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VALUE-ADDED IRON- AND PROTEIN-RICH LADDOO FOR MARTIAL ARTS ATHLETES: PRODUCT DEVELOPMENT, NUTRITIONAL ANALYSIS, SENSORY ACCEPTABILITY AND SHELF-LIFE EVALUATION

Prajakta Nande[1] and Meghna Pandit[2]

[1]Sr. Assistant Professor, Department of Home Science, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur, Maharashtra-440033, India
[2]Research Scholar, Department of Home Science, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur, Maharashtra-440033, India
Corresponding Author: Dr. Prajakta Nande, prajaktanande@yahoo.co.in
ORCID: https://orcid.org/0000-0001-5688-3242

ABSTRACT
Martial arts practitioners undergo intense physical training that requires specialized nutrition for optimal performance, muscle recovery, and overall health. Among the key nutrients that support athletic performance, protein and iron are crucial, with deficiencies in these nutrients potentially impairing strength, energy levels, and recovery. This study aimed to develop a protein- and iron-rich laddoo, a traditional Indian sweet snack, as a dietary supplement tailored for young martial arts players. The laddoo incorporated nutrient-dense ingredients such as sesame seeds, garden cress seeds, roasted bengal gram, black raisins, skimmed milk powder, cocoa, sugar, and ghee. The nutritional composition of the laddoo was analysed to determine its protein and iron content, along with other macro and micronutrients. Sensory acceptability and shelf-life stability were evaluated. Nutritional composition analysis revealed that the laddoo provided 15.09 % protein, 10.6 % iron, and 417.16 kcal of energy, along with other vital nutrients. Sensory evaluation showed high acceptability with a mean score of 10 for taste and flavour. The shelf-life study indicated that the laddoos maintained their quality for up to 30 days under ambient storage conditions. The results suggest that this fortified laddoo could serve as a convenient, nutrient-dense, and traditionally acceptable source of nutrition for martial arts athletes, supporting muscle recovery and overall performance.

KEYWORDS: Iron-rich laddoo, protein, martial arts, nutritional composition, sensory evaluation, shelf life, supplementation, traditional food.

INTRODUCTION

Martial art is a physically demanding sport that requires a unique blend of strength, speed, endurance, and mental focus. Athletes involved in martial arts require optimal nutrition for peak performance, as it significantly impacts their body composition, training adaptations, and overall health. A well-balanced diet tailored to their specific nutritional needs is crucial for achieving optimal performance levels, efficient recovery, and reducing injury risks (Amawi et al., 2024). Among the nutrients critical to achieving these goals are iron and protein. Iron plays a fundamental role in transporting oxygen throughout the body, which is essential for maintaining endurance during intense physical activities (Hinton, 2014). Protein is integral to muscle repair and growth, particularly after strenuous physical exertion, and is a key component of an athlete's recovery process.

Iron deficiency is notably common among athletes, especially those participating in endurance or strength-based sports such as martial arts, (Nolte et al, 2024), where prolonged physical activity demands a consistent supply of oxygen to the muscles. An iron deficiency can lead to fatigue, impaired aerobic performance, and increased injury risk. Protein is equally important, as it is essential for muscle tissue repair, building lean muscle mass, and overall recovery. For martial arts athletes, insufficient protein intake can lead to prolonged recovery periods, decreased performance, and an increased risk of injury. Ensuring adequate levels of both these nutrients can significantly improve athletic performance, promote better recovery, and reduce the risk of deficiencies.

Despite the importance of these nutrients, many athletes do not consume adequate amounts through conventional meals (Moss et al, 2023). Convenience, accessibility, and palatability often hinder adherence to a proper diet. One potential solution is to develop a nutrient-dense supplement in the form of a traditional food that is easy to consume and integrate into an athlete's diet. In many cultures, traditional foods have been consumed for their nutritional benefits, with recipes passed down through generations. In India, laddoos are a popular confection made from a variety of ingredients, such as pulses, nuts, and sweets, often associated with celebrations and health. Laddoos are typically rich in calories and fats, but they can be modified to meet the nutritional demands of specific populations, such as athletes.

