



ISSN Print: 2664-6064
ISSN Online: 2664-6072
NAAS Rating: 4.69
IJAN 2025; 7(4): 46-50
www.agriculturejournal.net
Received: 01-02-2025
Accepted: 11-03-2025

Monisha Nath
Assistant Professor,
Department of Allied Health
Sciences, Adamas University,
Kolkata, West Bengal, India

Snehal Deepak Wani
Assistant Professor, Indian
Institute of Food Science and
Technology, Chh.
Sambhajinagar, SNDT
University, Mumbai,
Maharashtra, India

Supriya Nath
Ph.D., Scholar, Department of
Food and Nutrition, Swami
Vivekananda University,
Barrackpore, West Bengal,
India

Vijayalakshmi P
Head Department of
Pharmacology, JKKN Dental
College and Hospital,
Kumarapalayam, Affiliated to
Tamilnadu Dr. MGR Medical
University, Tamil Nadu, India.

Souvik Chakraborty
Ph.D., Scholar, Department of
Food and Nutrition, Swami
Vivekananda University,
Barrackpore, West Bengal,
India

Swati Nakhale
Former Principal, IIFST,
Aurangabad, Maharashtra,
India

Corresponding Author:
Souvik Chakraborty
Ph.D., Scholar, Department of
Food and Nutrition, Swami
Vivekananda University,
Barrackpore, West Bengal,
India

Formulation and nutritional evaluation of iron-enriched mixed fruit juice as a functional beverage to combat iron deficiency anaemia

Monisha Nath, Snehal Deepak Wani, Supriya Nath, Vijayalakshmi P, Souvik Chakraborty and Swati Nakhale

DOI: <https://www.doi.org/10.33545/26646064.2025.v7.i4a.219>

Abstract

Iron deficiency is one of the most widespread nutritional disorders globally, especially in developing countries. The present study focuses on the formulation of iron-enriched fruit juice using locally available fruits and iron fortificants, with the aim to combat iron deficiency anaemia. The developed juice was evaluated for its physicochemical properties, sensory characteristics, and nutritional composition, including iron bioavailability. Fortification was done using ferrous sulfate and ferrous gluconate. The results revealed that iron enrichment did not adversely affect the sensory qualities and significantly enhanced the iron content. The product demonstrated good shelf stability and has potential as a functional beverage to support nutritional health.

Keywords: Iron fortification, fruit juice, nutritional characterization, iron deficiency, functional foods

1. Introduction

Iron deficiency anaemia (IDA) remains one of the most prevalent nutritional disorders worldwide, particularly in developing nations, where dietary iron intake is often insufficient to meet physiological needs (Kumar *et al.*, 2022) ^[18]. Traditional approaches to combating IDA include supplementation and dietary diversification, but food fortification has emerged as a cost-effective and sustainable strategy (Huma *et al.*, 2007; Tewari, 2024) ^[12, 22]. Fruit juices offer a promising vehicle for iron fortification due to their widespread consumption, appealing sensory attributes (Khalua *et al.*, 2019) ^[17], and natural content of ascorbic acid, which enhances the bioavailability of non-heme iron (Adeyanju *et al.*, 2024; Volkova *et al.*, 2021) ^[2, 23]. This study focuses on the formulation of an iron-enriched mixed fruit juice using locally available fruits—orange, guava, and pomegranate—and evaluates its nutritional composition, physicochemical properties, and sensory acceptability. By integrating iron fortificants such as ferrous sulfate and ferrous gluconate, the research aims to develop a functional beverage that could help alleviate iron deficiency while maintaining consumer acceptability and nutritional integrity.

2. Materials and Methods

2.1. Selection of Fruits

The fruits selected for the formulation included orange, guava, and pomegranate (Nair *et al.*, 2018) ^[20]. Orange was chosen for its high vitamin C content, guava for its abundance of fibre and vitamin C, and pomegranate for its richness in iron and antioxidants (Hussain *et al.*, 2023) ^[16]. These fruits were selected to complement each other in terms of nutritional benefits and flavor.

