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Development Of Iron (Ferrous Fumarate) Enriched Functional Cookies: A Nutritional Strategy To Mitigate Iron Deficiency In Young Adult Females

Muskan Riaz
Students of Bachelors of Human Nutrition and Dietetics (DHNFT), Faculty of Allied Health Sciences, Superior University, Lahore Email: muskanriaz74@gmail.com

Ali Raza*
Lecturer of Department of Human Nutrition and Food Technology (DHNFT), Faculty of Allied Health Sciences, Superior University, Lahore
Email: aliraza01@superior.edu.pk

Laiba Shahid
Students of Bachelors of Human Nutrition and Dietetics (DHNFT), Faculty of Allied Health Sciences, Superior University, Lahore Email: laibashahid189@gmail.com

Sana Saddique
Students of Bachelors of Human Nutrition and Dietetics (DHNFT), Faculty of Allied Health sciences, Superior University, Lahore Email: sanasaddique69@gmail.com

Author Details

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Corresponding E-mail & Author*:
Muskan Riaz
Email: muskanriaz74@gmail.com

Abstract

Background: Iron deficiency anemia is a common nutritional disorder among young adult females. The present study focused on developing iron-fortified cookies to help reduce iron deficiency anemia in females aged 19-25 years.

Objective: To formulate iron-fortified cookies and evaluate their nutritional composition and sensory acceptability.

Methodology: Three cookie formulations were prepared by fortifying wheat four with different iron concentrations: T1 (10 mg/100 g flour), T2 (15 mg/100 g flour), and T3 (20 mg/100 g flour). Proximate and iron analyses were conducted according to the guidelines of the Association of Official Analytical Chemists (AOAC). Sensory evaluation was carried out by fifteen trained panelists using a 9-point hedonic scale to assess taste, aroma, texture, color, and overall acceptability. Statistical analysis was performed using one-way ANOVA followed by the LSD test.

Results: The nutritional analysis revealed that T3 contained the highest iron content, followed by T2 and T1, indicating that T3 was the most effective formulation nutritionally. Sensory evaluation showed no significant differences among treatments in taste, aroma, texture, color, and overall acceptability ($p > 0.05$). TI was comparatively less preferred, while T2 achieved the highest overall acceptability score ($7.0 \pm 1.24/9$). T3 demonstrated better taste and texture while providing superior iron fortification.

Conclusion: Among all formulations, T2 emerged as the most practical and acceptable option for managing iron deficiency anemia because it provided a balanced combination of sensory acceptability and nutritional benefits.

Introduction

Iron deficiency anemia (IDA) is one of the most common nutritional deficiencies worldwide, particularly affecting women of reproductive age. According to the World Health Organization, nearly 30% of females aged 15-49 years suffer from anemia globally, with higher prevalence reported in developing countries due to poor dietary intake and limited access to nutrient-rich foods [1]. In Pakistan, anemia affects approximately 41-43% of women, especially those living in rural areas [2]. Young adult females aged 19-25 years are more vulnerable because of increased nutritional requirements, irregular eating habits, academic stress, and dependence on low-nutrient foods [3]. Iron plays an essential role in hemoglobin formation, oxygen transport, cognitive development, immunity, and energy metabolism; however, poor dietary practices and low iron absorption continue to contribute to widespread deficiency [4]. Several dietary and physiological factors contribute to iron deficiency anemia. South Asian diets are mainly plant-based and rich in carbohydrates but contain low amounts of highly bioavailable iron [5].

Non-heme iron from plant foods is poorly absorbed, and compounds such as phytates, tannins, calcium, tea, and coffee further reduce its absorption [6]. Inflammation and elevated hepcidin levels also decrease intestinal iron absorption and iron availability for erythropoiesis, increasing the risk of anemia [7]. In addition, rapid urbanization and increased intake of processed foods have resulted in "hidden hunger," where calorie intake is sufficient but micronutrient intake remains inadequate [8].

Menstrual blood loss, skipping meals, and poor nutritional awareness among university students further worsen iron deficiency among young females [9]. Food fortification has emerged as a practical and sustainable strategy to combat micronutrient deficiencies. Bakery products, especially cookies, are considered suitable vehicles for fortification because they are affordable, widely consumed, easy to prepare, and have a long shelf life [10]. Ferrous fumarate is commonly used in food fortification because of its high iron content, good bioavailability, stability, and minimal impact on sensory characteristics such as taste, color, and texture [11].

