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A Review on Iron and Folate Products: Nutrition, Health Benefits, and Dietary Advice

Mrunmai Sonawane[1], Tipale Mayuri*[2] and Jadhav Balaji[3]

[1-3] Department of Food Technology, NIMS Institute of Allied Medical Science and Technology (NIMS University), Jaipur - 303 121, Rajasthan, India

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Abstract

Iron and folate are essential micronutrients crucial for various physiological processes in the human body. This review provides a comprehensive analysis of the nutritional significance, health benefits, and dietary recommendations associated with iron and folate-based products. Iron plays a pivotal role in oxygen transport, energy metabolism, and DNA synthesis, while folate is vital for cell division, DNA synthesis, and red blood cell formation. Deficiencies in these nutrients can lead to anemia, neural tube defects, and impaired cognitive function. Iron and folate supplementation have shown to alleviate these deficiencies and improve overall health outcomes. However, excessive intake of iron can be harmful, leading to oxidative stress and organ damage. Therefore, dietary recommendations emphasize achieving a balance between meeting nutritional needs and avoiding toxicity. Incorporating iron-rich foods such as lean meats, beans, and fortified cereals, along with folate-rich sources like leafy greens, citrus fruits, and fortified grains, can help maintain optimal levels of these nutrients. This review underscores the importance of adequate iron and folate intake for promoting overall health and well-being.

***Key words*:** Folate, Iron, Micronutrient, Nutrition, RDA

Iron and folate are two vital micronutrients that play pivotal roles in maintaining human health. Iron is essential for the formation of hemoglobin, the protein in red blood cells responsible for transporting oxygen throughout the body, while folate is crucial for DNA synthesis and cell division. Deficiencies in these nutrients can lead to serious health issues, emphasizing the importance of adequate intake through diet or supplementation. Iron deficiency is one of the most common nutritional deficiencies worldwide, affecting approximately 25% of the global population, particularly women and children in developing countries [1]. Folate deficiency, while less prevalent, is still a significant concern, especially among pregnant women, where inadequate intake can lead to neural tube defects in newborns [2]. Deficiencies in iron and folate can have profound implications for health, ranging from anemia, fatigue, and impaired cognitive function in the case of iron deficiency to neural tube defects, megaloblastic anemia, and increased risk of cardiovascular diseases in the case of folate deficiency [3]. To address these nutritional challenges, a wide range of iron and folate-based products have been developed, including supplements, fortified foods, and enriched grains. These products aim to provide convenient and effective ways to increase intake and prevent deficiencies, especially in high-risk populations. The purpose of this review paper is to provide a comprehensive analysis of iron and folate-based products, focusing on their nutritional significance, health benefits, and dietary recommendations.

Overview of folate

Folate refers to a group of water-soluble B vitamins, including folic acid (synthetic form) and naturally occurring forms such as folate found in foods. It is essential for numerous cellular functions, including DNA synthesis, repair, and methylation.

Function of folate

1. *DNA synthesis and repair*: Folate is a key factor in the synthesis and repair of DNA, the genetic material present in all cells. It provides one-carbon units necessary for the production of nucleotides, the building blocks of DNA, thereby ensuring accurate replication and maintenance of genetic information [2].

2. *Cell division and growth*: Folate plays a critical role in cell division and tissue growth by facilitating the synthesis of nucleotides and supporting the formation of new cells. Adequate folate intake is particularly important during periods of rapid growth and development, such as pregnancy and infancy [2].

3. *Methylation reactions*: Folate serves as a coenzyme in various methylation reactions, where it donates methyl groups for the modification of DNA, RNA, proteins, and other molecules. Methylation is essential for regulating gene

***Correspondence to:** Tipale Mayuri, E-mail: tipale.mayuri@nimsuniversity.org; Tel: +91 8668856844

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expression, maintaining cellular function, and modulating various physiological processes [4].

4. *Homocysteine metabolism*: Folate, along with vitamins B_6 and B_{12}, plays a crucial role in the metabolism of homocysteine, an amino acid derived from methionine. High levels of homocysteine in the blood are associated with an increased risk of cardiovascular diseases, and adequate folate intake helps regulate homocysteine levels and promote cardiovascular health [5].

Recommended dietary intake and significance for health

The recommended dietary intake of folate varies depending on age, gender, and life stage. In the United States, the recommended dietary allowance (RDA) for folate is shown in (Table 2) [6].