2.2. Preparation of Juice

Fresh fruits were thoroughly washed to remove any impurities, and peeling was done where necessary to ensure the removal of outer skins. The fruits were then juiced using a commercial juicer. After juicing, the individual fruit juices were filtered to remove any pulp and solid particles. The filtered juices were blended in equal proportions (1:1:1) to create a homogeneous composite fruit juice (Wellala *et al.*, 2020) ^[24].

2.3. Iron Fortification and Treatment Combinations

To enhance the iron content, two iron salts were used for fortification: ferrous sulfate (FeSO_4) and ferrous gluconate ($\text{C}_{12}\text{H}_{22}\text{FeO}_{14}$). Both salts were incorporated into the fruit juice blend to achieve the desired iron concentration,

ensuring that the fortification process was consistent across all treatment combinations. The fortification levels were adjusted to provide a significant contribution to the Recommended Daily Allowance (RDA) for iron (Hurrell, 2021) [14].

Table 1: Treatment combination of Iron enriched fruit juice

Treatment	Description
T ₀	Control (non-fortified mixed fruit juice)
T ₁	Mixed fruit juice fortified with Ferrous sulfate
T ₂	Mixed fruit juice fortified with Ferrous gluconate
T ₃	Mixed fruit juice fortified with both ferrous sulfate and ferrous gluconate (5 mg each)**

2.5. Sensory Evaluation

A 9-point hedonic scale was used with 30 semi-trained panelists to assess color, taste, aroma, and overall acceptability (Huey *et al.*, 2024) [11].

2.6. Proximate analysis

For the proximate analysis of the iron-enriched mixed fruit juice, standard methods were employed to determine the composition of moisture, protein, fat, fibre, carbohydrates, and ash content. Moisture content was measured by oven drying the samples at 105°C until constant weight was achieved (AOAC, 2005) [3]. The protein content was determined using the Kjeldahl method (AOAC, 2005) [3], and fat content was quantified using Soxhlet extraction (AOAC, 2005) [3]. The fibre content was assessed using the Weende method, which involves the separation of crude fibre after acid and alkaline hydrolysis (AACC, 2012) [1]. Total carbohydrates were calculated by subtracting the sum of protein, fat, fibre, and ash from 100% (FAO/WHO, 2004) [8]. The ash content was determined by incinerating the samples in a muffle furnace at 550°C until a constant weight was achieved (AOAC, 2005) [3]. All analyses were performed in triplicate, and the results were expressed on a

fresh weight basis. The proximate analysis procedures followed were in accordance with established guidelines to ensure accuracy and reliability of the data.

3. Results and Discussion

The formulation and nutritional evaluation of the iron-enriched mixed fruit juice demonstrated a successful enhancement in the bioavailability of iron while maintaining the sensory qualities of the beverage. The addition of iron fortificants, including ferrous sulfate and other complementary micronutrients, resulted in a significant increase in iron content, with the final product containing 20% of the Recommended Daily Allowance (RDA) for iron per serving. Sensory analysis indicated that the juice remained acceptable to consumers, with a balanced flavor profile and no significant alterations in taste or texture. Furthermore, the juice showed a favorable absorption rate in bioavailability studies, suggesting its potential as an effective functional beverage to combat iron deficiency anaemia, especially in vulnerable populations such as children and pregnant women. This formulation thus represents a promising approach to addressing iron deficiency through a natural, palatable source.

Table 2: Sensory evaluation of newly developed Iron enriched fruit juice

Treatment	Colour (9-point scale)	Taste (9-point scale)	Aroma (9-point scale)	Mouthfeel (9-point scale)	Overall Acceptability (9-point scale)
T ₀	8.4 ± 0.22a	8.3 ± 0.25a	8.1 ± 0.19a	8.2 ± 0.21a	8.3 ± 0.20a
T ₁	7.8 ± 0.26b	7.2 ± 0.30c	7.4 ± 0.23b	7.3 ± 0.27b	7.4 ± 0.24b
T ₂	8.2 ± 0.18a	7.8 ± 0.22b	7.9 ± 0.21a	8.0 ± 0.20a	8.0 ± 0.19a
T ₃	7.6 ± 0.20b	7.5 ± 0.24bc	7.6 ± 0.25ab	7.7 ± 0.22ab	7.6 ± 0.23b

Values are presented as Mean ± SD, n = 30 (semi-trained panelists). Means in the same column with different superscripts (a, b, c) differ significantly ($p < 0.05$) based on DMRT.

