

An In-Depth Analysis of Iron-Enhanced Processed Foods Accessible on E-Commerce Platforms

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Abstract. Governments of nearly all countries have developed programs and policies to fight against anaemia. However, the data depict an inevitable presence of the deficiency among almost one-third of the global population. Iron delivery by diet seems to be a workable, affordable, and long-term solution. According to numerous clinical trials, one of the best ways to prevent iron deficiency is to consume meals rich in or enriched with iron. Iron supplementation through diet, however, has shown to have minimal side effects. Therefore, scope of novel iron-rich ingredients and iron-fortified goods that are more affordable, more stable, and have a high bioavailability, is vast. Modern processing techniques open plentiful avenues to achieve more effective fortification of such food items. This review focuses on delivery of this vital micronutrient through supplementation techniques and their applicability in addressing iron needs of populations, especially the vulnerable groups. The evaluations reveal consumer perceptions, nutritional value, and market availability on online platforms, the greatest sources of iron fortification and delivery and continue to be the most widely accessible foods, including cereals, baked goods, dairy products, drinks, and condiments.

KEY WORDS: Anaemia, consumer perception, fortified foods, healthy food, online and market availability

1. INTRODUCTION

Iron-rich processed foods are essential for maintaining human health because they prevent iron deficiency anaemia, which affects a huge number of people globally, particularly women and children [1]. Iron is required for the production of haemoglobin, the immune system, energy metabolism, cognitive function, and muscular function. Adequate iron levels promote healthy immune system function, brain growth, and cognitive function while also increasing physical and energetic capability. Fortified meals are especially advantageous for some groups, such as growing children and pregnant women, who have higher iron requirements [2]. Furthermore, iron-fortified foods provide a simple and easily available source of this essential component, especially for persons who adhere to dietary limitations such as vegetarians and vegans. A public health strategy that tackles a severe nutritional deficiency, enhances overall wellbeing, and ensures appropriate intake is to fortify processed foods with iron. Many underdeveloped nations are at risk for iron deficiency anaemia which can be brought on by Unbalanced dietary regimens, high in naturally occurring Phytochelators low heme content, frequently linked to IDA. Unsurprisingly, women and children are more likely to get IDA due to menstrual bleeding. Also, NFHS 4 & 5 share the data that anaemic cases are increasing day by day, and women are taking iron folic acid supplements.

2. SIGNIFICANCE OF IRON FORTIFICATION

By influencing organoleptic qualities like flavour and colour, iron helps preserve food, extending its shelf life and maintaining its freshness. Accurately identifying the raw material content of food items is essential to ensuring their safety and quality. The shortcomings of earlier approaches have been overcome by the development of contemporary techniques, which have greatly enhanced the detection of iron in food [3]. As a component of haemoglobin, a protein found in RBC, that is in charge of carrying oxygen, throughout the body, iron is essential. Iron's importance in the human diet is further highlighted by the fact that it is necessary for the creation of energy and the proper operation of several enzymes.

As global health issues evolve, nutrition and health technologies lead the way in addressing issues such as food security and deficiency of essential nutrients. This research shows how underutilized superfoods such as Foxtail millets, Garden Cress Seeds, and cauliflower leaves can be converted into a highly nutritious multipurpose flour (MPF). This research investigates how often neglected superfoods like Foxtail millets, Garden Cress Seeds, and cauliflower leaves can be extremely versatile in transforming them into multipurpose flour, namely, highly nutritious multipurpose flour (MPF). Iron and calcium in MPF

contend against malnutrition and anemia. MPF is not spoilable and has a shelf life of 120 days: it has successfully applied with ordinary foods such as snacks, cakes, and cookies, and remains beneficial. Incorporating into this research will then be the new thinking with traditional nutrition in making smarter and sustainable foods that are nourished to an individual but will assure well-being at length [4].

3. IRON-DEFICIENCY AND ITS IMPLICATIONS

NFHS-5 also global One-third of the global population lacks sufficient iron. Ingesting iron through food is a feasible, cost-effective, and sustainable remedy for this issue. Clinical trials suggest that one of the most current ways to prevent iron deficiency is by consuming meals that are supplemented with iron. However, enriching food with iron may lead to adverse reactions. Hence, it is vital to innovate and produce cost-effective, stable, and highly bioavailable iron enriched ingredients and fortified products. Furthermore, the advancement of modern processing techniques is crucial in achieving more efficient fortification. With the rise of e-commerce, buying food has never been easier—but this shift also brings new challenges and opportunities, especially when it comes to iron-enhanced processed foods.

