



# Nutrition and quality evaluation of fortified millet chikki with enhanced cost effectiveness

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## Introduction

Food fortification in India traces back to the mid-20th century with iodization of salt to combat iodine deficiency disorders. Subsequently, fortification efforts expanded to other staples like wheat flour, edible oils, and milk, targeting widespread malnutrition. The value chain approach in food processing was used for analyzing the supply chain aspects of millets to strengthen the linkages, increase efficiency, competitiveness, and profitability. The Food Safety and Standards Authority of India (FSSAI) mandated fortification standards in 2016, promoting the addition of essential micronutrients to various foods (**Bishai and Nalubola 2022**). Fortification is a practice involves adding vitamins and minerals to commonly consumed foods during processing to increase their nutritional value. It is a proven, safe and cost-effective strategy for enhancing diets and for the prevention and control of micronutrient deficiencies (**Thakur et al., 2023**). Despite the availability of various food processing technologies that can convert millets into value-added products, their adoption in the food processing industry remains limited. This low market demand stems from challenges such as the scarcity of high-quality seeds, inadequate equipment, limited technical knowledge, and consumer misconceptions regarding the sensory qualities of millet. However, the versatile potential of millets is attracting research interest. Enhanced focus on millet cultivation and processing could significantly boost market demand and unlock numerous opportunities for large-scale production of millet-based products (**Mahajan et al., 2024**). Emphasizing millet's nutritional benefits and overcoming the technical and perceptual barriers could pave the way for greater consumer acceptance and industry adoption, ultimately contributing to healthier dietary practices and sustainable agricultural development.

The aim of this study rules out the nutrition and quality evaluation of prepared fortified millet chikki with enhanced cost effectiveness in market.

## Literature Review

(Venkateswarlu *et al.*, 2023) discussed about the micronutrient deficiency that is being manifested as ‘hidden hunger’ in many developing countries to which millets seem to be a probable solution. Millets like sorghum, pearl millet and finger millet are consumed as whole grains and are rich source of vitamins, minerals, and dietary fibre. Therefore, regular consumption of millets helps in diversification of diets and imparts many health benefits along with battling hidden hunger.

Using pearl millet, Balasubramanian *et al.* (2012) reported on the manufacturing of inexpensive snacks. A lot of researcher have tried to prepare composite millet flours by substituting generally used cereal flours to manufacture various food products like ready-to-use foods, pasta preparation etc. This approach is very convenient technique to get nutritionally improved with increased functionality

(Samtiya *et al.*, 2023) found that, the millets exhibit superior nutrition, boasting higher levels of calcium, dietary fibre, and protein. Moreover, they are gluten-free, making them highly beneficial for individuals with celiac disease or gluten intolerance. Traditional processing methods further enhance the nutritional properties of millets, rendering them suitable for large-scale utilization and the creation of diverse value-added food products.

Avoiding gluten and sticking to a diet may seem easy but the major food items are made from wheat like Pasta, cakes, cookies, morning cereals, etc. Avoiding these things would necessitate a radical shift in lifestyle, which not everyone could accomplish. Thus, demand for gluten-free food items is increasing today (Goyal *et al.*, 2015).

The market demand for gluten free foods is increasing due to frequent incidences of celiac disease and increasing awareness on consumption of gluten free foods. Since millet are gluten-free and also excellent sources of micro and macro nutrients such as vitamins, minerals, dietary fibers and phenolic compounds. Taking this topic, (Selladurai *et al.*, 2023) highlighted the product development using two millet varieties that are gluten free and outline their nutritional benefits.

## Materials and Methods

Nutrition and quality evaluation of fortified millet chikki involves several steps. Such as follows :

### 1. Selection of Millets and other Ingredients

Sorghum (*Sorghum bicolor*), Pearl millet (*Pennisetum glaucum*) and Finger millet (*Eleusine coracana*) were selected for formulation of chikki as in **Table 1**. Before processing the raw materials, it was ensured that the grains are clean, free from pests, and of high quality. These millet were used as flour by grinding them into powder like material. All the three millet flour was mixed in a clean container before further process. Other raw materials like groundnut, jaggery, liquid glucose and Premix of vitamins and minerals were also used for the product development as in **Table 2**. The use of jaggery was of high-quality, ensuring it is free from impurities. There are many health benefits of jaggery hence, giving it a touch of healthy snacking for all age groups.

