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Development of millet grain Khakhra fortified with Mornga powder

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Abstract
The present study aimed to develop a nutritious and functional khakhra by incorporating moringa powder into millet grain flour. Millets are rich in dietary fiber, minerals, and antioxidants, while leaves are an excellent source of protein, vitamins, calcium, iron, and bioactive compounds. Different formulations of khakhra were prepared by adding varying levels of moringa powder to millet flour and evaluated for their nutritional, sensory, and physical properties.
The fortified khakhra showed a significant improvement in protein, dietary fiber, iron, calcium, and antioxidant content compared to the control sample. Sensory evaluation indicated that the formulation containing an optimum level of moringa powder was highly acceptable in terms of color, taste, texture, aroma, and overall acceptability. The product also exhibited good shelf stability and maintained its quality during storage.
The study concludes that millet grain khakhra fortified with moringa powder is a healthy, value-added snack with enhanced nutritional benefits and good consumer acceptability. This product can contribute to improving dietary quality and promoting the utilization of millet and moringa in functional food development.

Keywords: Millet, Khakhra, Moringa powder Fortification, Functional food, Nutritional quality, Sensory evaluation

Introduction
Millets are among the oldest cultivated cereal grains and are widely recognized for their exceptional nutritional value and health-promoting properties. They are rich in dietary fiber, proteins, essential minerals, vitamins, and bioactive compounds, making them suitable ingredients for the development of functional foods. Due to their low glycemic index and gluten-free nature, millets are increasingly gaining popularity among health-conscious consumers and individuals with specific dietary requirements. ((Anitha *et al*., 2024; Kaur *et al*., 2019). Khakhra is a traditional Indian ready-to-eat snack prepared by roasting thin dough sheets until crisp. It is appreciated for its taste, convenience, long shelf life, and versatility. Conventionally prepared from wheat flour, khakhra can be nutritionally enhanced by incorporating millet grains, thereby increasing its fiber, mineral, and antioxidant content. (Dayakar Rao *et al*., 2021; Shinde & Kulkarni, 2026). Moringa (Moringa oleifera) is widely known as a "miracle tree" because of its remarkable nutritional profile. Moringa leaves are rich in proteins, calcium, iron, potassium, vitamins A, C, and E, as well as various antioxidants and phytochemicals. The incorporation of moringa leaf powder into food products has gained considerable attention as a natural and economical approach to improving nutritional quality and combating micronutrient deficiencies. (Gopalakrishnan *et al*., 2016). The present study, "Development of Millet Grain Khakhra Fortified with Moringa Powder," aims to formulate a nutritious and acceptable khakhra by combining the health benefits of millet grains and moringa powder. The fortified product is expected to provide enhanced nutritional value, improved functional properties, and good sensory acceptability while promoting the utilization of locally available and sustainable food resources. This study also seeks to contribute to the development of value-added millet-based products that can meet the growing consumer demand for healthy and functional snack foods.

Materilas and Methods

Procurement of Raw Materials

Millet grains (such as pearl millet, finger millet, or foxtail millet), moringa leaf powder, wheat flour (if used as a binding agent), edible oil, salt, and spices were procured from the local market. All raw materials were cleaned and stored under hygienic conditions until use.

Preparation of Millet Flour

The millet grains were cleaned to remove impurities and foreign materials. The cleaned grains were washed, dried, and ground into fine flour using a grinder. The flour was sieved to obtain a uniform particle size.

Preparation of Khakhra Formulations

Different formulations of khakhra were prepared by incorporating moringa powder at various levels into millet flour. For example:

Table 1: Formulation of millet flour and moringa powder

Treatment	Millet Flour (%)	Moringa Powder (%)
T_0 (Control)	100	0
T_1	97	3
T_2	95	5
T_3	93	7
T_4	90	10

Salt, spices, and a small quantity of edible oil were added to each formulation. Water was added gradually to prepare a soft dough.

Preparation of Khakhra

The dough was allowed to rest for 15–20 minutes. Small portions of dough were rolled into thin circular sheets and roasted on a hot griddle at moderate temperature while pressing gently until crisp and golden brown. The prepared khakhras were cooled to room temperature.

Packaging and Storage

The cooled khakhras were packed in airtight polyethylene pouches to prevent moisture absorption and stored at room temperature for further analysis.

