM DPPH methanol solution was added to different concentration of 2.5 ml solution of the MOLP (50 µg/ml, 250 µg/ml, 500 µg/ml) and allowed to react at room temperature for 30 min in dark. The control was prepared in similar way but without the sample. Methanol was used for the baseline correction and the absorbance of resulting mixture was measured at 518 nm and calculated as percentage antioxidant activity (AA %), using the formula:

$$AA\% = [(Abs_{blank} - Abs_{sample}) \times 100]/Abs_{blank}, \ Abs = absorbance$$

2.9: Determination of Post Prandial Glycemic Responses

2.9.1: Sample

After the overall acceptability of the products, a group of 30 healthy young males and females were recruited based on written consent. Sample was selected on some pre-determined criteria. Participants meeting the following

Inclusion criteria:Age ranges between 18 to 22 years and BMI ranges from 18 – 25.8.

Exclusion Criteria: Participants were being excluded for any of the following reasons: History of diabetes, cardiovascular diseases, anemia, hormonal imbalances, gastrointestinal diseases or other chronic illnesses dislike of or allergic to selected food products.

2.9.2: Glycemic Response Test

On two different days and through computer generated random order, each subject was given two identical looking (±58 gms) bread along a plain water (±250 mL) differing only in the addition of 15 gm MOLP. Prior to the test day before each experiment, the subjects were asked not to consume any food after 9 p.m. The subjects were asked to consume their routine meal (with usual foods and usual quantities). After 9 p.m., only water was allowed. On the test day the participants arrived till 8:00 a.m. were seated in a comfortable room and the fasting blood was obtained by finger prick and the glucose concentration was measured by means of a glucometer GlucoMen LX 2 through strips with glucose-oxidase-based test strips (A. Menarini Diagnostics s.r.l, Firenze, Italy). Immediately after this, each subject received the test meal and was allowed to consume comfortably within 10 minutes. Postprandial blood glucose was tested at 30, 90, 120, 180, and 270 minutes through method as described above.

2.10: Statistical analysis:

Data was analyzed using Statistical Package for Social Science (SPSS) version 20 for statistical analysis such as mean, standard deviation and paired t test.

RESULTS AND DISCUSSION

3.1: Proximate Composition of Experimental and Wheat Bread:

Moringa Oleifera leaves powder and wheat flour were chemically analyzed, obtained results are summarized in Table 1. The results revealed that *Moringa oleifera* leaves could be considered as a good source of protein, ash, crude fat and crude fiber compared with these compounds in wheat flour, where they recorded 10.76 ± 0.20, 3.23 ± 0.25, 2.20 ± 0.15 and 3.00 ± 0.3 with p values 0.03, 0.002, 0.05 and 0.03 respectively. These p values show a significant difference between the two sample of p value ≤ 0.05. While the moisture and carbohydrate content of the regular bread were higher 35.96 ± 0.25, 53.0 ± 0.10 than the experimental bread. The results observed in the research are in agreement with the Riaz et al., 2021, Mushtaq et al., 2021, Grammel et al., 2016 and Riaz and Wahab 2021 whose studies reported similar increased levels pf protein, crude fiber, fats and ash in food products supplemented with moringa leaves emphasizing the fact that MOLP can make good bio-fortifiers.

Table 1: Proximate Composition of Experimental and Wheat Bread

Parameters	Mean ± Std		P value
	Moringa Bread	Wheat Bread	
Moisture	33.23±0.25	35.96±0.25	0.03
	Difference -2.73 Percentage -7.59		
Crude Ash	3.23±0.25	1.36±0.32	0.002
	Difference 1.87 Percentage 114.72		
Crude Fiber	3.00±0.3	1.6±0.40	0.03
	Difference 1.37 Percentage 84.04		
Crude Protein	10.76±0.20	8.80±0.75	0.03
	Difference 1.96 Percentage 22.27		
Crude Fat	2.20±0.15	1.46±0.15	0.05
	Difference0.74 Percentage 50.68		
Carbohydrates	49.56±0.46	53.0±0.10	0.004
	Difference-3.44 Percentage -6.49		