Table 2 RDA for folate

Adults (19 Years and older)	400 Micrograms/day
Pregnant women	600 Micrograms/day
Breastfeeding women	500 Micrograms/day

It's important to note that certain populations, such as pregnant women, may require higher intakes to meet increased physiological demands. Adequate folate intake is essential for maintaining overall health and preventing various health conditions.

Some key aspects of its significance for health include

1. *Prevention of neural tube defects*: Folate plays a critical role in preventing neural tube defects, such as spina bifida and anencephaly, during fetal development. Adequate folate intake before and during pregnancy is associated with a reduced risk of these birth defects [7].

2. *Reduction of cardiovascular disease risk*: Folate, along with vitamins B_6 and B_{12}, helps regulate homocysteine levels in the blood. Elevated homocysteine levels are associated with an increased risk of cardiovascular diseases, and adequate folate intake can help lower this risk [7].

3. *Support for healthy cell division and growth*: Folate is essential for DNA synthesis and cell division, making it crucial for tissue growth, repair, and maintenance. Adequate folate intake supports healthy growth and development, particularly during periods of rapid growth, such as infancy and adolescence [8].

4. *Prevention of megaloblastic anemia*: Folate deficiency can lead to megaloblastic anemia, characterized by abnormally large red blood cells and symptoms such as fatigue, weakness, and pale skin. Ensuring adequate folate intake helps prevent megaloblastic anemia and supports optimal red blood cell formation [2].

Bioavailability of folate from different food sources

The bioavailability of folate, or the extent to which it is absorbed and utilized by the body, can vary depending on the food source and its chemical form. Folate naturally present in food sources such as leafy greens, legumes, fruits, and vegetables is typically in the form of polyglutamates, which are less bioavailable than the monoglutamate form found in fortified foods and supplements [10]. The bioavailability of folate from natural food sources can also be influenced by factors such as food processing, cooking methods, and interactions with other nutrients present in the diet. Folic acid, the synthetic form of folate used in fortified foods and supplements, is more bioavailable than naturally occurring folate due to its monoglutamate form [10]. Fortified foods and supplements containing folic acid are designed to provide a more readily absorbable source of folate, especially for individuals at risk of deficiency. The bioavailability of folate from different food sources can be influenced by various factors, including digestive enzymes, absorption mechanisms, and interactions with other nutrients [2]. Certain genetic variations, such as polymorphisms in genes involved in folate metabolism, can also affect the bioavailability and utilization of folate from dietary sources [9]. While naturally occurring folates in foods are beneficial and necessary as part of a healthy diet, fortified foods and supplements provide a more reliable and consistent source of bioavailable folate, especially in populations at risk of folate deficiency or with increased folate needs, such as pregnant women. This approach helps ensure that everyone, regardless of their dietary habits or health conditions, can achieve the necessary folate levels to maintain health and prevent various health conditions. The data in (Table 2) shows the natural as well as fortified sources of folate.

Table 2 Natural and fortified sources of folate

Natural sources		Fortified sources	
Leafy green	Spinach, kale, collard greens	Fortified grains	Bread, pasta, rice
Legumes	Lentils, chickpeas, black beans, kidney beans	Fortified juices	Orange juice
Citrus fruits	Oranges, grapefruits and lemons	Fortified milk and dairy products	Milk, yoghurt, cheese
Other sources	Asparagus, avocado, broccoli	Fortified beverages	Meal replacement shakes or plant-based milk alternatives

Source: USFDA Data Central 2024 [11]

Overview of iron

Iron is an essential mineral that is vital for numerous physiological processes in the human body. It is a critical component of various proteins and enzymes involved in oxygen transport, energy production, and cellular function.

1. *Energy production*: Iron is necessary for the proper functioning of mitochondria, the cellular organelles responsible for energy production through aerobic respiration. Iron-containing enzymes, such as cytochromes, play crucial roles in electron transport and ATP synthesis [12].

2. *Neurological function*: Iron is essential for normal neurological function, including neurotransmitter synthesis, myelin formation, and synaptic plasticity. Iron deficiency can lead to cognitive impairment, developmental delays, and other neurological symptoms [13].