This study proposes the development of an iron- and protein-rich laddoo, specifically designed to cater to the

nutritional needs of martial arts players. The objective of the study is to create a fortified laddoo using ingredients that are naturally rich in iron and protein, assess its nutritional composition, evaluate its sensory appeal, and determine its shelf life stability under various storage conditions and assess its potential as a supplement for martial arts players.

MATERIALS AND METHODS

2.1. Selection of Ingredients

The selection of ingredients was based on their nutritional profiles, particularly their content of protein and iron, as well as other beneficial nutrients such as healthy fats, vitamins, and minerals. The ingredients were chosen for their widespread availability, nutritional benefits, and compatibility with the dietary needs of martial artists.

- **Sesame Seeds**: Sesame seeds are an excellent source of protein, iron, calcium, and healthy fats. They have been traditionally used in various cultures as a natural remedy for fatigue and to support bone health. The seeds contain approximately 14 mg of iron per 100 g (ICMR, 2017) and are beneficial for improving iron status.
- **Garden Cress Seeds**: Garden cress seeds are rich in iron, protein, fibre, and various vitamins and minerals. These seeds are often used in Ayurvedic medicine for their therapeutic properties, particularly for improving iron levels in the body.
- **Roasted Bengal Gram**: High in protein (22 g per 100 g), roasted bengal gram is used for its nutritional value and nutty flavour. It also contains dietary fibre, which supports digestive health. It also adds a mild, nutty flavour and a crunchy texture to the laddoo. This ingredient is particularly beneficial for athletes who require a plant-based source of protein to aid muscle recovery.
- **Black Raisins**: Black raisins are rich in iron and antioxidants. The natural sugars in raisins provide an immediate source of energy, making them a suitable addition for athletes who require quick recovery foods after intense physical activity.
- **Skimmed Milk Powder**: A rich source of protein, providing approximately 36 g of protein per 100 g. Skimmed milk powder is an excellent source of high-quality protein and calcium, which supports both muscle recovery and bone health. It adds creaminess and texture to the laddoo without significantly increasing the fat content.
- **Cocoa**: Cocoa adds flavour and contains antioxidants known to improve cardiovascular health. It also contains a moderate amount of iron, complementing the other ingredients in the laddoo.
- **Powdered Sugar**: Sugar serves as a source of quick energy, crucial for martial artists who may need to replenish glycogen stores during or after training sessions. It also helps in binding the ingredients together and balances the flavours of the laddoo.
- **Ghee (Clarified Butter)**: A traditional fat source in Indian cooking, ghee is rich in healthy fats, which provide energy and helps in the absorption of fat-soluble vitamins like vitamin D. It also helps in binding and enhances the taste and texture of the laddoo, making it a palatable snack for athletes.

Table 1 shows the composition of the laddoo –

Table 1: Ingredient Composition of Laddoo

Sr. No.	Ingredients	Quantity (%)
1	Bengal gram (roasted) powder	14.71
2	Garden cress seeds	2.94
3	Gingelly seeds powder (white)	22.06
4	Raisins black (crushed)	29.41
5	Skimmed milk powder	14.71
6	Ghee	2.94
7	Cocoa unsweetened	1.47
8	Powdered sugar	11.76

2.2. Laddoo Preparation

The preparation process for the laddoo was optimized to maintain the integrity of the nutrients while ensuring a pleasant texture and flavour. The roasted bengal gram was ground into a fine powder. The sesame seeds and garden cress seeds were toasted lightly to enhance their flavour and nutritional bioavailability. These ingredients were then combined in a large mixing bowl with crushed black raisins, skimmed milk powder, powdered sugar, and cocoa. The mixture was then bound together with ghee, which helped to form the dough. The dough was shaped into round laddoos and set aside to cool. The laddoos were then stored in an airtight container to preserve freshness.