Proximate Analysis: Proximate analysis provides an overall picture of the nutritional composition and quality of the developed khakhra. By comparing the control sample (T_0) with millet-containing treatments (T_1, T_2, T_3, T_4 etc.), researchers can determine how millet incorporation affects moisture, protein, fat, fiber, ash, carbohydrate and energy. (AOAC International. (2023).

1. Moisture Content: Moisture represents the amount of water present in the khakhra. A known quantity of khakhra is heated in a hot-air oven until a constant weight is obtained. The loss in weight represents the moisture content.

2. Protein Content: Protein is commonly estimated by the **Kjeldahl method**. The nitrogen present in the sample is determined and converted into protein using an appropriate conversion factor.

3. Fat content: Fat is extracted from a known quantity of dried sample using an appropriate solvent, commonly through a Soxlet extraction method. After extraction, the solvent is removed and the remaining fat is weighed.

4. Ash Content

Ash represents the total mineral residue remaining after complete combustion of the organic matter in the sample. A known amount of khakhra is placed in a pre-weighed crucible and incinerated in a muffle furnace at a suitable temperature until a constant weight of ash is obtained.

5. Crude Fiber: Crude fiber represents the relatively indigestible fibrous portion of the food.

Millets are generally recognized as useful sources of dietary fiber, so incorporation of millet can influence the fiber content of khakhra.The sample is subjected to controlled acid and alkali digestion, followed by filtration, washing, drying and weighing. The residue is then determined after ashing.

6. Carbohydrate Content

Carbohydrates are generally the major energy-providing component of cereal-based products such as khakhra.

In proximate analysis, carbohydrate is commonly determined by difference rather than directly.

7. Energy Value

Energy value indicates the amount of energy supplied by the food when consumed.

It is generally calculated using the Atwater factors:

Calculation

Carbohydrate (%)=100−[Moisture+Protein+Fat+Ash+Fiber]

Thus, any change in moisture, protein, fat, ash or fiber will affect the calculated carbohydrate value.

Table 2: Proximate composition, energy and hardness of millet grain khakhra

Sample code	Moisture	Protein	Fat	Ash	Fiber	Carbohydrate	Energy value 9Kcal/100g)	Hardness
T_0 (Control)	5.81	8.83	9.25	3.33	1.41	71.30	401.59g	11.82
T_1	6.14	9.07	9.38	3.43	1.65	70.23	401.52	16.91
T_2	6.25	9.47	9.79	3.82	1.83	68.84	401.32	19.09
T_3	6.44	9.91	10.09	4.03	2.05	67.47	400.38	20.99
T_4	6.67	10.33	10.44	4.42	2.30	65.84	398.66	22.13
SE	0.08	0.19	0.14	0.08	0.05	0.46	0.45	0.55
C.D (p>0.05)	0.26	0.61	0.45	0.26	0.19	1.47	1.45	1.76

Values are mean of three independent determinations WF: millet flour: Moringa leaves powder.

Sensory Evaluation: The developed millet grain khakhra samples were evaluated for their sensory acceptability by a semi-trained panel using the 9-point Hedonic Scale. The 9-point Hedonic Scale is a widely used method for measuring the degree of liking or disliking of food products.The khakhra samples were evaluated by a semi-trained panel using a 9-point Hedonic Scale (Peryam, D. R., & Pilgrim, F. J. (1957)

Table 3: Sensory Evaluation of millets grain khakhra fortified with moringa powder

Treatments	Color and appearance	flavour	Consistence	Mouth feel	Overall Acceptability
T1	8.02	8.15	8.35	8.01	8.12
T2	8.2	8.32	8.66	8.23	8.20
T3	8.1	8.23	8.28	8.12	8.14
T4	8.10	8.12	7.20	8.01	8.0

8. Statistical Analysis

The experimental data obtained from nutritional and sensory evaluation were analyzed statistically. Mean values and standard deviations were calculated, and the significance of differences among treatments was determined using appropriate statistical methods. This methodology helps in developing a nutrient-rich millet khakhra fortified with moringa powder and evaluating its nutritional quality and consumer acceptability.

3. Results and Discussion

Millet grain khakhra prepared from different mixtures of millet grain flour fortified with moringa powder is subjected to proximate composition, energy and hardness of millet grain khakhra recorded for different parameters are presented in Table 2.