Depending on the recipe, the ingredients were put for mixing one by one along with the millet flour. The roasted millets were converted into coarse flour using a traditional or modern mill.

## 2. Preparation of value added millet chikki

All the ingredients being of different sizes, jaggery syrup was used to bind it into a bar or chikki form. Jaggery with a small amount of water in a thick-bottomed pan was continuously stirred until the jaggery dissolves and reaches a hard-ball stage. Then, gradually the millet-nut mixture along with vitamins and minerals premix was added into the jaggery syrup, stirring continuously to ensure even coating.

At an ambient room temperature, the chikki was allowed to set and settle down in form of a bar which was further cut into specific sized bars. The cooled chikki was then sent for further evaluation by storing in an airtight containers to maintain freshness.

## 3. Fortification of the millet chikki

The millet chikki developed hereby underwent Nutrient Fortification to enhance the nutritional value, using premix of vitamins and minerals.

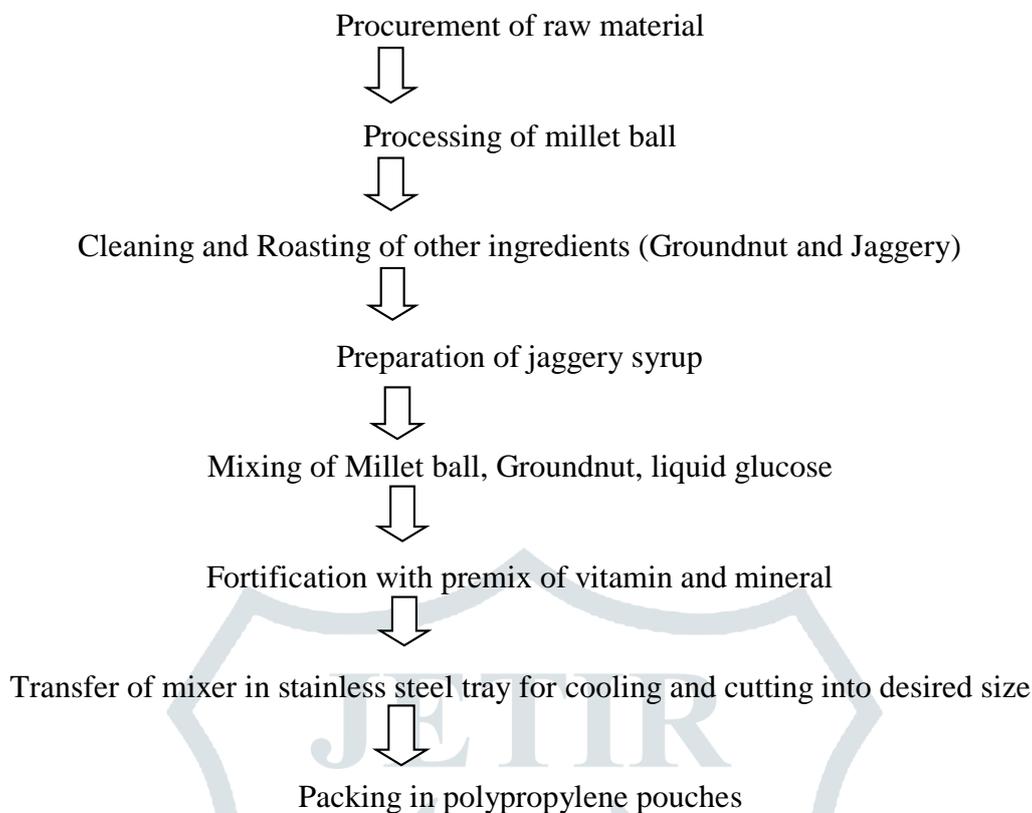
**Table 1 : Proportion of millet flour**

Millet	Percentage (%)	Quantity(Kg.)
Sorghum flour	40	60
Pearl millet flour	40	60
Finger millet flour	20	30
Total	100 %	150Kg.