2.3 Nutritional Composition Analysis

The nutritional analysis of the laddoo was performed at a certified food testing laboratory. The following parameters were measured:

- **Protein content**: Protein content was measured using the Kjeldahl method, a widely accepted procedure for quantifying nitrogen in food, from which protein content is calculated (Nielsen, 2017).
- **Fat content**: The Soxhlet extraction method was used to quantify the fat content in the laddoo.
- **Carbohydrates**: The carbohydrate content was estimated by difference, subtracting the values of protein, fat, and moisture from the total weight.
- **Caloric value**: The caloric value of the laddoo was calculated by summing the energy contribution from protein, fat, and carbohydrates.
- **Minerals & Vitamins content**: The content of minerals (iron, calcium, phosphorus, magnesium, and zinc) and vitamins (Vitamin B1, Vitamin B2, Vitamin B3, Vitamin B9, Vitamin A, Vitamin D, and Vitamin C), were determined using Standard Chromatography Techniques.

2.4 Sensory Evaluation

The laddoo was judged on its palatability by examiners. Eight panellists from Department of Home Science, Rashtrasant Tukadoji Maharaj Nagpur University, Maharashtra, rated the product thrice on appearance, colour, taste, texture, flavour, and acceptability.

Recipe was graded using four stage ranking from highest score of 10 to lowest score of 4 for all sensory traits (very good for score 10, good for score 8, fair for score 6 and poor for score 4. The score card format & key for the sensory evaluation of laddoo are depicted in Tables 2 and 3, respectively.

Table 2 - Score Card for Laddoo

Sr. No	Trials	Date	Appearance	Colour	Texture	Flavour	Taste	Acceptability
1	Trial I							
2	Trial II							
3	Trial III							

Table 3 - Key for Laddoo

Sr.	Appearance	Colour	Texture	Flavour	Taste	Acceptability	Scores
1	Very Good	Very	Very Good	Very	Very	Highly	10
2	Good	Good	Good	Good	Good	Acceptable	8
3	Fair	Fair	Fair	Fair	Fair	Slightly	6
4	Poor	Poor	Poor	Poor	Poor	Unacceptable	4

The data was analysed to calculate average scores for each attribute and to determine the overall preference for the laddoo among the participants.

2.5 Shelf Life Study

The shelf life of the laddoo was evaluated by storing it at room temperature (25°C). Samples were taken at days 0, 08, 16, 24, and 32 for analysis, which included:

- **Sensory attributes**: The laddoo was re-evaluated at each time point for appearance, taste & odour.
- **Microbial contamination**: Yeast & Mould Count and Total Bacterial Count were performed, by Standard Plate Count Method, at each time point to evaluate for microbial contamination.

The data was used to determine the stability of the laddoo under ambient storage conditions.

RESULTS AND DISCUSSION

3.1 Nutritional Composition

The nutritional composition analysis of the developed laddoo showed that 100-gm of the laddoo provides 15.09 gm of protein, 10.6 mg of iron, 417.16 kcal of energy and significant amounts of other vital nutrients critical for athletic performance. Comprehensive list of analysed nutrients and their values are detailed in Table 4.

Table 4 - Nutritional Composition of Laddoo (per 100 g)

S.N	Test Parameter	Measurement Unit	Test Method	Test Result
1	Energy	kcal	USDA Agricultural Handbook No. 74 (By Calculation)	417.16
2	Total Protein	g	IS 7219 : 1973	15.09

3	Total Carbohydrate	g	USDA Agricultural Handbook No. 74 (By Calculation)	55.72
4	Total Fats	g	IS 15271 : 2003	14.88
5	Calcium (as Ca)	mg	ANtr/7.2/Res-Inorg/08:2019	452.08
6	Iron (as Fe)	mg	ANtr/7.2/Res-Inorg/08:2019	10.60
7	Phosphorus	mg/kg	ANtr/7.2/Res-Inorg/08:2019	3968.47
8	Magnesium	mg	ANtr/7.2/Res-Inorg/08:2019	139.60
9	Zinc	mg/kg	ANtr/7.2/Res-Inorg/08:2019	33.49
10	Vitamin B1	mg	By HPLC	0.32
11	Vitamin B2	mg	By HPLC	0.28
12	Vitamin B3	mg	By HPLC	0.14
13	Vitamin B9	mg	By HPLC	0.78
14	Vitamin A	mg	By HPLC	0.16
15	Vitamin D	mg	By HPLC	0.26
16	Vitamin C	mg	By HPLC	0.58

The high iron content can be attributed to the sesame seeds, garden cress seeds, and black raisins, while the protein content is sourced primarily from roasted Bengal gram, skimmed milk powder, and sesame seeds. Although the iron is predominantly non-haem, pairing the laddoo with a vitamin C-rich food can improve iron absorption. The laddoo serves as an effective supplement for athletes in need of these two essential nutrients.