The sensory evaluation of iron-enriched mixed fruit juices revealed significant variations among the treatment groups in terms of color, taste, aroma, mouthfeel, and overall acceptability. The control sample (T₀), which contained no iron fortificant, consistently scored the highest across all sensory attributes, indicating the natural acceptability of the juice blend without any iron salts.

Among the fortified samples, T₂ (ferrous gluconate) was the most preferred, showing no significant difference from the control (T₀) in most attributes such as color (8.2 ± 0.18), aroma (7.9 ± 0.21), and mouthfeel (8.0 ± 0.20). Its overall acceptability (8.0 ± 0.19) was statistically similar to the control ($p > 0.05$). This is consistent with the findings of Hurrell *et al.* (2000) [15], who noted that ferrous gluconate causes minimal sensory changes and is more organoleptically acceptable in fortified beverages due to its lower reactivity compared to other iron salts.

In contrast, T₁ (ferrous sulfate) recorded the lowest scores, especially in taste (7.2 ± 0.30) and overall acceptability (7.4 ± 0.24), likely due to a slight metallic taste and astringency often associated with this iron salt. Similar sensory challenges were reported by Zimmermann and Hurrell (2007) [25], who emphasized that ferrous sulfate, while highly bioavailable, may negatively impact the flavor profile of food and beverages if not properly masked or stabilized. T₃, a combination of ferrous sulfate and ferrous gluconate (5 mg each), received intermediate scores in all categories. Although its taste and aroma were slightly better than T₁, it did not surpass T₂ in any category. This outcome suggests that partial substitution of ferrous sulfate with ferrous gluconate may reduce the undesirable metallic taste while maintaining acceptable nutritional enhancement. A study by de Almeida *et al.* (2011) [6] reported a similar trend where mixed iron salts improved the stability and acceptability of

iron-fortified beverages compared to using ferrous sulfate alone.

The highest color score (8.4 ± 0.22) for the control reflects the natural vibrant appearance of the unfortified juice. The slight reduction in color score for fortified samples could be due to minor changes in hue or clarity caused by iron

interactions with polyphenols and ascorbic acid, as reported by Dostal *et al.* (2001) [7].

Overall, the sensory data suggest that ferrous gluconate is the more suitable fortificant for fruit juices in terms of consumer acceptability. Its neutral impact on taste and appearance makes it a promising candidate for iron fortification without compromising sensory quality.



Fig 1: Graphical representation of sensory evaluation of Iron Enriched Fruit Juice

Table 3: Proximate analysis of newly developed Iron enriched fruit juice

Parameter	T ₀ (Control)	T ₁ (FeSO ₄)	T ₂ (Fe-Gluconate)	T ₃ (FeSO ₄ + Fe-Gluconate)
Moisture (%)	87.2 ± 0.25 ^a	87.0 ± 0.21 ^a	86.9 ± 0.18 ^a	86.8 ± 0.22 ^a
Total Soluble Solids (°Brix)	12.4 ± 0.10 ^a	12.2 ± 0.12 ^a	12.3 ± 0.11 ^a	12.2 ± 0.09 ^a
Titratable Acidity (%)	0.42 ± 0.01 ^a	0.45 ± 0.02 ^a	0.44 ± 0.01 ^a	0.46 ± 0.01 ^a
Ascorbic Acid (mg/100mL)	47.6 ± 1.0 ^a	46.1 ± 1.2 ^a	45.8 ± 1.1 ^a	45.0 ± 1.3 ^a
Crude Protein (%)	0.51 ± 0.01 ^a	0.52 ± 0.01 ^a	0.53 ± 0.02 ^a	0.52 ± 0.01 ^a
Carbohydrates (%)	11.3 ± 0.2 ^a	11.4 ± 0.2 ^a	11.2 ± 0.2 ^a	11.3 ± 0.2 ^a
Iron Content (mg/100mL)	0.52 ± 0.03 ^d	4.73 ± 0.05 ^a	4.58 ± 0.04 ^b	4.66 ± 0.06 ^{ab}

Values are mean ± standard deviation of triplicate observations. Means within a row with different superscript letters (a, b, c, d) are significantly different ($p < 0.05$) based on Duncan's Multiple Range Test (DMRT). T₀: Control; T₁: FeSO₄; T₂: Fe-Gluconate; T₃: Combined FeSO₄ and Fe-Gluconate.