Previous studies demonstrated that iron- fortified biscuits and cookies improved hemoglobin levels and cognitive performance among adolescent females [12]. Functional foods enriched with iron can therefore provide additional health benefits while maintaining consumer acceptability and convenience [13]. Despite the growing evidence regarding iron fortification, limited research has specifically focused on young adult females aged 19-25 years in Pakistan. Most studies targeted children, pregnant women, or adolescents, leaving a research gap regarding university-going females and their dietary needs [14].

Therefore, this study aimed to develop iron-fortified cookies using ferrous fumarate and evaluate their nutritional composition and sensory acceptability. The study focused on formulation, iron analysis, and sensory evaluation including taste, aroma, texture, and color. However, long- term clinical assessment of hemoglobin or iron biomarkers was beyond the scope of the research. The findings may support future functional food development, nutrition education, and public health interventions aimed at reducing iron deficiency anemia in Pakistan.

LITERATURE REVIEW

Sung H. et al. (2020) conducted a study in Indonesia to evaluate the effectiveness of iron-fortified cassava composite flour cookies in improving hemoglobin levels among adolescent girls with anemia. The study used a single-blind pre-test and post-test experimental design and included 56 participants divided equally into intervention and control groups. Over a period of three months, the intervention group consumed iron-fortified cookies weekly while the control group followed their regular diet. Hemoglobin levels improved in both groups from baseline to mid-intervention, with the intervention group increasing from 11.6 ± 0.9g/dL to 12.0 ± 1.3 g/dL. Although no significant difference was found between groups after ANCOVA analysis, participants with higher compliance and lower baseline hemoglobin levels showed better improvement. The study concluded that iron-fortified cookies may improve iron status when consumed regularly and emphasized the importance of dietary quality and adherence in achieving positive outcomes [15].

Appiah AO et al. (2023) investigated the effect of Turkey berry-fortified biscuits on hemoglobin concentration and cognitive performance among adolescent school girls in Ghana. Participants were randomly divided into intervention and control groups, where the intervention group consumed biscuits fortified with dried Turkey berry, a natural source of iron and antioxidants, while the control group received non-fortified biscuits. At the end of the intervention, hemoglobin levels increased from 11.74g/dL to 12.39 g/dL, and cognitive performance scores also improved significantly. The study suggested that regular intake of iron-rich functional foods can improve iron status and cognitive development in adolescent females. Researchers concluded that Turkey berry-fortified biscuits could serve as an effective functional food for reducing iron deficiency anemia, although they recommended larger sample sizes and longer intervention periods for future studies [16].

Bal et al. (2015) studied the impact of iron-fortified biscuits containing 10-20 mg iron/100g on hemoglobin levels among participants with iron deficiency. Participants were divided into intervention and control groups, where the intervention group consumed iron-fortified biscuits daily for four months while the control group received non-fortified biscuits. Hemoglobin levels in the intervention group increased significantly from 10.34 ± 1.12 g/dL to 11.40 ± 0.98 g/dL, with a mean increase of +1.06 g/dL ($p < 0.01$). Sensory evaluation showed that fortification did not negatively affect taste, aroma, or appearance, indicating good consumer acceptability. The study concluded that iron-fortified bakery products could be an effective and practical strategy for reducing iron deficiency anemia without compromising sensory quality [17].

Bhattacharya et al. (2021) developed iron-fortified whey protein biscuits using whey protein concentrate and ferrous sulfate at different fortification levels ranging from 10 to 30 mg/100 g. The study aimed to improve the nutritional quality of bakery products while maintaining sensory acceptability. Nutritional analysis revealed a significant increase in iron and protein content in fortified biscuits compared to the control formulation. Sensory evaluation using a hedonic scale demonstrated that moderate levels of fortification maintained acceptable taste, texture, appearance, and overall acceptability, while excessive iron addition slightly reduced consumer preference because of metallic taste and color changes. The researchers concluded that iron-fortified whey protein biscuits can serve as functional foods with enhanced nutritional value and acceptable sensory characteristics, making them suitable for addressing iron deficiency anemia [18].

MATERIALS AND METHODS

1. RESEARCH DESIGN:

This research was an experimental RCT.

