Research Article

Development, Standardization And Nutritional Evaluation Of Traditional Iron-Supportive Foods Based On Dietary Habits Of Anaemic Adolescent Girls

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Abstract

Iron deficiency anaemia remains one of the most prevalent nutritional disorders among adolescent girls and continues to be a major public health concern in India. Dietary practices such as meal skipping, inadequate intake of iron-rich foods, and consumption of beverages that inhibit iron absorption contribute substantially to poor iron status. The present study was undertaken to assess dietary behaviour and to develop, standardize, and nutritionally evaluate traditional iron-supportive food products using locally available nutrient-rich ingredients. The study was conducted among 243 anaemic girls aged 16–18 years from educational institutions of Panchkula district, Haryana. Dietary information was collected using a structured questionnaire. Based on identified dietary gaps, two traditional food products, namely Sautéed Amla–Moringa Veggie and Coriander–Marwa Chutney, were developed and standardized through a two-stage sensory evaluation process using a 9-point hedonic scale. Nutritional composition was calculated using the ICMR–NIN Nutritive Value of Indian Foods database. Dietary assessment revealed that 56.0% of respondents consumed only two meals per day and 43.2% frequently skipped breakfast. Daily consumption of tea, coffee, or soft drinks with meals was reported by 49.4% of participants. Lack of appetite (75.4%) and cravings for fast food (42.9%) were the major reasons for skipping meals. Among the developed products, Sautéed Amla–Moringa Veggie, containing 6 g of moringa leaf powder, and Coriander–Marwa Chutney, containing 20 g of Marwa leaves, obtained the highest sensory acceptability scores. Significant differences ($p \leq 0.05$) were observed among the developed formulations for most sensory attributes. Nutritional evaluation demonstrated that the standardized products provided appreciable amounts of iron, folate, calcium, and vitamin C. The findings indicate that incorporating nutrient-dense traditional ingredients such as moringa, Marwa, foxnut, and amla into acceptable food products may serve as a sustainable food-based strategy to improve dietary iron intake among adolescent girls.

Keywords: Adolescent girls, Amla, Iron bioavailability, Iron deficiency anaemia, Marwa, Moringa, Sensory evaluation, Traditional foods.

Introduction

Anaemia is a major global public health concern, affecting approximately 500 million women aged 15–49 years. The highest burden is observed in the WHO African and South-East Asia Regions, where anaemia affects an estimated 106 million and 244 million women, respectively (World Health Organization, 2024). Iron deficiency anaemia, the most common form of anaemia, is one of the most widespread nutritional disorders globally and continues to disproportionately affect adolescent girls. The demand for iron increases substantially during adolescence due to rapid physical growth, expansion of blood volume, and the onset of menstruation. Inadequate dietary iron intake and poor iron bioavailability further increase the risk of anaemia in this vulnerable population. Despite the implementation of supplementation and food fortification programmes by the central and state governments, the prevalence of anaemia among Indian adolescents remains alarmingly high, underscoring the need for sustainable, culturally acceptable, food-based strategies to improve iron intake and utilisation (International Institute for Population Sciences [IIPS] & ICF, 2021).

Haryana has a substantial adolescent female population, with approximately 2.25 million girls aged 10–19 years (Office of the Registrar General & Census Commissioner, India, 2011). This large population segment represents an important target group for nutrition and health interventions. Despite notable improvements in health and nutrition indicators, undernutrition continues to affect a considerable proportion of adolescent girls in India. Evidence from the National Family Health Survey, NFHS-5, 2019–21, indicates that approximately 14% of girls aged 15–19 years are underweight (International Institute for Population Sciences [IIPS] & ICF, 2021). Diksha et al. (2020) reported that 8.72% of adolescent girls in rural Haryana were thin, while a more recent study in

Gurugram reported undernutrition among 15.4% of adolescent girls, suggesting that undernutrition remains a significant public health concern in the state (Vashist et al., 2025).
Traditional Indian foods and locally available plant-based ingredients offer considerable potential for addressing micronutrient deficiencies through regular dietary practices (Narwal et al., 2026). However, the consumption of many nutrient-rich traditional foods has declined among adolescents due to a growing preference for processed, convenience, and fast foods, coupled with limited awareness of the nutritional benefits of indigenous foods. Consequently, there is increasing interest in developing functional food products that incorporate traditional ingredients with established nutritional value into convenient and acceptable dietary forms.
Among locally available traditional ingredients, Moringa oleifera leaves are recognized as excellent sources of iron, calcium, copper, folate, protein, and antioxidants (Peñalver et al., 2022). Marwa (Origanum majorana) leaves also contribute appreciable amounts of iron and other minerals, whereas foxnuts (makhana, Euryale ferox) and Bengal gram provide protein, energy, and essential micronutrients (Wang et al., 2021; Kumar et al., 2023). Coriander leaves are rich in vitamins, minerals, and bioactive compounds, while amla (Emblica officinalis) is one of the richest natural sources of vitamin C (Tan et al., 2023). The nutrient composition of these ingredients has been comprehensively documented in the Indian Food Composition Tables published by the Indian Council of Medical Research–National Institute of Nutrition (ICMR–NIN) (Longvah et al., 2017). The inclusion of vitamin C-rich ingredients is particularly advantageous because vitamin C enhances the absorption and bioavailability of non-haem iron from plant-based foods, thereby improving iron utilization and supporting haemoglobin synthesis (Heffernan et al., 2017; Ramachandran et al., 2024).
Food product development and standardization provide an effective approach for incorporating these nutrient-dense traditional ingredients into acceptable and convenient dietary forms that can be consumed regularly by adolescents. Developing culturally familiar foods enriched with complementary nutrients offers a sustainable food-based strategy to improve dietary iron intake while maintaining sensory acceptability and encouraging long-term dietary adherence. Therefore, the present study was undertaken to assess dietary behaviour and meal-skipping patterns among anaemic adolescent girls in Panchkula district, Haryana, and to develop, standardize, and nutritionally evaluate two traditional iron-supportive food products, namely Sautéed Amla–Moringa Veggie and Coriander–Marwa Chutney.