Moisture: The moisture content increased gradually from 5.81% in T_0 (control) to 6.67% in T_4. The increase may be attributed to the moisture present in millet grain khakara and its ability to retain water. The differences among treatments were statistically significant at the 3% level, as the increase exceeded the CD value in most comparisons.

Protein: Protein content showed a continuous increase from 8.83% in T_0 to 10.33% in T_4. This improvement is mainly due to the higher protein content of millet grain khakara compared with the control formulation. Thus, incorporation of moringa powder enhanced the nutrional value of millet khakhra.

Fat: Fat content increased from 9.25% in T_0 to 10.44% in T_4. The gradual increase indicates that contributed to the overall fat content of the developed khakhra.

Ash: Ash content increased from 3.33% in T_0 to 4.42% in T_4. The higher ash content indicates an improvement in the mineral content of khakhra with increasing incorporation of Moringa leaf powder.

Crude fiber: A progressive increase in fiber content was observed from 1.41% in T_0 to 2.30% in T_4. This increase can be attributed to the naturally high dietary-fiber content of millet grain khakara.

Carbohydrate: Carbohydrate content decreased from 71.30% in T_0 to 65.84% in T_4. This reduction is associated with the replacement of a portion of the millet flour with Moringa leaf powder, which contains relatively higher protein, ash and fiber and consequently lowers the calculated carbohydrate proportion.

Energy value: The energy value decreased slightly from 401.59 kcal/100 g in T_0 to 398.66 kcal/100 g in T_4. The decrease corresponds with the reduction in carbohydrate content. However, the overall energy values remained relatively close among the treatments.

Hardness: Hardness increased markedly from 11.82 in T_0 to 22.13 in T_4. The increasing hardness. Thus, higher incorporation of moringa leaf powder produced a firmer khakhra.

Overall interpretation

Overall, incorporation of moringa leaf powder from T_1 to T_4 improved the nutritional profile of millet khakhra, particularly protein, ash and crude fiber, while carbohydrate and energy values showed increasing also resulted in greater hardness. Among the treatments, T_4 recorded the highest protein (10.33%), fat (10.44%), ash (4.42%) and fiber (2.30%), whereas T_0 had the highest carbohydrate (71.30%) and energy value (401.59 kcal/100 g).

Sensory Evaluation

Millet grain khakhra prepared from different mixtures of millet grain flour fortified with moringa powder is subjected to sensory evaluation and scores are recorded for different parameters are presented in Table 3.

Color and appearance: The mean color and appearance score for different treatments of millet grain khakhra are ranged from 8.02 to 8.12.

The treatment T1 (8.12) is found to be significantly superior over the rest of the treatments. It was observed that an increase in the level of moringa powder in khakhra decreases the score of color and appearance slightly [10-11].

Flavor: It is observed that the mean score for the flavor of millet grain khakhra for treatments T0, T1, T2 T3, and T4 are 8.15, 8.32, 8.23, and 8.12 respectively. The treatment T1 is superior over T0 and T2 treatments. It is observed from above findings that 97% of millet flour mixed with 3% of moringa powder will give rich flavor to khakhra.

Consistency: The mean score for the consistency attributes of millet grain khakhra ranges from 7.20 to 8.66. The treatment T1 (8.66) is significantly superior over the rest of the treatments.

Mouth feel: The highest mouth feel score is observed for treatment T1 (8.23) followed by T2 (8.12), T0 (8.01) and T3 (8.0). 3% of moringa powder mix with millet grain flour mix is most acceptable (T1).

Overall acceptability: The mean score for treatment T0, T1, T2 T3 and T4 are 8.12, 8.20, 8.14 and 8.0 respectively. The treatment T1 (8.12), T2 (8.20), and T0 (8.12) ranked among like very much to like extremely. The treatment T1 (8.12) is most accepted by the judges. So use of 3% of moringa powder mix with millet grain flour is more acceptable than the other treatment combinations [8-9].

Conclusion Addition of moringa powder into millet grain flour makes is more nutritious and also helps in improving the keeping quality of the end product. The optimum amount of moringa powder mix with millet grain flour that can be used in the process of preparation of khakhra is up to 3%.

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