Online platforms have the potential to improve access to iron fortified products, making them more available to people who might struggle with iron deficiency. There remain issues like an ambiguous label, costly prices and too many processed foods that need to be resolved. We need to have better ways of helping people make better choices, like more informative labelling on products, better product visibility, and individualized recommendations, instead of merely selling these foods online. Online shopping websites, legislators or platforms and nutritionists in the future will be important partners in helping us make buying groceries online help everyone eat better and be easy to do. Food e-commerce has modified the shopping way all over the world, especially in the western countries where convenience, quality of service, and personal tastes hugely weigh upon choices. The study identified different online models for food shopping B2C, O2O-Food Delivery Services, and Click-and Collect-in accommodating different consumer needs. While convenience and variety attract consumers, other problems like price, trust, and service quality deter some into shopping offline. A major impetus for this new trend in online food shopping has been the recent COVID-19 pandemic accentuating the importance of user-friendly platforms, credible product information, and trustworthy services to these consumers. For the future, businesses should make it their focus on making online food shopping even more affordable, more transparent, and conceptually more accessible to wider audiences. With the growth of digital food retailing, a balance between innovation

and consumer trusts is going to be important for long-term sustainability [5].

4. CONSUMER AWARENESS AND MARKET AVAILABILITY

Even still iron-fortified processed foods are available widely in a variety of commercial settings, including supermarkets, retail stores, and Big Basket, there are still a number of study gaps about their effects and consumer behaviour. Nothing is known about how consumers' awareness and knowledge of the advantages of foods fortified with iron affects their purchase decisions and about how these products are really used or how well they work to improve iron status in various demographic groups [6].

Long-term health effects of regular intake of these fortified goods are likewise little researched. Furthermore, socioeconomic issues influencing access to and consumption of iron-fortified foods must be investigated, particularly in low-income groups. The study's purpose is to look at the market availability and customer preferences for commercially available processed iron-rich meals. Despite the rising availability of iron-fortified items through various commercial channels such as Big Basket supermarkets, and retail stores, there is a lack of comprehensive information on their accessibility, customer awareness, and consumption patterns.

This study will examine the various iron-fortified commodities available, determining their iron content and bioavailability. It will also investigate customers' knowledge, attitudes, and purchasing behaviours related to these products. Vital parts of the food supply are made up of both fresh and processed foods. Both food security (ensuring that sufficient food is available) and nutrition security (ensuring that food quality meets human nutrient needs) are contributed to by processed food.

The right balance of iron in food is essential not only to maintain nutritional quality, but also to ensure safety and comply with international food regulations. The comparison of global quality regulations and requirement focusing on five regions as in European union.

Iron is a critical micronutrient for growth, and deficiency is the major cause of anemia, particularly in impoverished nations. Iron deficiency anemia (IDA) causes serious concerns, including preterm delivery, cognitive deficits in children, and higher morbidity in women. Iron supplementation, fortification, dietary variety, biofortification, and nutritional education are some strategies for combating IDA. However, fortification must guarantee customer safety and product stability. Combining these strategies can successfully treat IDA. Many processed and fortified foods are out of the price range of the poor and incorporating them into daily 3

meals via alternate channels such as free distribution has various obstacles, including boosting nutrition awareness, introducing the created product, and applying it. Certain products are reinforced with iron, including as Despite having a low iron level, yoghurt is one of the significant fermented milk products with many nutritional and physiological advantages. For the creation of iron-fortified probiotic sweet corn blend milk yoghurt, sweet corn milk was added at a rate of 30% along with cow milk and ferrous lactate [7].

5.IMPACT OF PROCESSED AND FORTIFIED FOODS ON NUTRITION SECURITY

Research was conducted to produce and evaluate the nutritional value of an iron-rich instant muffin mix (IRIMM) developed as a supplemental food for children (ready to serve).

In India, rice enriched with iron, folic acid and vitamin- B12 is gradually being, distributed through various social welfare projects, with the goal of covering the whole country by March 2024. The production of cereals and pulses in India, detailing both the quantity in million tonnes and the percentage share of each crop.