Methodology

Study Population and Collection of Demographic Data

This cross-sectional study was conducted among 243 adolescent girls aged 16–18 years enrolled in educational institutions of Panchkula district, Haryana. Participants were selected using a purposive sampling technique following a health screening camp. Haemoglobin concentration was assessed as part of the screening process, and girls with haemoglobin levels <12.0 g/dL (classified as anaemic) and willing to participate in the study were included. Data were collected after obtaining informed consent from the participants.
A structured and pre-tested questionnaire (underwent expert review) was administered to collect information on demographic characteristics, socio-economic background, dietary habits and meal consumption patterns. The questionnaire was developed based on previously published dietary assessment tools and modified according to the objectives of the study. It consisted of sections covering meal frequency, meal skipping, beverage consumption, fast-food intake, food preferences and awareness regarding dietary iron absorption and food preferences during college hours. The questionnaire was pre-tested among 10 adolescent girls and necessary modifications were made before final administration.
The collected information was analysed to identify prevailing dietary practices and factors that could potentially influence iron intake and bioavailability among the respondents. The findings were subsequently used to guide the development and standardisation of nutrient-rich traditional food products that incorporate iron-rich ingredients, along with complementary nutrients known to support iron absorption and utilisation.

Data analysis

Data were analysed using descriptive statistics, including frequencies, percentages, means, and standard deviations. Sensory evaluation scores were expressed as mean ± standard deviation and subjected to one-way Analysis of Variance (ANOVA). Significant differences among treatment means were separated using Duncan's Multiple Range Test (DMRT). Chi-square goodness-of-fit tests were performed to determine whether the observed distributions of meal frequency, meal-skipping patterns, and tea/coffee/soft drink consumption differed significantly from an equal distribution across categories. Chi-square tests of independence were used to assess associations between meal-skipping status and fast-food craving. The Mann–Whitney U test was employed to compare the frequency of tea/coffee/soft drink consumption between meal skippers and non-skippers because the variable was ordinal. Statistical significance was established at $p < 0.05$. All analyses were conducted using statistical software equivalent to SPSS procedures.

Material Used

Ingredients for Sautéed Amla–Moringa Veggie

Fresh amla (Indian gooseberry), curry leaves, and moringa leaves required for the preparation of Sautéed Amla–Moringa Veggie were procured from the local vegetable market of Panchkula, Haryana. Mustard oil, mustard seeds, jaggery powder, desi khaand, turmeric powder and garam masala were obtained from local retail outlets. Fresh moringa and curry leaves were thoroughly washed under running water to remove adhering dirt and impurities. The cleaned leaves were shade-dried at room temperature until crisp and then ground separately into fine powders using a domestic grinder. The prepared powders were stored in airtight containers until further use. The required quantities of moringa leaf powder and curry leaf powder were accurately weighed and incorporated into the product formulations during standardization and preparation. Fresh amla fruits were selected for uniform size and quality, washed thoroughly, and used for product development and sensory evaluation.

Ingredients for Coriander–Marwa Chutney

Fresh coriander leaves, Marwa (marjoram) leaves, green chillies, ginger, curd, foxnuts (makhana), roasted Bengal gram, and green peas required for the preparation of Coriander–Marwa Chutney were procured from the local market of Panchkula, Haryana. The ingredients were selected based on their freshness, quality, and suitability for product development. All ingredients were cleaned and prepared in accordance with standard culinary practices before use in the development and standardisation of the chutney variants.

All packaged ingredients were purchased from Food Safety and Standards Authority of India (2020) approved brands and were used within their labelled shelf-life period to ensure quality and safety. The products were developed in convenient and acceptable forms suitable for incorporation into the daily diets of adolescent girls.

Recipe development

Method of Preparation of Sautéed Amla– Moringa Veggie

Sautéed Amla–Moringa Veggie was designed as a convenient accompaniment to meals to improve iron intake and bioavailability among adolescent girls, as per the methods described in Figure 1.

Fresh amla fruits washed thoroughly under running water

⇩

Amla fruits pressure-cooked with a minimal quantity of water (sufficient to be completely absorbed during cooking) for one whistle. Water not discarded (to minimize nutrient losses)

⇩

After cooling, deseeding of fruits and separation into individual segments

⇩

Mustard oil heated in a separate pan

⇩

Mustard seeds added in the pan and allowed to splutter

⇩

Dried and crushed curry leaves added along with turmeric powder and sautéed briefly

⇩

Amla segments and black salt added and mixed thoroughly

⇩

Jaggery powder and garam masala incorporated

⇩

After mixing uniformly, pan removed from heat

⇩

Moringa leaf powder sprinkled over the mixture; stirred continuously to ensure uniform distribution

⇩

Product allowed to cool to room temperature; ready for consumption

Figure 1: Method of Preparation of Sautéed Amla– Moringa Veggie

Standardization of Sautéed Amla-Moringa Veggie

A two-stage standardization process involving ingredient selection followed by optimization of moringa leaf powder quantity was adopted for the development of Sautéed Amla–Moringa Veggie. In the first stage, three variants were prepared to evaluate the effect of different sweetening agents on sensory acceptability. Each formulation contained 200 g cooked and deseeded amla, 10 g mustard oil, 5 g mustard seeds, 2 g curry leaves powder, 2 g turmeric powder, 3 g moringa leaf powder, and 2 g garam masala. Variant V1 served as the control without any added sweetener, whereas Variants V2 and V3 were supplemented with 10 g of desi khaand and 10 g of jaggery powder, respectively. Black salt was added according to taste and excluded from nutrient calculations. The developed variants were subjected to organoleptic evaluation using a 9-point hedonic scale, and the most acceptable formulation was selected for further standardization.