3. *Oxygen transport*: One of the primary functions of iron is to facilitate the transport of oxygen from the lungs to tissues throughout the body. Iron is a key component of hemoglobin, the protein in red blood cells that binds to oxygen in the lungs and releases it to cells and tissues [14].

4. *Immune function*: Iron plays a crucial role in immune function, as it is required for the proliferation and function of immune cells, including lymphocytes, macrophages, and neutrophils. Iron deficiency can impair immune function and increase susceptibility to infections [15].

5. *DNA synthesis and repair*: Iron is involved in the synthesis and repair of DNA, the genetic material present in all cells. Iron-containing enzymes, such as ribonucleotide reductase, are essential for the conversion of ribonucleotides to deoxyribonucleotides, the building blocks of DNA [16].

Recommended dietary intake and significance for health

The recommended dietary intake of iron varies based on factors such as age, gender, and life stage. (Table 3) shown the iron requirement for different age groups.

Iron is essential for various physiological functions in the body, and meeting the recommended dietary intake is crucial for maintaining overall health [17]. Iron is a critical component of hemoglobin, the protein in red blood cells responsible for transporting oxygen from the lungs to tissues throughout the body. Iron-containing enzymes, such as cytochromes, play crucial roles in electron transport and ATP synthesis, supporting optimal energy metabolism and physical performance. Adequate iron intake supports a robust immune response and helps protect against infections and diseases. It is necessary for normal neurological function, including neurotransmitter synthesis, myelin formation, and synaptic plasticity. Heme iron and non-heme iron are two forms of dietary iron found in foods, Heme iron is found in animal-based foods and is more readily absorbed by the body compared to non-heme iron [18]. Non-heme iron is found in plant-based foods and fortified products. It is less readily absorbed by the body compared to heme iron, but certain dietary factors can enhance or inhibit its absorption. (Table 4) shows the iron rich food sources.

Table 3 RDA for different age group

19-50 years (Men)	8 milligrams/day
19-50 years (Women)	18 milligrams/day
Pregnant women	27 milligrams/day
Women over 50 years	8 milligrams/day

Table 4 Iron rich food sources

Heme		Non-heme	
Red meat	Beef, lamb, and pork	Legumes	Beans, lentils, chickpeas
Poultry	Chicken, turkey, and duck	Nuts and seeds	Pumpkin seeds, sesame seeds, hemp seeds
Fish and seafood	Tuna, salmon, sardines	Fortified foods	Breakfast cereals, bread, and plant-based milk alternatives

Source: USFDA Data Central 2024 [11]

Factors affecting iron absorption in the body

Several factors can affect the absorption of dietary iron in the body. Here are some key factors:

Iron status: The body's iron status influences iron absorption. When iron stores are low, absorption increases, and vice versa. This mechanism helps regulate iron levels and maintain homeostasis [21].

Form of iron: Iron exists in two forms: heme iron (found in animal-based foods) and non-heme iron (found in plant-based foods and fortified products). Heme iron is more readily absorbed than non-heme iron [22].

Iron content in the diet: The amount of iron consumed in the diet affects absorption. Higher iron intake generally leads to lower absorption efficiency, while lower intake increases absorption [21].

Gastrointestinal factors: Gastrointestinal conditions such as celiac disease, inflammatory bowel disease, and gastric bypass surgery can impair iron absorption due to damage to the intestinal mucosa or alterations in gastric acidity [23].

Consequences of iron deficiency and strategies for prevention

Iron deficiency can lead to various consequences ranging from mild symptoms to severe health complications.

1. *Anemia*: Iron deficiency is the leading cause of anemia worldwide. Anemia occurs when there is a decrease in the number of red blood cells or a decrease in the amount of hemoglobin in the blood, leading to symptoms such as fatigue, weakness, shortness of breath, and pale skin [24].

2. *Impaired cognitive function*: Iron deficiency has been associated with impaired cognitive function, including decreased attention, memory, and problem-solving abilities. This is particularly significant in infants, children, and adolescents, as iron deficiency during critical periods of growth and development can lead to long-term cognitive deficits [25].

3. *Increased risk of preterm birth and low birth weight*: Iron deficiency in pregnant women has been associated with an increased risk of preterm birth, low birth weight, and other adverse pregnancy outcomes. Adequate iron intake during pregnancy is essential for supporting fetal growth and development and reducing the risk of complications [26].