2. AREA OF STUDY:

The research work was carried out at the Pakistan Council of Scientific and Industrial Research Laboratories, and Culinary Laboratory of the Faculty of Allied Health Science, Superior University, Lahore, Pakistan.

3. DURATION OF STUDY:

This study was completed in 4 months after the approval of the synopsis from institutional review board committee.

4. PROCUREMENT OF RAW MATERIALS

All required row materials, including wheat flour, sugar, shortening, eggs, baking powder, vanilla essence, and ferrous fumarate as the iron fortificant. All ingredients were procured from the local market within Lahore to ensure accessibility and feasibility for community-level production.

5. PREPARATION OF RAW MATERIAL

Raw materials were [18]:□ Received and verified □ Packed in air-tight containers

- Stored in cool dry place
- Labelled with batch numbers
- Kept away from direct sunlight

5.1 Treatment Plan:

Treatments	Wheat Flour (%)	Butter (%)	Sugar (%)	Iron (%)
T0 (Control)	58.80 %	17.6 %	23.5 %	0 %
T1	58.80 %	17.6 %	23.5 %	0.010 %
T2	58.80 %	17.6 %	23.5 %	0.015 %
T3	58.80 %	17.6 %	23.5 %	0.020 %

6. FORMULATION OF COOKIES:

Four types of cookies were formulated, one was control sample (T0) without fortification of iron with 100% wheat flour and three fortified samples (T1, T2, T3) with different iron ratios. The ratio of iron for each sample was based on previous study *i.e.* 10, 15 and 20 mg/100 g flour [18]. Cookies were baked at 170^0 C for 6 minutes as described in previous study done by Bhattacharya et al. (2021) [18].

6.1 Machines and apparatus required:

Microwave oven, weighing machine, blenders, sieve, rolling pin, rolling board, cutter [18].

7. FORMULATIONS:

7.1 Formulation and Preparation Flowchart

Following was the quantitative data of the ingredients, maintaining a consistent base of wheat flour, butter, and sugar, while varying the iron fortification levels across treatments. Minor and basic ingredients provided the supporting role and their values were kept constant to ensure that any observed differences were solely due to iron fortification levels.

Raw material selection

↓

Weighing of wheat flour

(T0: 58.80%, T1: 58.80%, T2: 58.80%, T3: 58.80%)

↓

Weighing of iron (Ferrous fumarate)

(T0: 0%, T1: 0.010%, T2: 0.015%, T3: 0.020%)

(Equivalent to: T0: 0mg, T1: 10mg, T2: 15mg, T3: 20mg per 100 g flour)

↓

Weighing of constant dry & minor ingredients

(Baking powder: 1.0 g → Baking soda: 0.5 g)
↓
Sieving of dry ingredients
(Wheat flour, iron source, baking powder, and baking soda passed through a 52-mesh sieve)
↓
Creaming of wet ingredients
(Whisking of 17.6% Butter + 23.5% Sugar + 1 mL Vanilla essence until a creamy texture is formed)
↓
Dry mixing
(Homogeneous mixing of all sieved dry ingredients)
↓
Addition of wet ingredients & Cream
(Combining the whisked butter-sugar mixture with the dry blended ingredients)
↓
Kneading to form dough
(Kneading the mixture with the help of a controlled amount of water until a uniform dough is formed)
↓
Rolling of dough
(Rolling the dough to uniform thickness using a rolling pin and board)
↓
Cutting & Shaping
(Shaping the biscuits using a standard cookie cutter)
↓
Baking
(Baking in a preheated oven at 170°C for 6 minutes)
↓
Cooling
(Cooling the baked cookies at room temperature before packaging)
↓
Packaging & Storage

DATA ANALYSIS:

Proximate analysis

Proximate analysis of the cookies was carried out using standardized Association of Official Analytical Chemists (AOAC) methods to determine moisture, crude protein, crude fat, crude fiber, ash content, nitrogen-free extract (NFE), iron content, and energy value [18, 19, 20,21].

Moisture content:

Moisture content was determined using the hot air oven method, while crude protein was estimated by the Kjeldahl method [18].

Crude Fat & Crude Fiber:

Crude fat analysis was performed using Soxhlet extraction with petroleum ether, and crude fiber was determined through acid and alkali digestion [18,19].