In the second stage, the selected jaggery-based formulation was standardized by varying the quantity of moringa leaf powder. Three variants designated as VM1, VM2, and VM3 were prepared by incorporating 3 g, 6 g, and 9 g moringa leaf powder, respectively, while maintaining all other ingredients and their quantities constant. The variants were subsequently evaluated using a 9-point hedonic rating scale to determine the optimum level of moringa leaf powder incorporation.

Method of Preparation of Coriander–Marwa Chutney

Coriander–Marwa Chutney was developed as a convenient accompaniment to meals to improve iron intake and bioavailability among adolescent girls, as per the method described in Figure 2. The prepared chutney was stored in the refrigerator until further sensory evaluation.

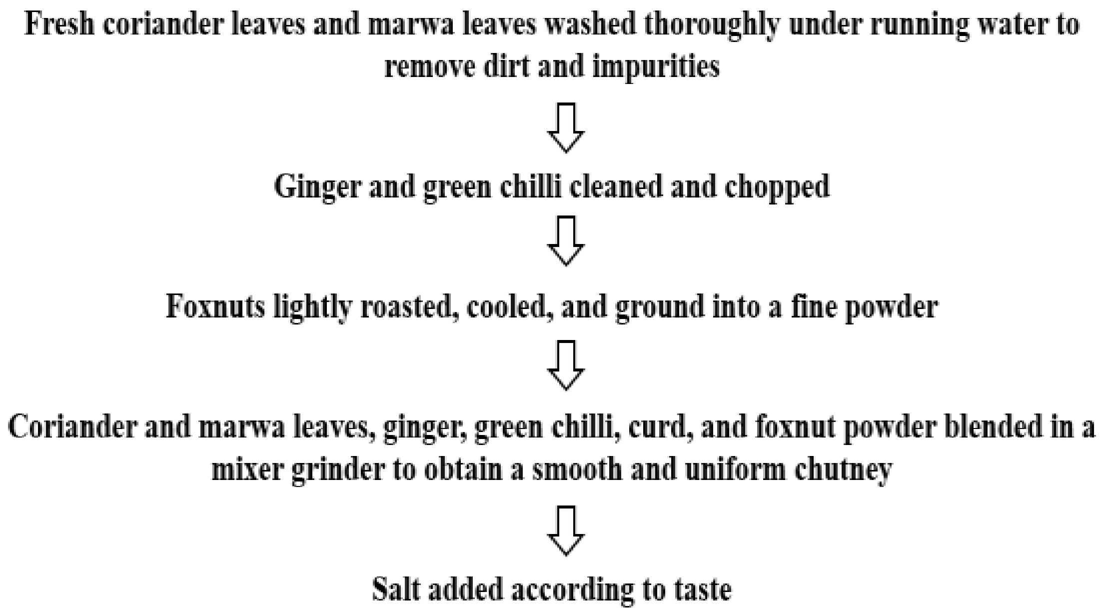

Figure 2: Method of Preparation of Coriander–Marwa Chutney

Standardization of Coriander–Marwa Chutney

A two-stage standardisation process, involving ingredient selection followed by optimisation of Marwa (marjoram) leaves, was adopted to develop Coriander–Marwa Chutney. In the first stage, three formulations were prepared by incorporating different nutrient-rich ingredients while maintaining constant quantities of coriander leaves (50 g), Marwa leaves (20 g), ginger (2 g), green chillies (5 g), curd (25 g), and salt as per taste. Formulation C1 was supplemented with 10 g of foxnut powder, C2 with 10 g of roasted Bengal gram powder, and C3 with 10 g of green peas. The developed formulations were subjected to organoleptic evaluation using a 9-point hedonic scale to determine the most acceptable variant.

Based on the sensory evaluation scores, the most acceptable formulation was selected for further standardization. In the second stage, the quantity of Marwa leaves was optimised by preparing three formulations designated as CM1, CM2, and CM3, containing 10 g, 20 g, and 30 g of Marwa leaves, respectively, while keeping all other ingredients and their quantities constant as in the selected formulation. The standardized formulations were again subjected to sensory evaluation using a 9-point hedonic scale to identify the optimum level of Marwa leaf incorporation.

Organoleptic Evaluation

The prepared formulations were subsequently evaluated for their sensory characteristics to determine the most acceptable product. A 9-point hedonic scale was used to evaluate colour, appearance, aroma, texture, taste, and overall acceptability, where a score of 9 indicated "liked extremely" and a score of 1 indicated "disliked extremely". A 10-member panel of teachers who had prior experience in sensory analysis, were provided with a sensory scorecard and prepared product samples. Each panellist gave their rating based on their likes and dislikes. After conducting the sensory evaluation, a statistical analysis was done.

Results

Dietary Behaviour of Anaemic Adolescent Girls

Meal Consumption Pattern

The frequency distribution of meals consumed per day by anaemic adolescent girls (n=243) is presented in Figure 3. More than half of the respondents (56.0%; 136/243) reported consuming two meals per day, followed by three meals per day (31.3%; 76/243). Only 9.9% (24/243) consumed one meal daily, while 2.9% (7/243) reported consuming four or more meals per day. The mean meal frequency was 2.27 ± 0.67 meals per day, indicating a highly significant predominance of twice-daily meal consumption.