*Values are presented as Mean ± SD of triplicates
**P Values (paired T scores) across the same column are significantly different ($p < 0.05$)

3.2: Mineral Content of Experimental and Control Bread:

Results of some essential minerals including Calcium (Ca), Magnesium (Mg), Zinc (Zn), Iron (Fe) and Copper (Cu) are given in table 2. The Calcium and Magnesium of Moringa leaves powder recorded the highest values being 207 ± 1.00, 212 ± 5.95 with p values of 0.000 and 0.002 respectively. Experimental bread seen higher in iron 12.36 ± 0.35 with P value 0.000. Similarly zinc levels increased with an addition of Moringa oleifera supplementation 7.96 ± 0.95 with P value 0.008. Cadmium content found low in supplemented bread 0.036 ± 0.041 than regular bread with P value 0.000. The results are compatible with the findings of Riaz et al., 2022, Premi and Sharma (2018) indicating elevated elemental composition through supplementation of moringa leaves. They recorded increased levels of calcium and iron. While Gammal et al., 2016 recorded high level of Calcium and Magnesium of MOLP being 489.20 and 342 mg/100g. Calcium is essential for tooth development, additionally, it support the preservation of cell equilibrium, muscle contraction, blood clotting and the regular operations of heart, neurons and muscle (Elshehy et al., 2018). The addition of MOLP is expected for enhanced bone health.

Table 2: Mineral Composition of Experimental and Control Bread

Parameters	Mean ± Std		P value
	Moringa Bread	Wheat Bread	
Calcium	207±1.00	12.16±1.01	0.000
	Difference 194.84 Percentage 1602.3		
Iron	12.36±0.35	3.50±0.45	0.000
	Difference 8.86 Percentage 253.14		
Zinc	7.96±0.95	1.13±0.32	0.008
	Difference 6.83 Percentage 604.42		
Magnesium	212±5.95	24.86±0.80	0.002
	Difference 187.14 Percentage 162.28		
Cadmium	0.036±0.041	28.1±0.23	0.000
	Difference -27.96 Percentage -99.87		

*Values were presented as Mean ± SD
**P Values across the same column are significantly different ($p < 0.05$)

3.3: Total Phenolic Content % Antioxidant Potential

Results of the Total Phenolic Content and DPPH free radical scavenging potential of the 100% MOLP, 00% wheat bread, and MOLP supplemented wheat bread (Table 3) showed that the bioactive component i. e. Total Phenolic Content of the 100% MOLP and MOLP supplemented wheat bread (100.79± 3.34 and 58.20 ± 3.05 mg GAE/100g) were significantly higher than the 100% wheat bread (29.37 ±1.63 mg GAE/100g).

DPPH scavenging activities (49.23 ±2.17, 38.15 ±1.93, and 65.58 ±4.78 % inhibition) were also significantly higher and increased significantly in the concentration at the 500 µg/mL. Overall, the % inhibition were also significantly higher than the 100% wheat bread. The enhanced bioactive and antioxidant properties of the MOLP supplemented bread in the current study are in agreement with the findings of Kaur et al (2019, 2017) and Nakov et al (2020) and are suggestive of the positive effects of MOLP in the prevention of Non-Communicable Diseases (NCDs).

Table 3: Phenolic and antioxidant potential of the Moringa oleifera leaf powder, fortified bread and wheat bread

Bioactive potentials	100% MOLP	100 % Wheat Bread	MOLP fortified Bread
Total Phenolic Content (mg GAE/100g)	100.79 ± 3.34	29.39 ± 1.63	58.20 ± 3.05
DPPH Scavenging (% Inhibition)			
50 µg/mL	80.96± 3.19	19.56 ± 1.26 [a]	49.23 ±2.17 [ab]
250 µg/mL	86.98 ±2.89	21.48±2.04[a]	38.15 ±1.93
500 µg/mL	99.82 ±4.88	32.41±2.53[ab]	65.58±4.78
P value	0.03	0.008	0.002
Vitamin C Standard	80.3± 1.61 (50 µg/mL)	88.73 ± 1.89 [a] (250 µg/mL)	99.7 ±0.56 [ab] (500 µg/mL)