Ash content & Nitrogen-Free Extract (NFE):

Ash content was measured by dry ashing in a muffle furnace, whereas NFE was calculated by difference method using following formula:

NFE (%) = 100 – (Moisture + Protein + Fat + Ash + Crude Fiber) [20,18].

Iron Determination:

Iron concentration in cookie samples was analyzed using Atomic Absorption Spectrophotometry (AAS) after acid digestion of the samples [18].

Energy Calculation:

Energy values were calculated using Atwater general factors by considering protein, fat, and carbohydrate contents.

Energy (kcal/100g) = (Protein x 4) + (Fat x 9) + (Carbohydrates x 4) [21].

Sensory Evaluation

Sensory evaluation of iron fortified cookies was conducted using fifteen participants. Semi-trained panelists were chosen for the assessment of cookies; all were the postgraduate teachers from Superior University's Allied Health Sciences Department. Cookies were assessed for taste, aroma, texture, color and overall acceptability using a 9-point hedonic scale [18]. A nine-point hedonic scale is a scale with nine numbers (1 being disliked extremely, 5 being neither like nor dislike, 9 being liked extremely) to assess five parameters: taste, aroma, texture, color and overall acceptability. Participants provided feedback and results were statistically analyzed.

RESULTS

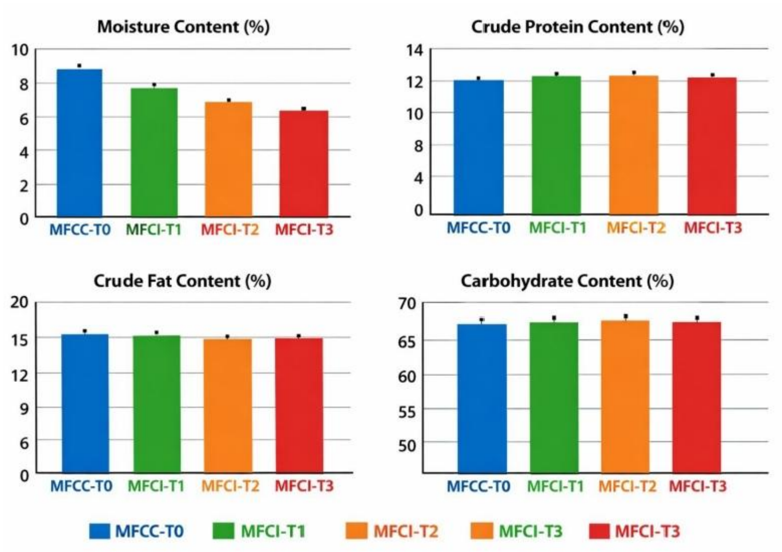
Proximate Analysis

The proximate analysis of the cookie samples demonstrated that iron fortification produced slight variations in nutritional composition while maintaining overall product quality. The control sample (T0) contained 66.51% carbohydrates, 6.72 ± 0.06% crude protein, 21.42 ± 0.05% crude fat, 3.34 ± 0.05% moisture, 1.18 ± 0.02% ash, and 0.44 ± 0.01% crude fiber, providing a total energy value of 487.26kcal/100 g.

Different treatments extraction of carbs, protein, fat, moisture, ash, fiber, energy