Among cereals, rice leads with 115.63 million tonnes, making up 44.44% of the total cereal production, followed by wheat at 101.20 million tonnes (38.90%) and coarse cereals at 43.33 million tonnes (16.66%). The total cereal production amounts to 260.16 million tonnes. In the pulses category, chickpea (*safed chana*) is the most produced, with 8.09 million tonnes, accounting for 45.87% of total pulse production. Other notable pulses include pigeon pea (*arhar*) at 2.84 million tonnes (16.12%) and black gram (*urad*) at 1.87 million tonnes (10.61%). The total production of pulses is 17.63 million tonnes, with various other pulses contributing smaller shares. As represented in a table also Table1: Production of Iron, Folic Acid, and Vitamin B12-Enriched Cereals and Pulses in India.

Table1: Production of Iron, Folic Acid, and Vitamin B12-Enriched Cereals and Pulses in India [8].

Category	Crop	Production (Million Tonnes)	Percentage of Total (%)
Cereals	Rice	115.63	44.44
	Wheat	101.20	38.90
	Coarse Cereals	43.33	16.66
Total Cereals	-	260.16	100.00
Pulses	Chickpea	8.90	45.87
	Pigeon Pea	2.84	16.12
	Black Gram	1.87	10.61

Other Pulses	-	4.83	27.40
Total Pulses	-	17.63	100:00

The causes and effects of iron deficiency and anaemia, focussing on comparing Double Fortified Salt (DFS) with other iron-fortified staple foods. It discusses factors that influence the effectiveness of iron-fortified foods. The evaluation of iron status varies based on the presence of inflammation, with biomarkers such as haemoglobin (Hb), serum ferritin (SF), transferrin receptor (TFR), and zinc protoporphyrin (ZPP) being useful in the absence of inflammation. the Estimated Average Requirement (EAR) of iron for different age and sex categories, assuming a diet with 10% bioavailable iron. For women aged 18–50 years, the EAR is 14.4 mg per day. Adolescents also have specific requirements, with boys aged 14–18 years needing 13.9 mg per day and girls in the same age range requiring slightly more at 14.2 mg per day. Among younger children, boys aged 9–13 years need 10.6 mg per day, while girls of the same age group require 10.3 mg per day. The EAR for children aged 4–8 years is 7.4 mg per day. This table provides a clear overview of iron needs across various stages of development and between genders, reflecting the varying demands based on age and sex. Iron deficiency (ID) is a common problem, especially in poor nations and among vulnerable groups such as mothers and children. Traditional iron sources such as meat, legumes, and fortified diets are important in resolving ID, but new superfoods like as algae, mushrooms, and fortified grains provide a potential option due to their high iron bioavailability and added anti-inflammatory properties. These superfoods, together with other techniques like probiotics and biofortification, represent a new frontier in ID therapy. They have the potential to outperform current medicines with fewer side effects and may soon become widely available as dietary supplements, enabling a comprehensive approach to iron replenishment and general health enhancement. A 2015 examination of 1,037 commercial baby and toddler diets found substantial variation in iron concentration. Infant cereals, which were largely fortified, had the greatest iron content (6.19 mg per RACC; 41.25 mg per 100 g). For toddlers, vegetable-based combinations had the highest iron content per RACC (2.97 mg), whereas grain-based sweets had the most iron per 100 g (6.45 mg). Juice and beverage items have the lowest iron levels. Identifying items with $\geq 10\%$ DV of iron, including baby cereals and toddler vegetable combinations, might help consumers choose higher iron alternatives Surveys on KAP identify misconceptions and misunderstandings that might hinder desirable activities and hamper behaviour change, emphasising the importance of

designing policy interventions that appropriately represent social intricacies. Pregnant women achieved the lowest scores in terms of knowledge and attitudes as knowledge is 27.75, attitudes 44.52 Practices 48.52 which is very less than the ASHA staff, SCHOOL staff and Anganwadi staff. This reveals a huge gap in nutrition education across all populations, emphasising the urgent need for tailored nutrition education programs.