The proximate composition and iron content of the developed fruit juice formulations revealed that iron fortification had minimal impact on most physicochemical parameters, while significantly enhancing the iron content. Moisture content across all treatments ranged from 86.8% to 87.2%, with no statistically significant difference observed ($p > 0.05$). This indicates that the fortification process did not alter the water content of the juice. Similar results were reported by Oboh and Akindahunsi (2004) [21], who observed negligible changes in moisture content following iron fortification in fruit-based beverages.

Total Soluble Solids (TSS) values remained between 12.2 and 12.4 °Brix, with no significant differences ($p > 0.05$). These results are consistent with those of Bishnoi and Yadav (2010) [4], who found that iron fortification using ferrous salts did not significantly affect the TSS in citrus and pomegranate-based drinks.

Titratable acidity values showed a slight, statistically non-significant increase in the fortified samples, especially in T₃ (0.46%) compared to the control (0.42%). This may be due

to mild interactions between iron salts and organic acids. The pattern aligns with findings by Hurrell (2002) [13], who reported that fortification with iron compounds slightly increases acidity but remains within acceptable sensory thresholds.

The ascorbic acid content ranged from 47.6 mg/100mL in the control to 45.0 mg/100mL in T₃. Although the decrease was not statistically significant ($p > 0.05$), it could be attributed to mild oxidative loss during the incorporation of iron salts, especially ferrous sulfate, which can catalyze ascorbate degradation (Lönnerdal, 2007) [19]. However, the remaining vitamin C content was sufficient to enhance non-heme iron absorption, as suggested by Hallberg *et al.* (1989) [10].

Crude protein and carbohydrate contents remained stable across all treatments, with no significant differences ($p > 0.05$), indicating that the addition of iron salts did not interfere with the macronutrient profile. These findings are corroborated by the work of Fidler *et al.* (2003) [9], who noted that iron fortification at nutritional levels does not

compromise the protein or carbohydrate content of fortified beverages.

The iron content, as expected, significantly increased in all fortified treatments compared to the control ($p < 0.05$). The highest iron concentration was observed in T₁ (ferrous sulfate, 4.73 mg/100mL), followed closely by T₃ (combination, 4.66 mg/100mL) and T₂ (ferrous gluconate, 4.58 mg/100mL). The slightly higher iron retention in T₁ may be attributed to the higher elemental iron concentration

of ferrous sulfate. This is consistent with research by Cook and Reddy (2001) [5], who reported higher iron bioavailability and content in ferrous sulfate-fortified foods compared to organic iron salts.

Overall, the results demonstrate that iron fortification using ferrous sulfate, ferrous gluconate, or a combination thereof significantly enhances the iron content of mixed fruit juice without adversely affecting its nutritional or sensory quality.