*Values were presented as Mean ± SD

**Values with different letter across the same row are significantly different ($p < 0.05$)

***P Values across the same column are significantly different ($p < 0.05$)

3.4: Sensorial Characteristics of the Breads

The sensory characteristics of the MOLP supplemented bread and 100% wheat bread are given in Table 4. According to the results 63.7 % slightly liked the appearance of moringa bread and 33.3 % moderately like. Majority of the people, 46.7 %, finds the texture of moringa bread mildly appealing, 37.5 % respondents neither like or dislike, while 13.3 % finds it moderately agreeable. The overall acceptability of the MOLP bread was 10.0% in the extremely liked category while 60.0 % of the respondents liked it under the slightly liked category. Majority of the panelists enjoy the flavor only marginally (62.2% like slightly) while 33.3 % find it tolerable. On the other hand, the control bread was found to be highly acceptable by 53.3 % like very much and 46.7% extremely loved it. Overall, the panelists found regular bread to be more acceptable, but value-added bread can be a good substitute due to its strong chemical composition profile. The findings of the current study agree with those of Boateng et al., 2018 and Riaz et al., 2021, who found that the control bread has higher palatability and acceptability attributes and Leon et al (2018) who reported similar lower sensorial acceptability of the MOLP supplemented meals.

Table 4: Sensory Evaluation of Processed and Control Bread:

Parameters	Moringa bread				Wheat Bread			
	Appearance	Texture	Taste	Over all acceptance	Appearance	Texture	Taste	Over all acceptance
Dislike	0	0	0	0	0	0	0	0
Dislike Very Much	0	0	0	0	0	0	0	0
Moderately Dislike		0	0	0	0	0	0	0
Dislike Slightly	0	0	0	0	0	0	0	0
Neither Like/Dislike	0	37.5	0	10.0	0	0	0	0
Like Slightly	63.7	46.7	62.5	60.0	0	0	0	0
Like Moderately	33.3	13.3	33.3	20.0	6.7	0	0	0
Like Very Much	2.5	3.5	4.2	10.0	53.3**	93.3**	40.0**	53.3**
Like Extremely					40.0	6.7	60.0	46.7

*Values were presented as Mean ± SD Of 15 panelists
**P Values across the same column are significantly different ($p < 0.05$)

3.5: Glycemic Responses of the Health adults to MOLP supplemented and wheat Breads

The glycemic responses of the healthy adults (Means ±SD of 15 participants each group and 02 replicates) and mean glycemic profiles of the two replicates of the 15 participants in both the groups to 100% wheat bread and MOLP supplemented wheat bread are given in Table 5 and Figure 1. In the figure glycemic responses are the means of duplicate while the error bars indicate the standard deviations. The kinetics and changes from the fasting blood glucose as the baseline showed non-significant difference in the experimental group and control group and among all the 30 participants and fell well within the recommended fasting blood sugar levels.

Postprandial blood glucose peaked almost at the same time (30 min) and the overall increase and decline throughout the test periods followed similar pattern, however, the glycemic responses of the subjects on both days in the experimental group (fed with MOLP supplemented bread0 showed an overall low blood glucose as compared to the control group (fed with 100% wheat bread).

This indicate that MOLP supplementation can help stabilize blood sugar among healthy adults and these differences were significant at 60, 120, and 240 minutes (P = 0.02, 0.01. and 0.002). These findings are indicative of the hypoglycemic effects of MOLP among healthy adults. The findings of the current study are in agreement with the findings of William et al (1993) and Ndong et al (2007). The results of Leone at al (2018), however, showed that supplementation of meals with MOLP had no significant effects on the glycemic responses among healthy adults though it exerted hypo effects among diabetics.