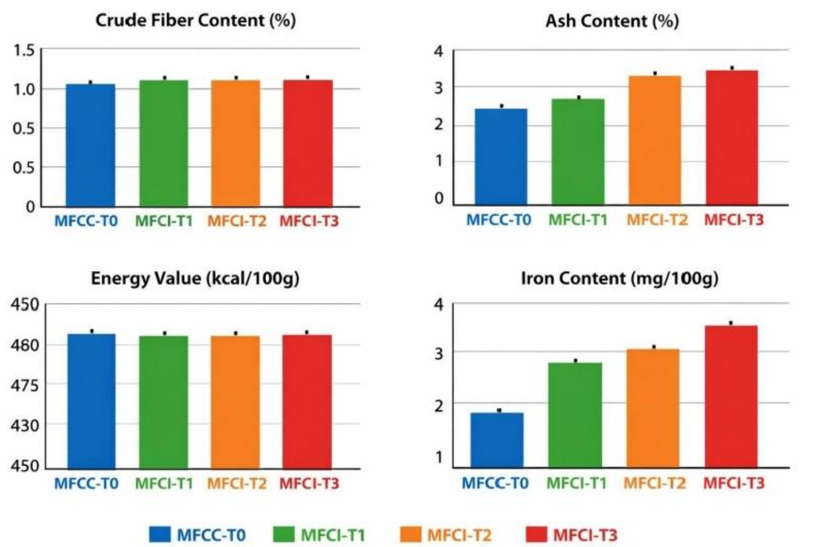
Parameter	T0 (Control)	T1	T2	T3
Moisture (%)	3.34 ± 0.05	3.28 ± 0.04	3.21 ± 0.03	3.16 ± 0.05
Ash (%)	1.18 ± 0.02	1.36 ± 0.03	1.52 ± 0.02	1.67 ± 0.03
Crude Protein (%)	6.72 ± 0.06	6.75 ± 0.05	6.81 ± 0.04	6.86 ± 0.05
Crude Fat (%)	21.42 ± 0.05	21.45 ± 0.05	21.47 ± 0.04	21.50 ± 0.05
Crude Fiber (%)	0.44 ± 0.01	0.46 ± 0.01	0.48 ± 0.02	0.50 ± 0.01
Nitrogen Free Extract (%)	66.51	66.90	66.70	66.31
Energy (kcal/100g)	487.26	486.85	486.18	486.51

% values of moisture, crude protein, fat and carbs among all treatment groups



As the concentration of ferrous fumarate increased from T1 to T3, moisture content showed a gradual decline, whereas ash, crude protein, crude fat, and fiber contents increased slightly. The highest fortified treatment (T3) showed the greatest ash content (1.67 ± 0.03%) and crude fiber (0.50 ± 0.01%) indicating improved mineral enrichment and nutritional value without major alteration in caloric content. Iron analysis confirmed successful fortification of cookies with ferrous fumarate at different treatment levels. The control sample (T0) naturally contained only 1.15 ± 0.05 mg iron/100 g flour, whereas fortified treatments showed progressively higher iron levels according to the amount of fortificant added. Treatment T1 fortified with 10 mg ferrous fumarate contained 6.42 ± 0.10 mg iron/100 g, T2 fortified with 15 mg contained 9.76 ± 0.12mg/100 g, and T3 fortified with 20 mg showed the highest iron content of 13.05 ± 0.15mg/100g. These findings demonstrate that iron fortification effectively enhanced the iron concentration of cookies and remained within the recommended dietary allowance for women of reproductive age.

% values of crude fiber, ash, energy and iron among different treatment groups



Quantities and iron content of ferrous fumarate used in fortified cookies.

Treatment	Ferrous Fumarate (mg/100g)	Iron content (mg/100 g)
T0	**-**	1.15 ± 0.05

T1	10	6.42 ± 0.10
T2	15	9.76 ± 0.12
T3	20	13.05 ± 0.15

Sensory Evaluation

Sensory evaluation revealed that iron fortification had no statistically significant effect on the organoleptic characteristics of cookies ($p > 0.05$). Parameters including taste, aroma, texture, color, and overall acceptability remained comparable among all treatments and the control sample. All sensory scores shared the same superscript letter "a," indicating no significant differences according to one-way ANOVA followed by LSD post hoc analysis.

Effect of iron fortification on sensory evaluation of iron fortified biscuits

Samples	Taste	Aroma	Texture	Color	Overall Acceptability
Control cookies (T0)	7.20 ± 1.93a	6.20 ± 2.27a	6.80 ± 1.82a	6.80 ± 2.11a	7.00 ± 1.65a
Fortified cookies (T1)	6.64 ± 2.06a	6.21 ± 2.19a	6.64 ± 1.55a	6.71 ± 2.02a	6.79 ± 1.63a
Fortified cookies (T2)	6.29 ± 1.77a	6.21 ± 1.85a	6.64 ± 1.65a	6.64 ± 1.86a	7.00 ± 1.24a
Fortified cookies (T3)	6.43 ± 1.40a	6.43 ± 1.45a	6.93 ± 1.21a	6.79 ± 1.37a	6.93 ± 1.00a
p-value	0.545	0.988	0.955	0.996	0.974
LSD (0.05)	1.33	1.44	1.15	1.37	1.03

These results suggest that incorporation of ferrous fumarate did not negatively affect consumer perception or eating quality of the fortified cookies. Among all fortified treatments, T2demonstrated the highest overall acceptability score (7.00 ± 1.24), equal to the control sample, while T3 also showed favorable consumer acceptance (6.93 ± 1.00). Texture scores were highest in T3 (6.93 ± 1.21), whereas control cookies had slightly higher taste scores (7.20 ± 1.93). The p-values for taste, aroma, texture, color, and overall acceptability were 0.545, 0.988, 0.955, 0.996, and 0.974 respectively, confirming that fortification levels did not significantly influence sensory properties. Overall, the study demonstrated that iron fortification using ferrous fumarate can improve nutritional quality and iron content of cookies without compromising sensory acceptability.