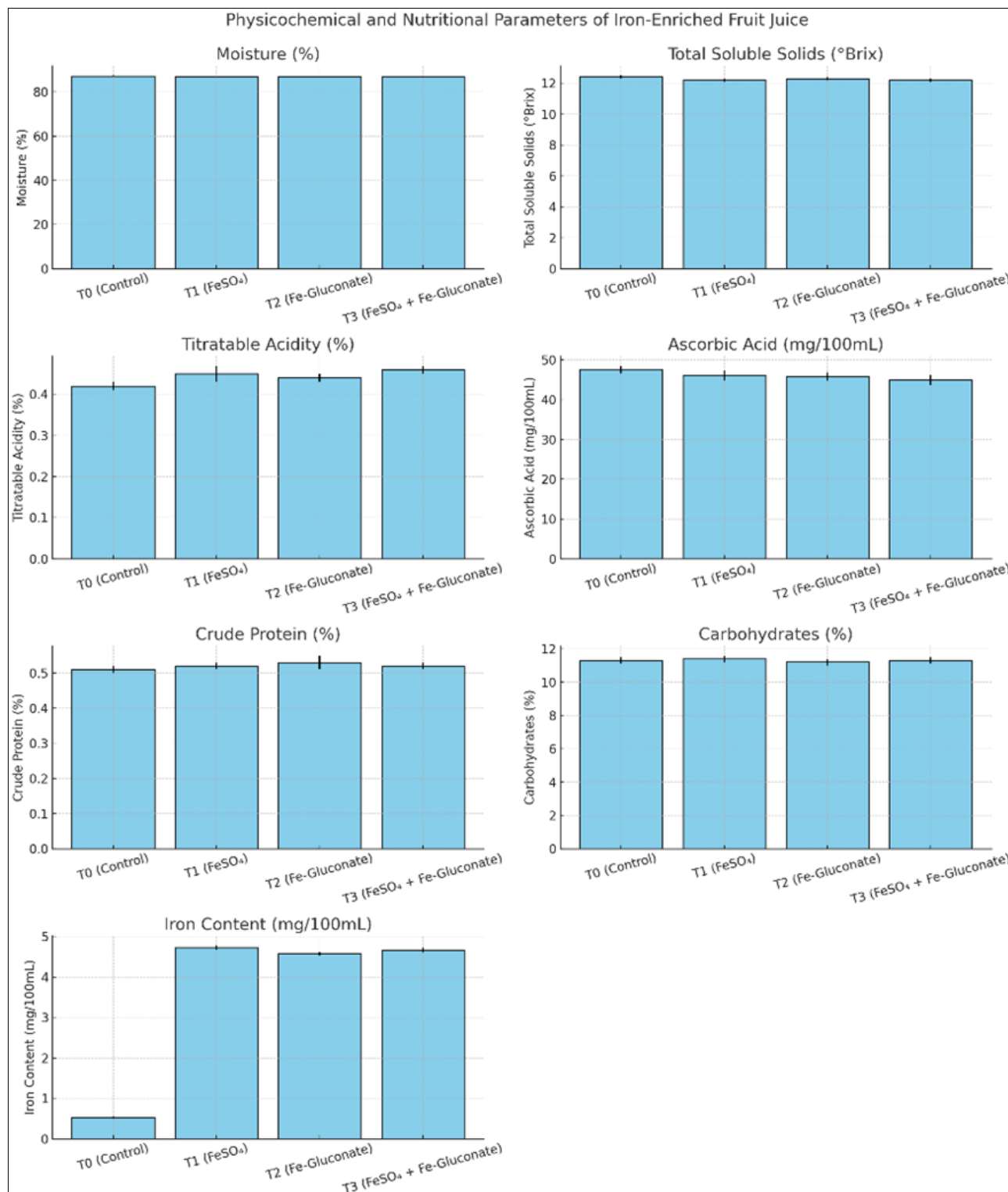


Fig 2: Graphical representation of Proximate analysis of Iron Enriched Fruit Juice

Conclusion

The present study successfully formulated and evaluated an iron-enriched mixed fruit juice using locally available fruits—orange, guava, and pomegranate—fortified with ferrous sulfate, ferrous gluconate, and their combination. The findings revealed that iron fortification significantly increased the iron content of the juice without compromising its sensory qualities or proximate composition. Among the fortification treatments, ferrous gluconate (T₂) emerged as the most acceptable based on sensory evaluation, closely matching the control in taste, aroma, and overall acceptability. The juice maintained good levels of ascorbic acid, which aids iron absorption, and showed no significant changes in moisture, protein, carbohydrate, or acidity, indicating that the fortification process preserved the nutritional integrity of the beverage. Therefore, this iron-enriched mixed fruit juice presents a promising functional beverage solution for combating iron deficiency anaemia, particularly in vulnerable populations such as children and pregnant women, by offering a palatable, nutrient-dense, and shelf-stable product.