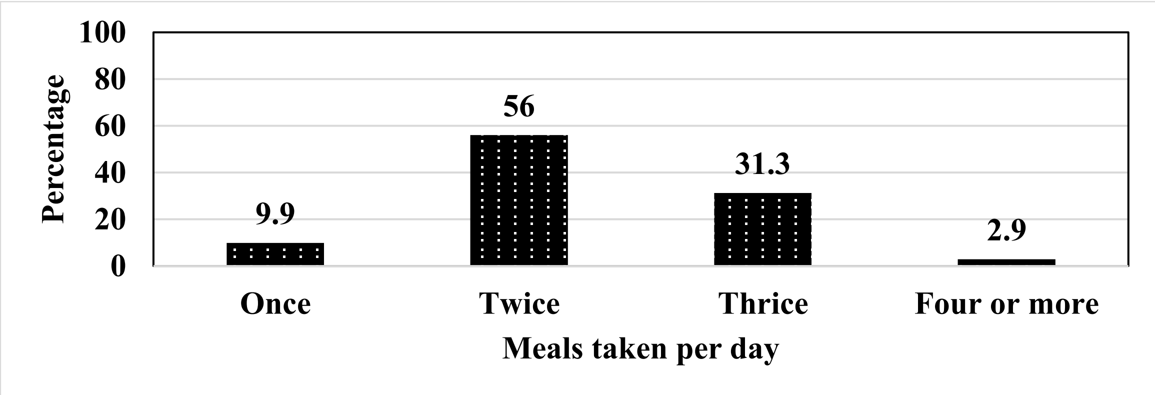

Figure 3: Distribution of the number of meals consumed per day among adolescent girls.
[χ^2 = 166.83, df = 3, p < 0.001].

Meal-Skipping Behaviour

Meal-skipping practices among the adolescent girls are shown in Figure 4. Breakfast emerged as the most frequently skipped meal, reported by 43.2% (105/243) of participants. In contrast, 21.0% (51/243) skipped lunch and only 7.8% (19/243) skipped dinner. Approximately 28.0% (68/243) of the respondents reported not skipping any meals. The observed distribution differed significantly from a uniform distribution (χ^2 = 63.35, p < 0.001), suggesting a marked tendency towards breakfast skipping among the study population.

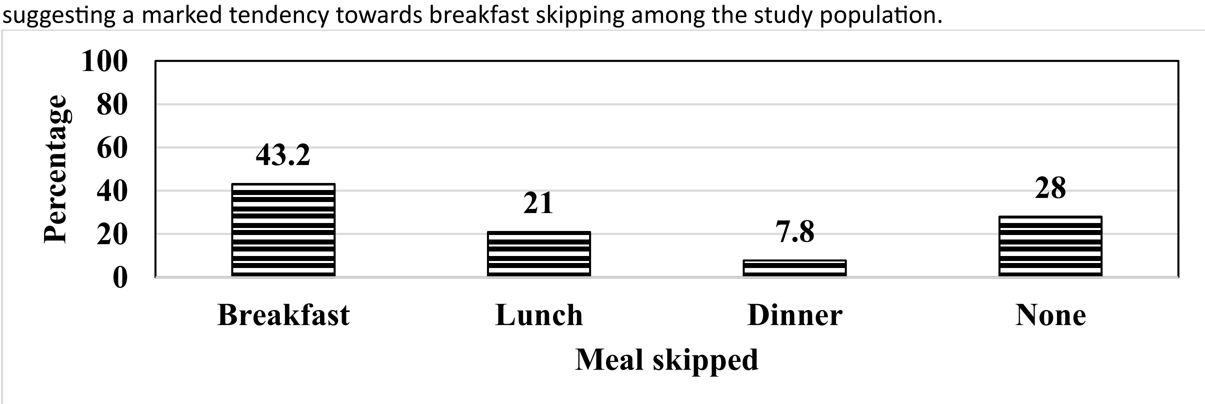

Figure 4: Frequency distribution of the meal most frequently skipped.
[$\chi^2 = 63.35$, df = 3, $p < 0.001$***]

Consumption of Tea, Coffee and Soft Drinks with Meals

The frequency of tea, coffee, and soft drink consumption with meals is presented in Figure 5. Nearly half of the participants (49.4%; 120/243) consumed these beverages daily, 23.9% (58/243) occasionally, and 10.3% (25/243) weekly. Only 16.5% (40/243) reported never consuming such beverages with meals. The mean consumption frequency score was 2.93 ± 1.18. Chi-square analysis indicated a highly significant difference among the consumption categories ($\chi^2 = 86.04$, $p < 0.001$), highlighting the widespread habit of consuming beverages daily during meals. Nearly half of the respondents consumed tea, coffee, or soft drinks with meals daily, which may adversely affect non-haem iron absorption.

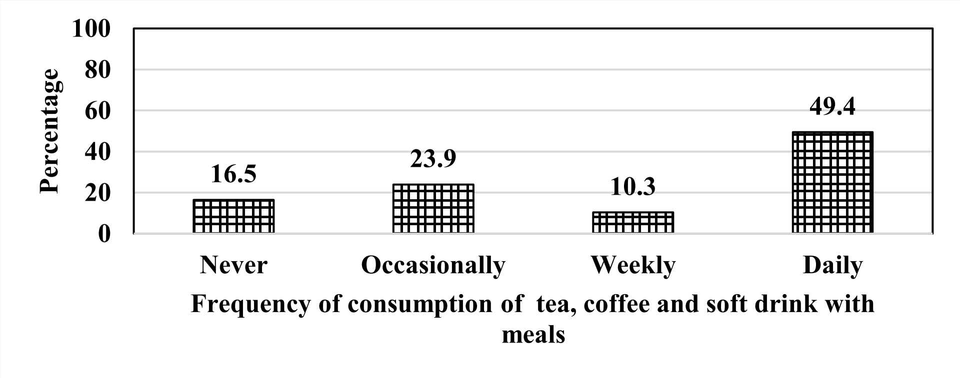

Figure 5: Frequency distribution of tea, coffee and soft drink consumption with meals.
[$\chi^2 = 86.04$, df = 3, $p < 0.001$***]

Reasons for Meal Skipping

To better understand the factors contributing to irregular meal consumption among the respondents, information regarding the reasons for meal skipping was collected and analysed. The findings are presented in Table 1. A total of 72% (175/243) of the girls skipped meals. Lack of appetite or absence of hunger was the most commonly reported reason, cited by 75.4% of meal skippers. Craving for fast food was reported by 42.9% of skippers, while 40.6% indicated no specific reason for skipping meals. A smaller proportion (7.4%) reported dislike of home-cooked food as a contributing factor. These findings suggest that physiological and behavioural factors play an important role in meal-skipping practices among adolescent girls.