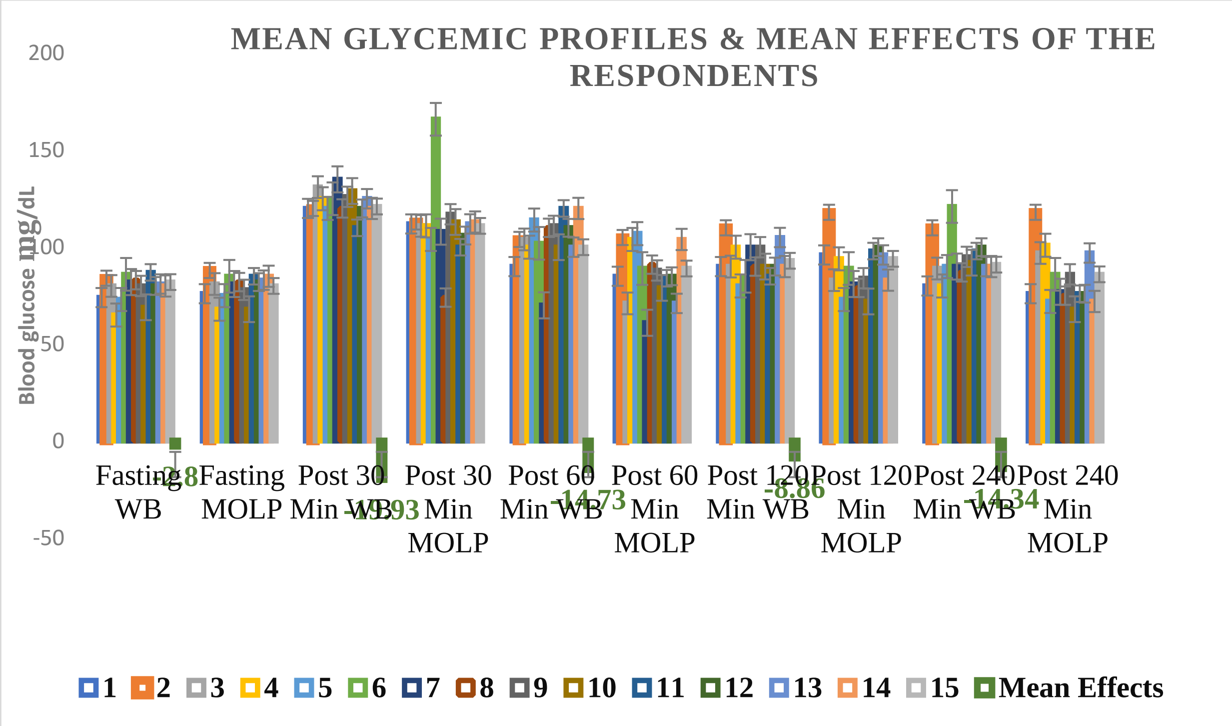
These hypoglycemic effects of the MOLP supplemented bread of the current study strongly exhibit the utility of MOLP as a hypoglycemic herbal drug and if promoted through supplementation of the staple and regular wheat bread can be of greater benefit towards the prevention of many non-Communicable diseases (NCDs). The overall acceptability though needs to be adjusted and lower doses may be considered with a persistent and regular intake.

Table 5: Glycemic Responses of the Participants to Moringa fortified and Control Breads

Parameters	Mean ± Std		Difference	Percentage	P value
	Moringa Bread	Control Bread			
Fasting	85.73±6.43	86.53±8.03	-2.8	0.01	0.19
Post 30 minutes	112.07±12.12	113.0±8.64	-9.93	- 17.6	0.6
Post 60 Minutes	86.87±12.44	100.60±6.12	-14.73	0.6	0.02
Post 120 minutes	91.67±12.06	98.53±9.14	-8.86	-8.99	0.01
Post 240 minutes	88.13±10.71	92.47±7.54	-8.34	14.94	0.002

*Values were presented as Mean ± SD (15 subjects in each group and two replicates)
**P Values across the same column are significantly different ($p < 0.05$)

Figure 1: Mean Glycemic Responses (Duplicates) of the Respondents to MOLP & Wheat Breads



CONCLUSION

The current study demonstrated that incorporating *Moringa oleifera* leaf powder (MOLP) into wheat-based bread is both feasible and beneficial. The results reveal that the addition of MOLP significantly enhanced the nutritional profile of the bread, notably increasing its protein, fiber, and mineral content, including calcium, magnesium, and iron. The bread enriched with MOLP showed a considerable increase in the total Phenolic content and antioxidant potential as compared to the control bread. It is noteworthy to report that MOLP supplemented wheat bread can significantly and positively effect glycemic responses among healthy adults. Overall, Moringa oleifera leaf powder is a valuable ingredient for fortifying bakery products due to its rich nutrient content and hypoglycemic properties. Future research should focus on evaluating the bioavailability of these nutrients to fully understand their impact on health for its practical applications in the prevention of NCDs in general public.