Strategies for prevention

Iron supplementation: Iron supplements may be recommended for individuals at risk of deficiency, such as pregnant women, infants, children, adolescents, and individuals with certain medical conditions (such as heavy menstrual bleeding or gastrointestinal disorders). Iron supplements should be taken under the guidance of a healthcare professional to ensure appropriate dosing and minimize the risk of side effects [19].

Fortification of foods: Fortifying staple foods with iron is an effective public health strategy for preventing iron deficiency on a population level. Fortified foods, such as grains,

cereals, and infant formulas, can provide additional dietary iron and help meet nutrient needs, especially in populations with limited access to diverse diets [20].

Importance of folate in iron absorption and utilization

Folate plays an important role in iron absorption and utilization in the body. Folate helps enhance the absorption of non-heme iron, the form of iron found in plant-based foods and fortified products. Folate works synergistically with vitamin C to increase the solubility of ferric iron (Fe^{3+}) in the intestinal lumen, converting it to ferrous iron (Fe^{2+}), which is more readily absorbed by enterocytes in the small intestine [27]. Adequate folate levels are necessary for the production of heme, which is essential for oxygen transport and energy metabolism. Without sufficient folate, heme synthesis may be impaired, leading to decreased hemoglobin levels and the development of anemia [28]. Folate is involved in the conversion of homocysteine to methionine, an essential amino acid. Elevated levels of homocysteine in the blood are associated with increased risk of cardiovascular diseases, including atherosclerosis and coronary artery disease. Adequate folate intake helps regulate homocysteine levels and promote cardiovascular health, indirectly contributing to iron utilization by maintaining vascular integrity and function [29]. Folate plays a crucial role in iron absorption, heme synthesis, red blood cell production, and the prevention of megaloblastic anemia. Ensuring adequate folate intake is essential for optimizing iron utilization and maintaining overall health.

Global perspectives on folate and iron deficiencies

Folate and iron deficiencies are significant public health concerns with global implications, particularly in developing countries and vulnerable populations.

Global burden of folate and iron deficiencies

Folate and iron deficiencies are among the most common micronutrient deficiencies worldwide, affecting millions of people, particularly in low- and middle-income countries [2]. Iron deficiency is the most prevalent nutritional disorder globally, affecting an estimated 1.24 billion people, with the highest burden observed in South Asia, sub-Saharan Africa, and East Asia [32].

Health consequences and economic implications

Folate and iron deficiencies can have serious health consequences, including anemia, impaired cognitive development, increased risk of maternal and child mortality, and reduced productivity and economic growth [3], [30]. The economic burden of folate and iron deficiencies is substantial, with estimated annual costs related to healthcare expenditures, lost productivity, and disability-adjusted life year exceeding billions of dollars globally [31].

Strategies for prevention and control

Addressing folate and iron deficiencies requires comprehensive, multi-sectoral approaches that encompass interventions targeting food fortification, dietary diversification, supplementation, and public health education [32]. Food fortification with iron and folic acid has been recognized as a cost-effective strategy for improving micronutrient status and reducing the burden of deficiencies, particularly in populations with limited access to diverse diets [33]. Strengthening health systems, promoting maternal and child health, and implementing nutrition-sensitive interventions are essential components of efforts to prevent and control folate and iron deficiencies on a global scale [33]. Folate and iron deficiencies represent significant public health challenges with far-reaching consequences for health, development, and economic prosperity. Addressing these deficiencies requires concerted efforts at the global, regional, and national levels to implement effective and sustainable interventions that improve access to and utilization of essential nutrients.

CONCLUSION

Iron and folate are vital for maintaining a healthy lifestyle and preventing disease. Ensuring adequate intake of these vital nutrients through a combination of diet, fortification, and supplementation is crucial for preventing deficiency diseases. Its importance grows during unique circumstances like as pregnancy, nursing, and the adolescent years. Naturally occurring food is a rich source of both nutrients, but they may be lost during food preparation, and these nutrients in their natural state are not fully absorbed by the human body. There are various processed food products available on the market that meet the daily need of iron and folate. This review includes the importance of iron and folate sources deficiency diseases and strategies for prevention and control. By advancing research in these emerging areas, scientists and practitioners can deepen our understanding of folate and iron nutrition, identify new opportunities for intervention, and develop targeted strategies to improve public health and individual well-being.

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