Table 1. Reasons cited for skipping meals among adolescent girls

Reason cited	Frequency (n)	% of total sample (n=243)	% among skippers (n=175)
Lack of appetite / no hunger	132	54.3	75.4
Craving for fast food	75	30.9	42.9
Dislike of home-cooked food	13	5.3	7.4
No specific reason	71	29.2	40.6

Fast-Food Craving Pattern

The frequency of fast-food cravings among the respondents was analyzed. Daily craving for fast food was reported by 33.3% (81/243) of participants, while 31.3% (76/243) experienced cravings two to three times per week; 17.7% (43/243) occasionally and 14.8% (36/243) once a week. Only 2.9% (7/243) reported never craving fast food. Collectively, nearly two-thirds of the participants experienced frequent fast-food cravings, reflecting a substantial inclination towards energy-dense convenience foods. Approximately two-thirds (64.6%; 157/243) reported craving fast food either daily or 2–3 times per week.

Food Preference Pattern

Food preference analysis revealed that 41.2% (100/243) of the respondents preferred home-prepared food while attending college, followed by canteen food (35.0%; 84/243), food vendors (15.2%; 37/243), and packaged foods (8.6%; 21/243). The findings indicate that although a substantial proportion of adolescent girls relied on home-prepared meals, more than one-third regularly depended on canteen food, which may influence overall dietary quality and nutrient intake.

Association Analysis

In addition to descriptive analysis, inferential statistical tests were performed to examine the distribution of dietary behaviours and the association between selected variables. The results of these analyses are presented in Table 2. Significant differences were observed in the distributions of meal frequency, meal-skipping patterns and tea/coffee/soft drink consumption ($p < 0.001$). However, no significant association was found between meal-skipping status and the frequency of fast-food cravings ($p = 0.104$). Similarly, tea/coffee consumption did not differ significantly between meal skippers and non-skippers ($p = 0.339$). These findings suggest that although meal-skipping behaviour was highly prevalent, it was not significantly associated with fast-food craving or beverage consumption patterns within the study population.

Table 2. Results of statistical tests of association

Statistical comparison	Test used	N	Test statistic	df	p-value
Distribution of meals/day	χ^2 goodness-of-fit	243	166.83	3	<0.001***
Distribution of meals skipped	χ^2 goodness-of-fit	243	63.35	3	<0.001***
Distribution of tea/coffee frequency	χ^2 goodness-of-fit	243	86.04	3	<0.001***
Fast-food craving vs meal-skipping status	χ^2 independence	243	2.64	1	0.104 NS
Tea/coffee consumption among skippers vs non-skippers	Mann–Whitney U	243	U = 6387.0	—	0.339 NS

NS = Not significant ($p \geq 0.05$). *** $p < 0.001$.

Sensory Evaluation of Sautéed Amla-Moringa Veggie

The sensory scores obtained for the first-stage formulations of Sautéed Amla–Moringa Veggie are presented in Table 3. The formulations were evaluated for colour, appearance, aroma, texture, taste, and overall acceptability to identify the most preferred sweetening agent. In the first stage, V3 was significantly superior to V1 and V2 for all sensory attributes and was therefore selected for further optimization (Table 3). To determine whether the observed differences in sensory scores among the developed variants were statistically significant, one-way ANOVA was performed.

Table 3: Mean sensory scores (Mean ± SD) of Sautéed Amla–Moringa Veggie variants evaluated using a nine-point hedonic scale

Sensory Attribute	Variants			ANOVA		
	V1	V2	V3	F-value	p-value	Significance
Colour	7.20^c ± 0.42	7.90^b ± 0.32	8.10^a ± 0.57	11.17	0.0003	***
Appearance	7.10^c ± 0.32	7.70^b ± 0.48	8.10^a ± 0.74	8.66	0.0012	**
Aroma	6.80^c ± 0.42	8.10^b ± 0.32	8.50^a ± 0.53	42.66	<0.001	***
Texture	6.50^c ± 0.53	7.60^b ± 0.52	8.30^a ± 0.48	31.76	<0.001	***
Taste	6.40^c ± 0.52	7.20^b ± 0.42	8.80^a ± 0.42	72	<0.001	***
Overall Acceptability	6.50^c ± 0.53	7.50^b ± 0.53	8.60^a ± 0.52	40.26	<0.001	***

Values are expressed as Mean ± SD (n = 10). Means within a row bearing different superscripts (a–c) differ significantly at $p \le 0.05$. One-way ANOVA was performed to evaluate differences among the sensory attributes of the developed variants. Values marked with different superscripts in the corresponding sensory evaluation table differ significantly at $p \le 0.05$. *, ** and *** indicate significance at $p \le 0.05$, $p \le 0.01$ and $p \le 0.001$, respectively.

Following the selection of the most acceptable sweetener, the quantity of moringa leaf powder was optimized. The mean sensory scores of the standardized formulations are presented in Table 5. In the second stage, VM2 (20 g moringa leaf powder) recorded the highest overall acceptability (8.70 ± 0.48) and was ranked first (Table 4). Increasing moringa powder to 30 g (VM3) significantly reduced colour, flavour, taste and overall acceptability, likely due to the stronger herbal flavour and characteristic aftertaste of moringa. One-way ANOVA was performed to evaluate the effect of varying moringa leaf powder levels on sensory attributes. Texture did not differ significantly among VM1, VM2 and VM3 ($p = 0.059$), indicating that moringa level primarily affected flavour-related attributes rather than product consistency.