REFERENCES

1. Abou-Zaid AA, Nadir AS. Quality Evaluation of Nutritious Chocolate and Halawa Tahinia Produced with Moringa (Moringa oleifera) Leaves Powder. Middle East J Applied Sci. 2014; 4(4):1007-1015.
2. Ajibola, C. F.; Oyrinde, V. O.; Adeniyan, O. S. Physicochemical and Antioxidant Properties of Whole-wheat Biscuits Incorporated with Moringa Oleifera Leaves and Cocoa Powder. *J. Sci. Res. Rep*. 2015, 7, 195–206.
3. AOAC (2003) Official Methods of Analysis of the Association of Official's Analytical Chemists. 17th Edition, Association of Official Analytical Chemists (AOAC), Arlington, Virginia.
4. AOAC (2012) Official Method of Analysis: Association of Analytical Chemists. 19th Edition, Washington DC, 121-130.
5. Babayeju, A.; Gbadebo, C.; Obalowu, M.; Otunola, G.; Nmom, I.; Kayode, R.; Toye, A.; Ojo, F. Comparison of Organoleptic properties of egusi and efo riro soup blends produced with moringa and spinach leaves. *Food Sci. Qual. Manag.* **2014**, *28*, 15–18.

6. Boateng, L., Nortey, E., Ohemeng, A. N., Asante, M., & Steiner-Asiedu, M. (2019). Sensory attributes and acceptability of complementary foods fortified with Moringa oleifera leaf powder. *Nutrition & Food Science*, *49*(3), 393-406.
7. Chinma, C.; Abu, J.; Akoma, S. Effect of germinated tigernut and moringa flour blends on the quality of wheat-based bread. *J. Food Process. Preserv.* **2014**, *38*, 721–727.
8. El-Gammal, R. E., Ghoneim, G. A., & ElShehawy, S. M. (2016). Effect of moringa leaves powder (Moringa oleifera) on some chemical and physical properties of pan bread. *Journal of Food and Dairy Sciences*, *7*(7), 307-314.
9. Elshehy, H., Agamy, N., & Ismail, H. (2018). Effect of fortification of biscuits with flaxseed on omega 3 and calcium content of the products. *Journal of High Institute of Public Health*, *48*(2), 58-66.
10. Govender L, Siwela M. The Effect of *Moringa oleifera* Leaf Powder on the Physical Quality, Nutritional Composition and Consumer Acceptability of White and Brown Breads. *Foods*. 2020; 9(12):1910.
11. Hasaballa, M. A.; Elsohaimy, S. A.; Shaltout, O. E.; Zeitoun, M. A. M. Chemical Composition and Bioactive Compounds of Leaves, Flowers and Seeds of Moringa Plant. *J. Adv. Agri. Res*. 2017, 22, 662–674.
12. Kaur M, Singh V, Kaur R (2017) Effect of partial replacement of wheat flourwith varying levels of flaxseed flour on physicochemical, antioxidant andsensory characteristics of cookies. Bioact Carbohydr Diet Fibre 9:14–20 Kaur P, Sharma P, Kumar V, Panghal A, Gat KJ, Y, (2019) Effect of addition of Flax-seed flour on phytochemical, physicochemical, nutritional, and textural properties of cookies. J Saudi Soc Agric Sci 18:372–377 KC, Y., Bhattarai, S., Shiwakoti, L. D., Paudel, S., Subedi, M., Pant, B. R., ... & Upadhyaya, J. (2022). Sensorial and chemical analysis of biscuits prepared by incorporating Moringa flower powder and leaf powder. *International journal of food properties*, *25*(1), 894-906.
13. Kokoh, A. A. M., Konan, B. N., Gnoumou, J. I. K., Elleingand, E., & Koffi, E. (2022). Effect of incorporation of yam flour and moringa powder in wheat bread on glycemic response. *Food and Nutrition Sciences*, *13*(9), 781-796.
14. Leone A, Bertoli S, Di Lello S, Bassoli A, Ravasenghi S, Borgonovo G, Forlani F, Battezzati A (2018). Effect of *Moringa oleifera* Leaf Powder on Postprandial Blood Glucose Response: In Vivo Study on Saharawi People Living in Refugee Camps. Nutrients.12;10(10):1494.
15. Leone, A., Spada, A., Battezzati, A., Schiraldi, A., Aristil, J., & Bertoli, S. (2015). Cultivation, genetic, ethnopharmacology, phytochemistry and pharmacology of Moringa oleifera leaves: An overview. *International journal of molecular sciences*, *16*(6), 12791-12835.
16. Mensor, LL., Fa'bio, S M, Gilda G L., Alexandre, S R., dos S T C, Cintia, S C et al (2001) Screening of Brazilian plant extracts for antioxidant activity by the use of DPPH free radical method. Phyther Res 15:127–130
17. Mohsen, S. M., Fadel, H. H., Bekhit, M. A., Edris, A. E., & Ahmed, M. Y. (2009). Effect of substitution of soy protein isolate on aroma volatiles, chemical composition and sensory quality of wheat cookies. *International journal of food science & technology*, *44*(9), 1705-1712.
18. Mushtaq, B. S., Pasha, I., Omer, R., Hussain, M. B., Tufail, T., Shariati, M. A., ... & Kharitonov, D. V. (2018). Characterization of Moringa oleifera leaves and its utilization as value added ingredient in unleavened flat bread (chapatti). *Journal of Microbiology, Biotechnology and Food Sciences*, *8*(1), 751-755.
19. Nakov G et al (2020) Influence of Apple peel powder addition on the physico-chemical characteristics and nutritional quality of bread wheat cookies.Food Sci Technol Int 26:574–582 Ndong M., Uehara M., Katsumata S., Suzuki K (2007). Effects of oral administration of *Moringa oleifera* Lam on glucose tolerance in goto-kakizaki and wistar rats. *J. Clin. Biochem. Nutr* ;40:229–233.