**Table 2 : Formulation of fortified millet chikki of 2500 gm lot-**

Ingredients	Amount	Percentage
Jaggery	1175 gm	47%
Peanut	1000 gm	40%
Millet balls	250 gm	10%
Liquid glucose	75 gm	3%
Premix of vitamin and mineral	25 gm	1%

## Flow chart of preparation of Fortified Millet Chikki -



## Nutritional Evaluation of Fortified Millet Chikki

### A. Determination of calcium-

Analysis of calcium was done by IS 5949:1990.

The most prevalent mineral in the body is calcium. Humans require calcium for the development and maintenance of strong bones, and teeth and bones contain 99% of the calcium in the body. It is also required to keep the brain and other body parts communicating in a healthy way. It affects how muscles move and how the heart works. Low calcium consumption is widespread throughout the world and can cause osteomalacia in adults and nutritional rickets in children. Foods enhanced with calcium may increase calcium intake. All life stages have substantial calcium requirements. The dietary reference values are designed to take into consideration the requirements for development, growth, maintenance of health, and functioning.

### B. Determination of Iron-

Analysis of iron was done by IS 14433:2006

As a component of hemoglobin, an erythrocyte (red blood cell) protein that carries oxygen from the lungs to the tissues, iron is a mineral that is found naturally in many foods, added to some food products, and sold as a dietary supplement. Iron also supports healthy connective tissue and muscle metabolism as a part of myoglobin, another protein that carries oxygen.

### C. Determination of vitamin A-

Analysis of vitamin A was done by IS 5886:1970

The term "vitamin A" refers to a class of fat-soluble retinoids, which include retinol and retinyl esters. Immune function, cellular communication, growth and development, and male and female reproduction are among the

functions of vitamin A . Vitamin A supports the growth and differentiation of cells and is essential for the normal formation and upkeep of the heart, lungs, eyes, and other organs. Preformed vitamin A (retinol and retinyl esters) and provitamin A carotenoids are the two forms of vitamin A found in the human diet . Foods derived from animals, such as dairy, eggs, fish, and organ meats, contain produced vitamin A . Plant pigments known as provitamin A carotenoids include beta-carotene, alpha-carotene, and beta-cryptoxanthin.

#### **D. Determination of vitamin B1-**

Analysis of vitamin B1 was done by IS 5398:1969

One of the water-soluble B vitamins is thiamin, sometimes known as thiamine. Another name for it is vitamin B1. In addition to being added to certain food products, thiamin can be found naturally in some foods and as a nutritional supplement. This vitamin is essential for energy metabolism, which in turn affects cell growth, development, and function. The primary metabolically active form of thiamin, thiamin diphosphate (TDP; sometimes called thiamin pyrophosphate), makes up around 80% of the about 25–30 mg of thiamin found in an adult human body. Although the large intestine's bacteria also produce free thiamin and TDP, it is currently uncertain how much of these bacteria contribute to thiamin nutrition. TDP is a necessary cofactor for five enzymes that are involved in the metabolism of lipids, amino acids, and glucose.

#### **E. Determination of vitamin B2-**

Analysis of vitamin B2 was done by IS 5399:1969

One of the water-soluble B vitamins is riboflavin, or vitamin B2. In addition to being added to certain food products, riboflavin can also be found naturally in some foods and as a nutritional supplement. Two important coenzymes, flavin adenine dinucleotide (FAD) and flavin mononucleotide (FMN; sometimes called riboflavin-5'-phosphate), require this vitamin as a necessary component. FAD or FMN make up more than 90% of the riboflavin found in food; the remaining 10% is made up of the free form, glycosides, and esters . The proximal small intestine is where most riboflavin is absorbed . Beyond 27 mg, the body retains very little riboflavin in the kidneys, liver, and heart and absorbs very little of it through single doses. When too much is eaten, it either isn't absorbed or the little that is is eliminated in the urine.