Table 4: Mean Sensory Scores (Mean ± SD) of Standardized Sautéed Amla–Moringa Veggie Variants Developed for Optimization of Moringa Leaf Powder Quantity

Sensory Attribute	Variants			ANOVA		
	VM1 (10 g Moringa)	VM2 (20 g Moringa)	VM3 (30 g Moringa)	F-value	p-value	Significance
Colour	8.00^a ± 0.47	8.20^a ± 0.63	6.70^b ± 0.48	23.26	<0.001	***
Appearance	8.10^a ± 0.74	8.40^a ± 0.70	6.70^b ± 0.48	19.5	<0.001	***
Aroma	8.50^a ± 0.53	8.50^a ± 0.53	7.30^b ± 0.48	18.25	<0.001	***
Texture	8.00^a ± 0.47	8.20^a ± 0.63	7.60^a ± 0.52	3.15	0.059	NS
Taste	8.30^b ± 0.48	8.70^a ± 0.48	6.30^c ± 0.48	70.86	<0.001	***
Overall Acceptability	8.90^a ± 0.32	8.70^a ± 0.48	6.40^b ± 0.52	96.5	<0.001	***

Values are expressed as Mean ± SD (n = 10). Means within a row bearing different superscripts (a–c) differ significantly at $p \le 0.05$ according to one-way ANOVA. Identical superscripts indicate no significant difference among the corresponding variants. F-values and p-values were obtained by one-way ANOVA. NS = not significant ($p > 0.05$); *** significant at $p \le 0.001$. Different superscripts in the corresponding sensory evaluation table indicate significant differences among variants at $p \le 0.05$.

Sensory Evaluation of Coriander–Marwa Chutney

The sensory characteristics of Coriander–Marwa Chutney formulations developed using different nutrient-rich ingredients were evaluated using a 9-point hedonic scale. The mean sensory scores are presented in Table 5. Among the three formulations, C1 supplemented with foxnut powder exhibited the highest sensory acceptability and ranked first, with an overall acceptability of 8.80 ± 0.42. The product received significantly higher scores for colour, appearance, aroma, texture, taste, and overall acceptability than the other variants. The superior acceptability of C1 may be attributed to the smooth consistency and mild flavour imparted by foxnut powder, which complemented the characteristic flavour of coriander and Marwa leaves. The C2 variant supplemented with roasted Bengal gram powder ranked second (7.40 ± 0.52). The incorporation of Bengal gram powder provided a characteristic nutty flavour and improved body to the chutney. Although the flavour profile was generally acceptable, the roasted notes were comparatively more pronounced than in C1, resulting in slightly lower sensory scores. The C3 variant containing green peas obtained the lowest overall acceptability (6.80 ± 0.42) and ranked third. The lower texture and overall acceptability scores suggest that the addition of green peas resulted in a comparatively loose consistency and less desirable mouthfeel, which negatively affected consumer preference.

Table 5: Mean sensory scores (Mean ± SD) of Coriander–Marwa Chutney variants evaluated using a nine-point hedonic scale

Sensory Attribute	Variants					ANOVA
	C1	C2	C3	F-value	p-value	Significance
Colour	9.00^{a}±0.00	7.40^{b}±0.52	7.40^{b}±0.52	48	<0.001	***
Appearance	8.50^{a}±0.53	7.60^{b}±0.52	7.10^{c}±0.32	23.43	<0.001	***
Aroma	8.30^{a}±0.67	7.30^{b}±0.48	7.10^{c}±0.32	15.72	<0.001	***
Texture	8.20^{a}±0.42	7.50^{b}±0.53	6.50^{c}±0.53	30.93	<0.001	***
Taste	8.80^{a}±0.63	7.20^{b}±0.42	6.60^{c}±0.52	52.04	<0.001	***
Overall Acceptability	**8.80^{a}±0.42**	**7.40^{b}±0.52**	**6.80^{c}±0.42**	70.63	<0.001	***

Values are expressed as Mean ± SD (n = 10). Means within a row bearing different superscripts (a–c) differ significantly at p ≤ 0.05. One-way ANOVA was performed to evaluate differences among the sensory attributes of the developed variants. Values marked with different superscripts in the corresponding sensory evaluation table differ significantly at p ≤ 0.05. *, ** and *** indicate significance at p ≤ 0.05, p ≤ 0.01 and p ≤ 0.001, respectively.

Overall, the findings indicate that the type of supplementary ingredient significantly influenced the sensory characteristics of Coriander–Marwa Chutney. Foxnut powder was found to be the most suitable ingredient for enhancing sensory quality and consumer acceptability, whereas green peas adversely affected texture and overall preference. Therefore, C1 was selected as the standardized formulation for subsequent nutritional evaluation and potential dietary application.

In the second stage, the quantity of Marwa leaves in C1 was optimized by preparing three formulations: CM1, CM2, and CM3 containing 10 g, 20 g, and 30 g Marwa leaves, respectively, while maintaining all other ingredients and their quantities constant. Among the three variants, CM2, containing 20 g of Marwa leaves, obtained the highest sensory scores and ranked first in overall acceptability (Table 6). The sensory evaluation of Coriander–Marwa Chutney revealed highly significant differences (p < 0.001) among the three formulations for all sensory attributes. The level of Marwa incorporation markedly influenced colour, aroma, texture, taste, and overall acceptability. Among the formulations, CM2 containing 20 g of Marwa leaves obtained the highest overall acceptability (8.80 ± 0.42) and was ranked first. The formulation received significantly higher scores for colour, appearance, aroma, texture, taste, and overall acceptability than the other variants. The balanced incorporation of Marwa leaves imparted a pleasant herbal flavour while maintaining the desirable sensory characteristics of coriander chutney. The CM1 formulation containing 10 g of Marwa leaves ranked second with an overall acceptability of 7.30 ± 0.48. Although acceptable, Marwa's lower level produced a less pronounced flavour profile and reduced overall sensory appeal compared with CM2. The CM3 formulation containing 30 g of Marwa leaves recorded the lowest overall acceptability (6.50 ± 0.53). Excessive incorporation of Marwa leaves imparted a comparatively strong herbal flavour and affected texture and taste, resulting in significantly lower consumer acceptability. Therefore, CM2 (20 g Marwa leaves) was selected as the standardized formulation for further nutritional evaluation. The significance of differences among the standardized Coriander–Marwa Chutney formulations was assessed using one-way ANOVA.