3.2 Sensory Evaluation

The sensory evaluation showed that the laddoo was highly acceptable with a mean score of 10. The taste and flavour received perfect ratings with mean scores of 10 each. The participants also approved the appearance (mean score 9.75), colour (mean score 9.75) and texture (mean score 9.92) of the developed laddoo. The mean scores for the analysed sensory attributes are detailed in Table 5.

Table 5 - Sensory Evaluation of Laddoo

Sr.No.	Sensory Attributes	Mean Scores
1	Appearance	97.5
2	Colour	97.5
3	Texture	9.92
4	Flavor	10
5	Taste	10
6	Acceptability	10

3.3 Shelf Life Study

The accelerated shelf-life study indicated that the laddoos stored under ambient conditions maintained their quality for up to 30 days.

Table 6 - Shelf-Life Analysis of Laddoo

S. N.	Test Parameters	Measure- -ment Units	Test Results				
			Initial (0 day)	Stage 1 (8 day)	Stage 2 (16 day)	Stage 3 (24 day)	Stage 4 (32 day)
1	Appearance	-	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable
2	Taste		Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
3	Odour	-	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable
4	Yeast & Mould	cfu/g	1.8×10^1	2.2×10^1	2.5×10^1	4.6×10^1	6.9×10^1
5	Total bacterial count	cfu/g	1.1×10^2	1.5×10^2	1.8×10^2	2.3×10^2	5.5×10^2

Table 6 presents a comprehensive evaluation of the shelf life of laddoo samples under ambient storage conditions, assessed across five stages from 0 to 32 days. The analysis encompasses sensory attributes, such as appearance, taste, and odour, alongside microbial parameters, including yeast and mould count and total bacterial count.

The sensory parameters, including appearance, taste, and odour, were consistently rated as agreeable or satisfactory

throughout the storage period, indicating that the laddoo maintained its sensory quality without significant deterioration. The microbial parameters, measured as colony-forming units per gram (cfu/g), revealed the highest microbial count of 6.9 x 10^1 of Yeast & Mould, and 5.5 x 10^2 of Total Bacterial Count at day 32, which remains under the permissible limit.

DISCUSSION

The laddoo developed in this study offers a significant nutritional boost for martial arts players, especially in terms of protein and iron intake. Protein is vital for muscle recovery and growth, which is crucial after intense training sessions. The iron content of the laddoo helps combat fatigue and supports endurance during prolonged training periods.

By incorporating ingredients such as sesame seeds, garden cress seeds, and Bengal gram, the laddoo is not only rich in protein but also in micronutrients that promote overall health. The inclusion of black raisins and ghee enhances the product's energy density, making it a quick source of calories for athletes who need to replenish glycogen stores quickly.

The product's suitability for martial artists is enhanced by its ability to provide a balanced macronutrient profile, offering both immediate energy from carbohydrates and sustained energy from fats and proteins.

The high sensory acceptability of the laddoo demonstrates its potential as a convenient and enjoyable supplement for athletes. Sensory characteristics such as flavour, texture, and appearance are essential for ensuring that athletes consistently incorporate the product into their diets. The positive feedback from participants suggests that the laddoo is likely to be embraced by martial arts practitioners as a regular snack or supplement.

CONCLUSION

The protein- and iron-rich laddoo developed in this study represents an effective and culturally familiar supplement for martial arts athletes. By combining nutrient-dense ingredients, the laddoo provides a convenient, energy-dense source of protein and iron, supporting muscle recovery and overall performance. The positive sensory evaluation indicates strong potential for widespread acceptability among martial artists, making it a promising candidate for further development and commercialization as a functional food product.

Future research could explore variations of this laddoo, including modifications to suit different dietary needs (e.g., vegan options) or preferences. Additionally, long-term studies could investigate the impact of incorporating such supplements into athletes' diets on their overall performance and recovery.

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