These findings demonstrated that pregnant women recognised a variety of benefits from consuming Iron Rich Foods (IRF) on a regular basis, including greater strength, improved maternal and infant health, and anaemia prevention. In the validation process, Sample 1(n=200) and Sample 2(n=226) showed similar mean ages (26.7 years, SD=6.5 vs. 27.5 years, SD=6.3, p=0.354). Ethnic distribution and health perceptions were comparable, but educational attainment differed (51.0% vs. 37.2% with no formal education, p=0.037). Literacy rates were higher in Sample 2 (52.7% vs. 37.5%, p=0.002). Exploratory factor analysis identified eight factors explaining 59.5% variance, with confirmatory analysis supporting this structure despite initial fit issues. These perceived advantages contributed to positive attitudes towards IRF, which were identical to those reported by pregnant women in Nepal and Niger. Concerns regarding possible drawbacks, such as the risk of hypertension, delivery problems, and speech damage in newborns, affected their perspectives. This study provides a viable and reliable technique for investigating the determinants influencing IRF intake among pregnant women in Senegal, which might be extended for use in other African countries. However, more validation is required to establish its prediction accuracy in other scenarios. Despite a drop in malnutrition in India over the last decade as a result of government measures, anaemia persists, with 59% of children under the age of three, 50% of pregnant women, and 53% of women aged 15 to 19. While staple foods account for almost 70% of total daily iron consumption, their high phytate concentration inhibits iron absorption. Iron supplements are a frequent intervention, but their efficacy is limited due to low compliance and unpredictable availability. This research investigates the relevance of dietary behaviours, cultural attitudes, and problems in adopting management methods to better explain the continued high incidence of anaemia, particularly in rural vegetarian diets where non-heme iron absorption is an issue. This study based on interventions in which black stools were prevented with supplemental iron intakes of 20-25 mg/day (in addition to a baseline consumption of 15 mg/day), a safe iron intake level of 40 mg/day for adults, including pregnant and lactating women, was discovered. Adjusted for children and adolescents using allometric scaling (body weight^{0.75}), safe

intake levels varied from 10 mg/day for children aged 1-3 years to 35 mg/day for 15-17 years. For newborns aged 7-11 months, who require more iron than younger children, limiting supplemental iron consumption to 25 mg/day resulted in a safe intake of 5 mg. This quantity was also applied to babies aged 4-6 months and included iron consumption from fortified meals and supplements.

The survey indicated a large growth in infant complementary foods (CCFs) in Germany over the last two decades, with the majority of items following national rules, however some are provided too early. Meat-based diets are predominant due to high iron requirements, but fish, despite its nutritional value, is under-represented. Pouches, which are now widely available, have been criticised for causing caries and containing inappropriate components, while superfluous snack items and sugary beverages remain popular, despite suggestions to restrict these for newborns [9]. A food-based strategy aims to improve nutrition by promoting the intake of nutrient-dense, diverse foods. Food-based dietary recommendations (FBDGs) emphasise the need of combining meals to achieve nutritional requirements, rather than providing particular component. Food security refers to the availability of sufficient, safe, and nutritious food that fits individuals' dietary needs and preferences for an active and healthy lifestyle [26]. Anaemia, a prevalent nutritional condition that affects one-third of the world's population, is mostly caused by iron deficiency. The World Health Organisation estimates that approximately two billion individuals are anaemic, including 40% of reproductive aged women and 42% of young children. According to NFHS-5 statistics, more than half of women and two thirds of children aged 6-59 months in rural Uttar Pradesh are anaemic, with a greater incidence among younger children and adolescents, particularly those from low-income households. Women with lower levels of education and those who are underweight have much greater incidence of anaemia [10]. This study looked into sex differences in Fe status, as well as the relationships the between Fe status, endurance and musculoskeletal, outcomes during military training. A sum of 2277 Brits Military trainees, (581 women), participated. 'Fe indicators and endurance performance (2.4 km run) were assessed at, the beginning in addition conclusion of training' (weeks 1-13).

The Government of India currently employs a 'targeted' food fortification strategy with iron, focusing on increasing iron intake in specific population subgroups rather than implementing universal fortification. Unlike mass fortification, which is government-mandated and involves adding micronutrients, to widely consumed, foods like cereals/ milk / condiments, targeted fortification is

more selective. FSSAI requires the use, of Ferric Pyrophosphate (FPP.) (28 to 42.5 mg/kg) or Sodium-Iron EDTA (14-21.25 mg/kg) for, iron protection in rice. Added FPP at higher levels because of its less, bioavailability. For example, using 35 mg of FPP to fortify one kilogram of rice is estimated to increase daily iron intake by 0.9mg/day in children aged 6-12 months, 5.9 mg/day in reproductive age of women, 6.0 mg/day for pregnant women, 6.2 mg/day in adult men (men) [11].