Table 6: Mean Sensory Scores (Mean ± SD) of Standardized Coriander–Marwa Chutney Variants Developed for Optimization of Marwa Leaf Powder Quantity

Sensory Attribute	Variants			F-value	p-value	Significance
	CM1	CM2	CM3			
Colour	7.30^{b} ± 0.48	9.00^{a} ± 0.00	7.20^{c} ± 0.42	74.68	<0.001	***

Appearance	$7.60^{b} \pm 0.52$	$8.50^{a} \pm 0.53$	$7.10^{c} \pm 0.32$	23.43	<0.001	***
Aroma	$7.30^{b} \pm 0.48$	$8.40^{a} \pm 0.52$	$6.60^{c} \pm 0.52$	32.22	<0.001	***
Texture	$7.50^{b} \pm 0.53$	$8.30^{a} \pm 0.48$	$6.50^{c} \pm 0.53$	30.93	<0.001	***
Taste	$7.10^{b} \pm 0.32$	$8.70^{a} \pm 0.48$	$6.40^{c} \pm 0.52$	69.50	<0.001	***
Overall Acceptability	$7.30^{b} \pm 0.48$	$8.80^{a} \pm 0.42$	$6.50^{c} \pm 0.53$	59.37	<0.001	***

Values are expressed as Mean ± SD (n = 10). Means within a row bearing different superscripts (a–c) differ significantly at p ≤ 0.05 according to one-way ANOVA. Identical superscripts indicate no significant difference among the corresponding variants. F-values and p-values were obtained by one-way ANOVA. NS = not significant (p > 0.05); *** significant at p ≤ 0.001. Different superscripts in the corresponding sensory evaluation table indicate significant differences among variants at p ≤ 0.05.

Nutritive value

All the ingredients in the most acceptable and standardized food products were analysed for iron, calcium, zinc, potassium, dietary fiber, Vitamin C, Vitamin B12, and folate using the Indian Food Composition Tables (Longvah et al., 2017).

The nutrient composition and percent contribution of the standardized Sautéed Amla–Moringa Veggie (formulation VM2) to the recommended dietary allowances (RDA) for adolescent girls are presented in Table 11. The VM2 formulation was found to be a rich source of vitamin C, providing 225.2 mg per 100 g and contributing 321.7 per cent of the recommended dietary allowance for adolescent girls. The product also supplied appreciable amounts of β-carotene (850 µg/100g of product), folate (28.6%), dietary fibre (13.2%), calcium (10.4%) and iron (7.5%). The combination of vitamin C-rich amla and nutrient-dense moringa leaf powder may enhance the bioavailability of non-haem iron and support strategies to improve iron nutrition among adolescent girls.

Table 7: Nutritional composition of standardized Sautéed Amla–Moringa Veggie and its contribution towards Recommended Dietary Allowances (RDA) for adolescent girls (per 100 g edible portion)

Nutrient	Per 100 g VM2	RDA	% RDA
Iron (mg)	2.4	32	7.5
Calcium (mg)	108.8	1050	10.4
Zinc (mg)	0.30	14.2	2.1
Potassium (mg)	250	3500	7.1
Folate (µg)	77.2	270	28.6
Dietary Fibre (g)	5.0	38	13.2
Vitamin C (mg)	225.2	70	321.7

*For food-based product evaluation, β-carotene is commonly compared against approximately 2400 µg/day β-carotene equivalent corresponding to the vitamin A requirement.

The nutrient composition and percent contribution of the standardized Coriander–Marwa Chutney to the recommended dietary allowances (RDA) for adolescent girls are presented in Table 8.

Table 8: Nutritional composition of standardized Coriander–Marwa Chutney and its contribution towards Recommended Dietary Allowances (RDA) for adolescent girls (per 100 g edible portion)

Nutrient	Per 100 g	RDA	% RDA
Iron (mg)	2.4	32	7.5
Calcium (mg)	108.8	1050	10.3
Folate (µg)	77.2	270	28.5
Vitamin C (mg)	63.2	70	90.2
Vitamin B12 (µg)	0.09	2.2	4.1

Discussions

The present study was undertaken to assess dietary behaviours associated with iron deficiency anaemia among adolescent girls and to develop acceptable traditional food products enriched with nutrients known to support