#### **F. Determination of vitamin B3-**

Analysis of vitamin B3 was done by IS 5400:1969

Among the water-soluble B vitamins is niacin, sometimes referred to as vitamin B3. Nicotinic acid (pyridine-3-carboxylic acid), nicotinamide (niacinamide or pyridine-3-carboxamide), and their related compounds, including nicotinamide riboside, are collectively referred to as niacin . Numerous foods naturally contain niacin, which is also added to some food products and sold as a dietary supplement. The primary metabolically active form of ingested niacin is converted by all bodily tissues into the coenzyme nicotinamide adenine dinucleotide (NAD). More than 400 enzymes in the body—more than any other coenzyme produced from a vitamin—need NAD to catalyze processes . In all tissues other than skeletal muscle, NAD is also transformed into another active form, the coenzyme nicotinamide adenine dinucleotide phosphate (NADP)

### G. Determination of vitamin C-

Analysis of vitamin C was done by IS 5838:1970

Water-soluble vitamin C, sometimes referred to as L-ascorbic acid, is added to certain foods, found naturally in others, and accessible as a dietary supplement. Since humans cannot endogenously generate vitamin C like most animals can, it is a necessary dietary component.

### H. Determination of vitamin B9-

Analysis of vitamin B9 was done by IS 7234:1974

Water-soluble B vitamin folate can be found as a dietary supplement or naturally occurring in certain foods. It can also be added to other foods. The general word for naturally occurring food folates and folates in dietary supplements and fortified foods, including folic acid, is folate (previously known as folacin and occasionally vitamin B9). Food folates are polyglutamates because they are in the tetrahydrofolate (THF) form and typically contain extra glutamate residues. The fully oxidized monoglutamate form of the vitamin, folic acid, is found in most nutritional supplements and fortified foods. Additionally, folate in the monoglutamyl form, 5-MTHF (also called L-5-MTHF, 5-methyl-folate, L-methylfolate, and methylfolate), is included in certain dietary supplements.

### Quality Evaluation of Fortified Millet Chikki

Quality evaluation of the value added product involves following steps such as:

#### 1. Determination of moisture content (FSSAI)-

Moisture content was analyzed by using Loss on drying method. When material is heated loss of weight occurs by removal of moisture ( Balasubramanian *et al.*, 2010).

#### 2. Determination of total ash (FSSAI)-

Total ash was determined by total incineration of organic matter. To burn off organic matter and to determine the inorganic matter (Erasmus *et al.*, 2018) muffle Furnace at temperature  $550\pm 25^{\circ}\text{C}$  for 3.5 hours was used.

#### 3. Determination of protein content (FSSAI)-

Protein content was determined by Kjeldahl method as in Fig. 01,02,03. As the major source of nutrition, protein is present in the food as a form of nitrogen (Singh *et al.*, 2024).



FIG 01- DIGESTION OF SAMPLE



**FIG 02- DISTILLATION OF SAMPLE**



**FIG 03- TITRATION OF SAMPLE**

#### **4. Determination of crude fat (FSSAI)-**

Crude fat was determined by Soxhlet extraction. Fat extractor uses solvent reflux and siphon principle for continuous extraction (**Karkannavar *et al.*, 2021**).

#### **5. Determination of crude fiber (FSSAI)-**

Following the chemical digestion and solubilization of any additional components present, the amount of crude fiber was measured gravimetrically. After burning, the weight of the fiber residue was adjusted for ash content (**Sood *et al.*, 2023**).

Instrument used- Soxhlet apparatus, hot plate, Hot air oven, muffle furnace.

#### **6. Determination of carbohydrates-**

Determination of carbohydrates was done by using following formula- (**Ch *et al.*, 2020**).

Total carbohydrates = 100 - (Moisture content+ protein + crude fat + total ash +crude fiber)

The amount of digestible carbohydrates in a food product is known as available carbohydrates. As a result, it excludes dietary fiber. The carbohydrate amounts of the ingredients are used to compute available carbohydrates in a product's nutrition calculation. When calculating accessible carbohydrates in a lab test, fat, protein, fiber, moisture, and ash are subtracted from 100%. As a result, this method's precision is constrained because it may compound several lesser errors. The only way that total and accessible carbohydrates are different is because total carbohydrates include fiber.

#### **7. Determination of calorific value-**

Calorific value was also measured by calculation method (**Kumar *et al.*, 2022**).