20. Pandey A, Pradheep K, Gupta R, Nayar ER, Bhandari DC. 'Drumstick tree'(Moringa oleifera Lam.): a multipurpose potential species in India. *Genetic Resources and Crop Evolution*. 2011;58:453-60.
21. Premi, M., & Sharma, H. K. (2018). Effect of drumstick leaves powder on the rheological, micro-structural and physico-functional properties of sponge cake and batter. *Journal of Food Measurement and Characterization*, *12*, 11-21.
22. Riaz, A., & Wahab, S. (2021). Efficacy of Moringa Leaves Powder as a Supplement in Whole Wheat Flour Biscuit. *Sarhad Journal of Agriculture*, *37*.
23. Sahay, S., Yadav, U., & Srinivasamurthy, S. (2017). Potential of Moringa oleifera as a functional food ingredient: A review. *Magnesium (g/kg)*, *8*(9.06), 4-90.
24. Saras, T. (2023). *The Miraculous Moringa: exploring the wonders of the Moringa leaf*. Tiram Media.
25. Sengev, A. I., Abu, J. O., & Gernah, D. I. (2013). Effect of Moringa oleifera leaf powder supplementation on some quality characteristics of wheat bread. *Food and nutrition sciences*, *4*(3), 270.
26. Siddhuraju P., Becker., K (2003) Antioxidant properties of various solvent extracts of total phenolic constituents from three different agroclimatic origins of drumstick tree (Moringa oleifera Lam.) leaves. J Agric Food Chem. 51(8):2144–2155
27. Stevens, G.; Baiyeri, K.; Akinnnagbe, O. Ethno-medicinal and culinary uses of *Moringa oleifera* Lam. in Nigeria. *J. Med. Plants Res.* **2013**, *7*, 799–804.
28. William F., Lakshminarayanan S., Chegu H (1993). Effect of some indian vegetables on the glucose and insulin response in diabetic subjects. *Int. J. Food Sci. Nutr.* ; 44:191–195.