6.PUBLIC HEALTH INSIGHTS AND CHALLENGES

Anaemia, which affects about 2 billion people worldwide, is frequently caused by iron deficiency. To address this, in 2012, the Odisha Government, and the World Food Programme India conducted a pilot fortification of the Mid-Day Meal (MDM) with iron, with encouraging results. Building on this, in 2016, the effort was expanded to include fortified rice, kernels (FRK) and, micronutrient powders (MNP). Both FRK and, MNP have shown successful in improving health outcomes, and the field tests intended to examine their real-world effectiveness in decreasing anaemia among school children. Certainly! Here's a more concise summary. Results showed demographic differences across groups, with the control having more affluent households (P < .05). The FRK group saw an 11% decrease in IFA receipt (from 90.62% to 78.46%), while the MNP group experienced a 30% increase (from 67.30% to 97.74%). The control group had stable, lower IFA receipt (59% pretest, 65%posttest). In terms of demographics, the FRK group had 17.59% of children from the poorest household's pretest and 19.53% post-test. The control group had 42.80% of children from general caste household's post-test. MDM consumption was high across groups, with 96.49% in FRK and 98.08% in MNP consuming it for 6 days. For IFA tablets, 90.62% of FRK and 97.74% of MNP children received them, compared to 57.22% in the control group pretest.

Table2: Impact of Fortified Rice Kernels (FRK) and Micronutrient Powders (MNP) on Anaemia Reduction Among School Children [12]

Parameter	FRK Group	MNP Group	Control Group
Pretest IFA Receipt (%)	90.62	67.30	59.00
Posttest IFA Receipt (%)	78.46	97.74	65.00
Change in IFA Receipt (%)	-11.00	+30.44	+6.00
Children from Poorest Households (%)	17.59(pretest) 19.53(protest)	-	-

Children from General Caste Households (%)	-	-	42.80
MDM Consumption for 6 Days (%)	96.49	98.08	-
IFA Tablets Received (Pretest) (%)	90.62	97.74	57.22

This study highlights the importance of iron in human nutrition and food quality. provides an overview of the iron content in various foods. Animal-based sources include seafood with the highest iron content at 30 mg per serving, followed by pork liver at 20 mg, and beef liver at 17 mg.

Other meats such as chicken liver, beef, lamb, chicken meat, and pork offer lower amounts of iron, ranging from 2 to 9 mg. On the plant side, cauliflower has the highest iron content at 16 mg, with lentils and white beans providing between 8 and 12 mg. Wheat bran, soybean, and buckwheat are also notable sources, containing 7 to 11 mg of iron. Cashews, peanuts, and dark chocolate offer lesser amounts, around 5 to 7 mg. This information focus the importance of incorporating both in animal and plant-based iron, sources into a balanced- diet for optimal health, as iron is crucial for transporting oxygen in the blood [13]. Iron fortification is an effective approach for ensuring adequate iron intake among the general population.

Despite the availability of iron-fortified meals in Sri Lanka, no laws restrict the amount of iron in these goods. The drive of this study is to fix the iron content in various iron fortified foods available, in the local market and how they contribute to the recommended daily allowances per serving. Using atomic absorption spectroscopy, the Fe content of popular, powdered milk, biscuits, and breakfast cereals consumed by 15-16-year-olds in Horana Divisional Secretariat was determined. Less than half of the tested items had Fe levels that matched what was on the label. Nonetheless, these iron-fortified foods can supply between 5% and 35% of the RDA for young children, adolescents, and adults (1 serving) [14].

7. CONCLUSION

It focuses on accessibility, quality and health advantages to highlight important information about iron-rich processed foods that are sold on e-commerce platforms. While low-resource areas have limited availability, the selection of iron-fortified products such as cereals, snacks, and beverages, has increased, especially in industrialized regions. The

iron forms that are used in products some use highly accessible forms such as ferrous sulphate or ferric pyrophosphate, while others use less potent forms like elemental iron.

While some products lack these beneficial minerals and others do contain vitamin C which helps in iron absorption. Many have phytates and calcium which are absorption inhibitors that reduce their nutritional value. Selecting efficient items is made more challenging for consumers by seeing online and reading out their labelling and their requirements. The study of review concludes that even though meals fortified with iron are widely available on online platforms but knowledge, awareness and practices of the products are not that much among the population of India.

Especially, in rural area as compared to the women those who are not working do not have any basic knowledge of iron fortified product and their health benefit. Additionally, the customers got confused by the lack of labelling on the product which may lead to false information of the product. For encouraging the people more towards the iron fortified food there should be 6 more campaigns and public health activities are essential to maximize the impact of iron fortified food product on reducing the iron deficiency globally.

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