Calorific value for carbohydrate is 4 kcal, protein 4 kcal, fat 9kcal. A gram of fat has an incredible 9 calories, while a gram of carbohydrates only contains 4. For every macronutrient, add up the calories. You can now calculate the total number of calories for a single serving of the item by adding the total number of calories for each individual count.

## Results and Discussion

Physico-chemical analysis of this fortified product involves examining its moisture content, ash content, fat, protein, carbohydrate levels, and mineral fortification, along with sensory attributes. Standards say that :

Moisture content in Fortified Millet Chikki typically ranges from 2-4%. Maintaining low moisture is crucial for shelf stability, as it prevents microbial growth and extends the product's shelf life.

Ash content, representing the total mineral content, is generally around 1-2%. This analysis helps in understanding the inorganic mineral content, essential for assessing the nutritional value.

Fat content in chikki, largely from peanuts and added oils, ranges from 15-20%.

Proteins, primarily from millet and peanuts, are found in the range of 10-15%. These macronutrients contribute to the energy density and nutritional profile of the chikki.

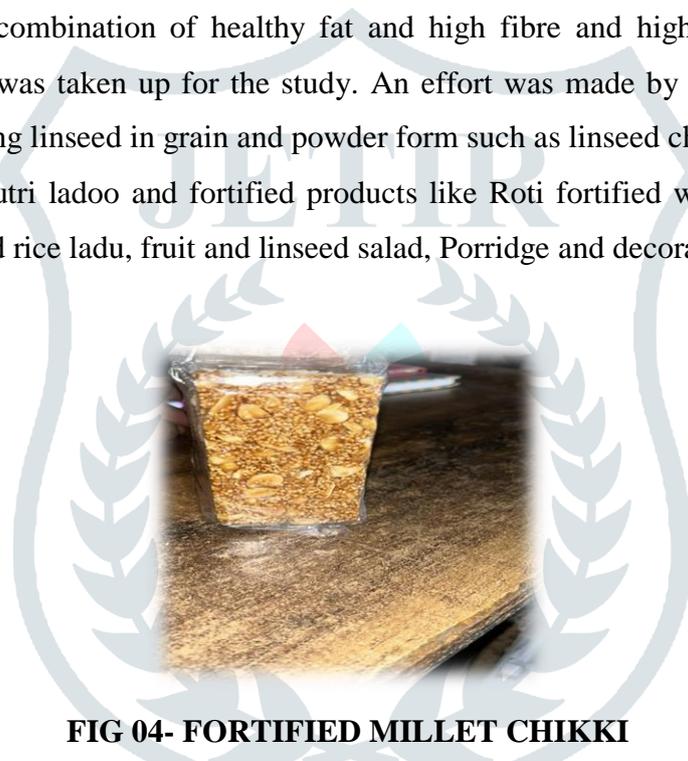
Carbohydrates, primarily from jaggery and millet, constitute around 60-70% of the chikki. These include both simple sugars and complex carbohydrates, providing quick energy and sustained release.

The given **Table 3** indicates the quality evaluation of Fortified Millet Chikki-

Parameters	Nutritive value (100gm)
Moisture %	3.87
Total ash %	1.94
Protein content gm	10.86
Crude fat %	15.42
Crude fiber %	1.26
Carbohydrates gm	67.91
Calorific value kcal	458.90
Calcium mg	280.12
Iron mg	5.65
Vitamin A (Retinol) mcg	256
Vitamin B1 (Thiamine) mg	0.46
Vitamin B2 (Riboflavin) mg	0.69
Vitamin B3 (Niacin) mg	4.67
Vitamin C (Ascorbic acid) mg	17.51
Vitamin B9 (Folate) mcg	67.88

Above table indicates the amount of nutritive value in 100 gm of fortified millet chikki. Fortified millet chikki provides sufficient amount of vitamin and minerals which can help in prevention of disease and malnutrition in growing children. After the optimization of various ingredients, the product as in **Fig.4** was found to be most favorable because of higher nutrition profile.