iron status. The findings revealed several dietary practices that may contribute to inadequate iron intake and poor iron bioavailability among the study population. These findings are consistent with those reported by earlier workers (Podder et al., 2018).
More than half of the respondents consumed only two meals per day, and a substantial proportion regularly skipped breakfast. Breakfast was identified as the most frequently skipped meal, followed by lunch. These findings are consistent with those of a cross-sectional study among Indonesian adolescent girls, which reported that breakfast skipping was significantly associated with the occurrence of anaemia, whereas skipping lunch or dinner showed no significant association. This emphasizes the importance of regular breakfast consumption in maintaining adequate nutrient intake and reducing the risk of iron deficiency anaemia (Awalinda et al., 2025). Similar observations have been reported in previous studies among Indian adolescents, in which skipping breakfast has been associated with reduced nutrient intake, poorer dietary quality, and an increased risk of micronutrient deficiencies (Chitra & Reddy, 2007; Arora et., 2012; Jain et al., 2019). Irregular meal consumption may reduce overall intake of iron-rich foods and compromise meeting recommended nutrient requirements.
The study further demonstrated that lack of appetite was the most commonly reported reason for meal skipping, followed by craving for fast foods. Frequent fast-food craving observed among the respondents reflects the ongoing dietary transition among adolescents towards energy-dense, nutrient-poor foods. Such dietary habits may displace traditional nutrient-rich foods from the daily diet and contribute to inadequate intake of iron, folate, vitamins, and other essential micronutrients. Similar concerns have been highlighted by previous researchers who reported increased consumption of processed foods and reduced dietary diversity among adolescents.
Nearly half of the respondents reported consuming tea, coffee, or soft drinks daily with meals. This finding is nutritionally important because polyphenols and tannins present in tea and coffee are known inhibitors of non-haem iron absorption. Regular consumption of such beverages with meals may therefore aggravate iron deficiency by reducing the bioavailability of dietary iron. It has been demonstrated earlier that vitamin C substantially enhances the absorption of non-haem iron and can counteract the inhibitory effects of certain dietary factors (Heffernan et al., 2017; Ramachandran et al., 2024) . These findings provided the rationale for incorporating vitamin C-rich ingredients into the developed food products.
Food product development focused on locally available traditional ingredients possessing high nutrient density and potential benefits for iron nutrition. Sensory evaluation demonstrated significant differences among the developed formulations. In the first stage of standardisation of Sautéed Amla–Moringa Veggie, the jaggery-based formulation achieved the highest sensory scores, suggesting that jaggery's mild sweetness effectively balanced the characteristic sourness of amla. During optimization of moringa incorporation, VM2 obtained the highest acceptability scores. Excessive incorporation of moringa powder reduced sensory acceptance, likely due to the stronger herbal flavour and slight bitterness associated with higher moringa leaf levels. Similar observations have been reported in studies involving moringa-fortified foods, where moderate incorporation levels generally provide better consumer acceptability than higher concentrations.
Among the Coriander–Marwa Chutney formulations, the foxnut-based variant (C1) achieved the highest overall acceptability. Foxnut powder contributed desirable texture and mouthfeel without masking the characteristic flavour of coriander and Marwa leaves. Optimization of Marwa leaf incorporation revealed that CM2 containing 20 g of Marwa leaves achieved superior sensory quality. Higher incorporation levels adversely affected flavour and overall acceptability due to the strong herbal characteristics of Marwa leaves. These findings highlight the importance of balancing nutritional enhancement with sensory quality during product development.
Nutritional evaluation indicated that both standardized products provided appreciable amounts of nutrients relevant to iron metabolism and haemopoiesis. The standardized Coriander–Marwa Chutney supplied iron, calcium, folate, vitamin C, and vitamin B12, contributing 8.9%, 10.9%, 25.7%, 97.2%, and 4.1% of the recommended dietary allowance, respectively. The high vitamin C content is particularly beneficial because it enhances non-haem iron absorption and may improve iron utilization from plant-based diets. Folate contributes to DNA synthesis and red blood cell formation, while calcium and vitamin B12 support overall nutritional status.
The standardized Sautéed Amla–Moringa Veggie exhibited an exceptionally high vitamin C content and provided substantial amounts of folate, dietary fibre, calcium, iron, zinc, potassium, and β-carotene. Amla is recognized as one of the richest natural sources of vitamin C, whereas moringa leaves contain significant quantities of iron, calcium, folate, carotenoids, and antioxidants. The combination of these ingredients is nutritionally advantageous because vitamin C promotes iron absorption, while folate and iron support erythropoiesis. β-carotene may further contribute to improved nutritional status through its provitamin A activity and antioxidant properties.

The findings of the present investigation support the growing body of evidence advocating food-based approaches for the prevention and management of iron deficiency anaemia. Unlike supplementation programmes, food-based strategies are culturally acceptable, sustainable, and capable of delivering multiple nutrients simultaneously. The incorporation of traditional ingredients such as moringa, Marwa, foxnut, coriander, and amla into commonly consumed foods may therefore represent an effective dietary approach for improving nutrient intake among adolescent girls.

Despite these promising findings, the present study has certain limitations. The nutritional evaluation was based on standard food composition data rather than laboratory estimation of the prepared products. Although this approach provides a practical estimate of nutrient content, variations arising from ingredient quality, processing methods, and cooking-related nutrient losses were not considered. Future studies should include laboratory-based nutrient analyses to confirm the nutritional composition of the developed products.

Conclusion

The dietary practices observed among the respondents indicate a substantial risk of inadequate iron intake and poor iron bioavailability. The developed traditional food products demonstrated excellent sensory acceptability and provided nutritionally important amounts of iron-supportive nutrients. Their regular inclusion in the diet may contribute to improved dietary quality and support efforts aimed at reducing the burden of iron deficiency anaemia among adolescent girls.

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Conflict of Interest

The author(s) do not have any conflict of interest.

Data Availability Statement

The manuscript incorporates all datasets produced or examined throughout this research study.

Informed Consent Statement

Written informed consent was obtained from all participants before enrolment in the study. For participants below the age of 18 years, written informed consent was obtained from their parents/legal guardians, and assent was obtained from the participants themselves. Written informed consent was also obtained from all members of the sensory evaluation panel before participation.

Permission to Reproduce Material from Other Sources

Not applicable.

Author Contributions

- Mani Narwal: Conceptualization, Methodology, Data Collection, Analysis, Writing – Original Draft.
- Damini Soni: Supervision, Writing – Review & Editing.
- Prabhjot Kaur: Supervision, Editing.

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