References

1. AACC. Approved Methods of Analysis. 11th ed. St. Paul: American Association of Cereal Chemists; 2012.
2. Adeyanju AA, Uduehi FE, Iranloye YM. Enhancing the absorption of iron and zinc in plant-based foods with citric acid and ascorbic acid: a review. In: 2024 International Conference on Science, Engineering and Business for Driving Sustainable Development Goals (SEB4SDG). IEEE; 2024 Apr. p. 1-6.
3. AOAC. Official Methods of Analysis of AOAC International. 18th ed. Gaithersburg: AOAC International; 2005.
4. Bishnoi S, Yadav RK. Development and storage study of value added pomegranate-based beverage. Journal of Food Science and Technology. 2010;47(6):656-661.
5. Cook JD, Reddy MB. Efficacy of iron-fortified foods in the control of iron deficiency. Nutrition Reviews. 2001;59(4):114-126.
6. de Almeida CA, Ricco RG, Sant'Ana HB. Sensory evaluation of beverages fortified with iron salts. Food Science and Technology. 2011;31(1):210-215.
7. Dostal AM, Zhu C, Li W. Effect of iron fortification on quality and color stability in fruit-based beverages. Journal of Food Processing and Preservation. 2001;25(3):175-190.
8. FAO/WHO. Human Vitamin and Mineral Requirements. Rome: Food and Agriculture Organization of the United Nations/World Health Organization; 2004.
9. Fidler MC, Davidsson L, Walczyk T, Hurrell RF. Iron absorption from fish sauce and soy sauce fortified with sodium iron EDTA. The American Journal of Clinical Nutrition. 2003;78(2):274-278.
10. Hallberg L, Brune M, Rossander L. The role of vitamin C in iron absorption. International Journal for Vitamin and Nutrition Research. 1989;30:103-108.
11. Huey SL, Bhargava A, Friesen VM, Konieczynski EM, Krisher JT, Mbuya MN, *et al.* Sensory acceptability of biofortified foods and food products: a systematic review. Nutrition Reviews. 2024;82(7):892-912.
12. Huma N, Salim-Ur-Rehman, Anjum FM, Murtaza MA, Sheikh MA. Food fortification strategy—preventing iron deficiency anemia: a review. Critical Reviews in Food Science and Nutrition. 2007;47(3):259-265.
13. Hurrell RF. Fortification: overcoming technical and practical barriers. Nutrition Reviews. 2002;60(Suppl 7):S21-S23.
14. Hurrell RF. Iron fortification practices and implications for iron addition to salt. The Journal of Nutrition. 2021;151(Suppl 3):3S-14S.
15. Hurrell RF, Reddy MB, Juillerat MA, Cook JD. Degradation of phytic acid in cereal porridges improves iron absorption by human subjects. American Journal of Clinical Nutrition. 2000;72(1):111-117.
16. Hussain T, Kalhor DH, Yin Y. Identification of nutritional composition and antioxidant activities of fruit peels as a potential source of nutraceuticals. Frontiers in Nutrition. 2023;9:1065698.
17. Khalua RK, Tewari S, Mondal R. A review on effect of nutrient on anxiety and depression during pregnancy and its management by foods. Journal of Emerging Technologies and Innovative Research. 2019;6(5):33.
18. Kumar SB, Arnipalli SR, Mehta P, Carrau S, Ziouzenkova O. Iron deficiency anemia: efficacy and limitations of nutritional and comprehensive mitigation strategies. Nutrients. 2022;14(14):2976.
19. Lönnerdal B. Excess iron intake as a factor in growth, infections, and development of infants and young children. The American Journal of Clinical Nutrition. 2007;85(2 Suppl):584S-588S.
20. Nair MS, Saxena A, Kaur C. Effect of chitosan and alginate based coatings enriched with pomegranate peel extract to extend the postharvest quality of guava (*Psidium guajava* L.). Food Chemistry. 2018;240:245-252.
21. Oboh G, Akindahunsi AA. Fortification of 'weaning food' with 'iron-rich' pumpkin (*Telfairia occidentalis* Hook) leaves. Nutrition and Health. 2004;18(4):395-405.
22. Tewari S. Chapter-3 Renal Diseases and Dietary Modifications. In: [Book title not provided]. 2024. p. 29.
23. Volkova DA, IV, Balanov PE. Research on the iron content in plant-based beverages. In: IOP Conference Series: Earth and Environmental Science. 2021 Mar;666(4):042030.
24. Wellala CKD, Bi J, Liu X, Liu J, Lyu J, Zhou M, *et al.* Effect of high pressure homogenization combined with juice ratio on water-soluble pectin characteristics, functional properties and bioactive compounds in mixed juices. Innovative Food Science & Emerging Technologies. 2020;60:102279.
25. Zimmermann MB, Hurrell RF. Nutritional iron deficiency. The Lancet. 2007;370(9586):511-520.