DISCUSSION

The present study demonstrated that iron-fortified cookies can serve as an effective and practical dietary strategy to improve iron intake among females of reproductive age who are at risk of iron deficiency anemia. Since cookies are widely consumed, convenient, and ready-to-eat snack products, they provide an appropriate vehicle for micronutrient fortification without requiring significant dietary modifications. The findings showed that fortification with ferrous fumarate successfully increased the iron content of cookies while maintaining acceptable nutritional quality and sensory characteristics. Sensory evaluation confirmed that taste, aroma, texture, color, and overall acceptability were not significantly affected by iron addition, indicating that the fortified cookies remained highly acceptable to consumers and suitable for regular consumption. The proximate analysis revealed only minor variations in nutritional composition among the fortified treatments.

Moisture content slightly decreased with increasing iron fortification, which may contribute to improved shelf stability of the cookies. Ash content increased progressively from T0 to T3, confirming successful incorporation of iron minerals into the formulation. Crude protein, fat, and fiber contents showed only minimal changes, indicating that iron fortification did not negatively influence the nutritional balance or functional quality of the product. Nitrogen-free extract and energy content showed a slight decline due to the increase in mineral content; however, carbohydrates remained the major nutrient component, preserving the cookies energy-providing function. Overall, the fortification process enhanced mineral value without compromising caloric or macronutrient composition. Sensory evaluation findings further supported the suitability of iron fortification in bakery products. All cookie samples received good sensory scores ranging from 6.20 to 7.20, reflecting favorable consumer acceptance. Although the control sample achieved the highest taste score, fortified samples T2 and T3 demonstrated comparable overall acceptability, suggesting that the addition of ferrous fumarate did not adversely affect sensory quality. Statistical analysis confirmed no significant differences ($p > 0.05$) among control and fortified samples for all sensory parameters.

These results indicate that ferrous fumarate is an appropriate fortificant for cookies because it effectively improves iron content while preserving desirable organoleptic properties, which is essential for consumer compliance and long-term dietary use. The findings of the present study are consistent with previous national and international research supporting the use of fortified bakery products to combat iron deficiency anemia. Similar studies by Pervez et al. (2023), Anis et al. (2023), and Bal et al. (2015) also reported improvements in iron intake and hemoglobin status through fortified food products while maintaining acceptable sensory characteristics. International studies by Sung et al. (2020) and Appiah et al. (2023) further confirmed the nutritional benefits of iron-fortified biscuits and cookies. However, the present study contributes additional evidence by demonstrating that ferrous fumarate-fortified cookies provide controlled iron enrichment with excellent sensory acceptability in young adult females in Pakistan, where iron deficiency remains a major public health concern.

CONCLUSION

Iron deficiency anemia remains an important nutritional problem in females of reproductive age especially in developing countries like Pakistan. The present study focuses on the development of iron-fortified cookies using ferrous fumarate and evaluated their nutritional content along with sensory acceptability in young adult females. The findings of this study tells that iron fortification had successfully improved the nutritional value of the cookies without having any negative effects on their sensory parameters. The results of sensory evaluation shows that taste, texture, color, aroma and overall acceptability remained the same saying that fortification did not affect the consumer preference.

This is an important result as acceptability plays a main role in success of functional foods interventions. Also, the study suggests that cookies can serve as a right vehicle for iron fortification due to their wide consumption and ease of adding into daily diets. The use of ferrous fumarate proved to be an effective method for improving iron content while maintaining product quality. Overall, iron-fortified cookies may represent a practical and acceptable food- based method to improve dietary intake of iron in young adult females and may participate to the nutritional management of iron deficiency anemia. However, further studies involving clinical assessment of hemoglobin levels and long-term effects of consumption are suggested to fully create their impact on iron status.

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