Similar results were reported for the nutritional composition of sorghum-finger millet Chakli by **Patekar *et al.*, (2017)** protein and fat content were highest in sorghum-finger millet chakli as compared to the control chakli. The study conducted by **Chavan *et al.*, (2016)** on even the sorghum chakli showed similar kind of nutritional composition. Moreover, (**Nath *et al.*, 2015**) mentioned that according to sorghum varieties, 100 g of jaggery may contain calories 383, sucrose 65-85g, fructose and glucose 10-15g, protein 0.4g, fat 0.1g, and contain traces of vitamins, amino acids, and antioxidants. Nutra chikki developed by (**Pallavi *et al.*, 2014**) had 18% protein, 20% fat, 6.42% Ca, 1.7% Fe, 4000 µg vitamin A and 2660 µg folic acid. Protein digestibility corrected amino acid score of nutra chikki was 0.78 whereas that of control chikki was 0.73. The enriched nutra chikki was evaluated for physico-chemical characteristics such as moisture, texture, peroxide value (PV), fatty acid composition in comparison with control peanut chikki. Nutra chikki, which had initial moisture content of 2–3%, did not alter much up to 60 days of storage at 27 °C and 37 °C. Utilizing a special group of nutrients, flax seed with a combination of healthy fat and high fibre and high in most of the B-vitamins, magnesium and manganese was taken up for the study. An effort was made by (**Shakuntala *et al.*, 2016**) to prepare many food items using linseed in grain and powder form such as linseed chutney powder, linseed holige, laddoo, fried snacks, burfi, nutri laddoo and fortified products like Roti fortified with linseed, chikki, biscuits , salted linseed biscuits, puffed rice ladu, fruit and linseed salad, Porridge and decorative articles.



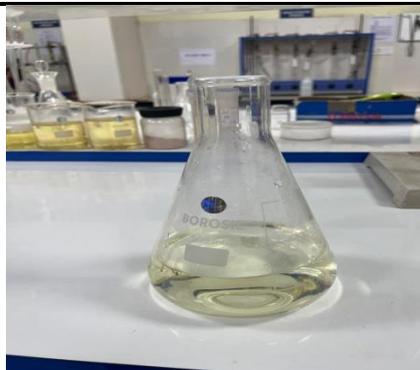
**FIG 04- FORTIFIED MILLET CHIKKI**



**FIG 05- DETERMINATION OF MOISTURE CONTENT**



**FIG 06- TOTAL ASH CONTENT**



**FIG 07- PROTEIN CONTENT DETERMINATION**

### Costing of Fortified Millet Chikki-

The production costs of millet and jaggery are relatively low, making the base product affordable. Mineral fortification, involving the addition of nutrients like iron, calcium, and vitamins, incurs additional costs but these are offset by the health benefits provided. By incorporating mineral fortification, the cost per unit increase is marginal, often ranging from 5-10% of the original product cost. Moreover, large-scale production and economies of scale further reduce the per-unit cost of fortified chikki as in **Table 4**.

**Table no.4 - Costing of fortified millet chikki**

Ingredients	Percentage %	Rs/kg	Quantity(kg)	Cost(rs)
Jaggery	47	40	1.175	47.00
Groundnut	40	140	1.000	140.00
Millet ball	10	75	0.250	18.75
Liquid glucose	3	40	0.075	3.00
Premix of vitamin and mineral	1	250	0.025	6.25
Total	101 %		2.525 kg	215.00
Other expenses		5	2.525 kg	12.625
SUM				227.625

Total costing of a lot of 2500 gm fortified millet chikki was 230 Rs (round off). 1 fortified millet chikki was of 20 gm so costing of 1 fortified millet chikki was 2 Rs/piece.

### Conclusion

The study on fortified millet chikki demonstrated significant improvements in nutritional quality and cost-effectiveness. By incorporating nutrient-dense ingredients, the fortified chikki showed enhanced protein, fiber, and micronutrient content compared to traditional versions. Sensory evaluations indicated high acceptability among consumers. Additionally, the cost analysis revealed that fortification could be achieved with minimal increase in production costs, making it an economically viable option for addressing nutritional deficiencies. Overall, fortified millet chikki presents a promising solution for improving dietary intake and health outcomes, particularly in resource-limited settings.

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