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An overview of iron-rich products to combat anaemia among adolescent girls

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Abstract: *Numerous health problems are associated with deficits in certain nutrients. Anaemia is a condition caused by a lack of healthy red blood cells or hemoglobin. The main blood protein that carries oxygen to bodily cells is hemoglobin. The main causes of anemia are severe blood loss, ongoing chronic illnesses, and poor nutrition. Many teenage girls' diets do not provide them with enough iron to meet their high physiological needs for menstruation, body tissue development, and increased red blood cell production. Iron, vitamin B12, and vitamin C deficiency are the main causes of anemia resulting from inadequate nutrition. Treatment for iron deficiency-related anemia involves supplementation. Deficits in specific nutrients are linked to a host of health issues. A deficiency of hemoglobin or healthy red blood cells results in anemia. Hemoglobin is the primary blood protein that transports oxygen to body cells. Anemia is primarily brought on by substantial blood loss, persistent chronic conditions, and inadequate diet. The significant physiological needs of teenage females for menstruation, body tissue growth, and increased red blood cell production are often not met by their diets, which deprive them of adequate iron. Anemia resulting from malnutrition is mostly caused by deficiencies in iron, vitamin B12, and vitamin C. Supplementation is used to treat anemia caused by iron deficiency.*

Key Words: *Adolescent, Anaemia, Diet, Green leafy vegetables, and Iron.*

1. INTRODUCTION

Anaemia is widely acknowledged as a serious nutritional problem that impacts people in both developed and developing countries, negatively impacting their economies and slowing down their growth. The main cause of anemia globally is iron deficiency; therefore, the phrases anemia and iron deficiency anemia are frequently used interchangeably. Reduced red blood cell volume or decreased hemoglobin (Hb) content in the blood are the hallmarks of anemia, a disorder that affects the whole body. Lack of micronutrients such as iron, folic acid, and vitamin B12, malaria, hookworm infections, and blood loss from chronic illnesses such as TB, intestinal diseases, menstruation, and delivery can all contribute to it.

While it can occur at any age, teenage females and expectant mothers are more likely to experience it. Globally, anemia affects around 25.4% of school-age children, 47.7% of young children, and an estimated 41.8% of pregnant women [1]. Iron deficiency anemia is mostly caused by low iron consumption, impaired iron absorption from diet, and increased iron demands, especially during development and pregnancy. The age period between maturity and childhood, or between 10 and 19 years old, is referred to as adolescence by the World Health Organization. The word "adolescence" comes from the Latin word "AD- OLESCERE," which means "TO GROW" or "TO MATURE" [2].

It is believed that girls' adolescence is a critical period in their development from young ladies to responsible adults. The transitional period between childhood and adulthood is called adolescence. Globally, there are over 1.2 billion individuals in the adolescent demographic. Most people agree that helping young people—especially girls—may accelerate efforts to lessen gender-based discrimination, poverty, and inequality. Adolescence is a critical developmental

period since it is marked by significant changes in a person's behavior, personality, and brain. This subgroup makes up around 22% of India's overall population [3].

The concept of "adolescence is a theoretical construct that is always changing and is based on physiological and psychological factors from historical and cultural perspectives. Many people view the years between the onset of puberty and the onset of adulthood as this critical developmental stage [4]. When a girl's physiological requirement for iron reaches its peak between the ages of 10 and 15, she usually experiences her pubertal growth spurt. Several physiological changes occur in girls throughout adolescence, including increased erythropoiesis, menarche, and sexual development, all of which have an impact on the amount of iron that they require. Teens who have finished their development spurt require more iron to make up for low body iron stores and depleted tissue zinc pools [5].

Adolescents' bodies require a lot of iron throughout puberty, yet this demand is frequently unmet. They frequently eat poor-quality meals. This has been theorized to be caused by inadequate caloric intake, poor eating habits brought on by concerns about one's weight, and maybe inactivity. Additionally, among individuals of this age, vegetarian diets—which often involve consuming a higher proportion of plant-based meals and a lower intake of animal products—have become more and more popular. While meat and other animal products are good sources of the mineral iron, many plant-based diets are high in dietary fiber and polyphenols. It is well recognized that foods containing these ingredients interfere with the body's ability to absorb iron. Regretfully, this implies that teenage girls'

Other than diet, variables that might worsen low iron intake include excessive menstrual loss, other blood loss (such as nasal bleeds), and intense physical exercise [7]. In a 2012 study conducted by UNICEF, more than 25% of teenage girls were underweight in 11 out of 64 countries, while more than 33% of adolescent girls were anemic in 21 out of 41 countries. Malnutrition in adolescent girls is associated with the poverty cycle that mothers pass on to their children [8].

When using traditional iron supplements, some people may have unfavorable side effects. This emphasizes the necessity of researching the creation of novel products that enhance the iron's stability, cost, and bioavailability. Studying natural functional molecules (such as lactoferrin, plant ferritin, and heme iron) should be the main goal in this field. When adding these iron-rich ingredients to food products, care should be used because consuming too much iron can have detrimental effects, such as a slowed down bone metabolism and an elevated risk of infection. As a result, the iron content of many meals that have been fortified with iron is not high.

Meals enriched with iron are among the greatest alternatives when it comes to safety and affordability. Foods that may include Fe or iron-carrying functional components that both transport and facilitate Fe absorption include cereal, dairy products, and herbal preparations [9]. The ability of plants to provide food, shelter, clothing, and medicine is essential to human life. They are also the basis for hundreds of years-old alternative medicinal techniques, including Chinese, Unani, and Ayurvedic medicine. Many individuals in developing countries still use medicinal plants to address their most basic medical requirements. Due to their broad availability, low cost, and lack of serious side effects, traditional alternative medicines have drawn interest from people all over the world in recent years.

For instance, the gogu plant, pearl millet, curry leaves, and moringa tree all play a significant part in the anemia of teenage females. These plants can be added to a diet as supplements. Iron insufficiency is a prevalent issue among teenage girls. The leaf is edible and can treat anaemia and calcium and vitamin deficits. It is possible to supplement the diet with additional minerals, such as iron-rich iron added to cereals like wheat and maize flour [10]. Because it contains a significant amount of iron and ascorbic acid, roselle is frequently cited as a treatment for anemia. Because ascorbic acid enhances the body's absorption of nonheme iron in anemic individuals, it may have an anti-anaemic impact [11].

2. MORINGA OLEIFERA

The moringa tree, or Moringa Oleifera, is a valuable plant known for its medicinal properties and nutritional benefits. Moringa leaves are packed with essential nutrients, including iron (28.2 mg, which is 25 times more than spinach and more easily absorbed into the bloodstream), vitamin A (16.3 mg), calcium (2003 mg), vitamin E (113 mg), protein (27.1 grams), vitamin C (220 mg), and vitamin B (113 mg, including riboflavin at 20.5 mg, thiamine at 2.6 mg, and nicotinic acid at 8.2 mg). In 100 grams of moringa leaves, the iron content is 28.2 milligrams, which is significantly higher than spinach and almonds (3 times more), and also has better absorption than almonds (1.77 times more) [12].

Moringa leaf extract can help increase blood hemoglobin (Hb) levels, particularly benefiting adolescent girls with anaemia [13]. When anaemia is present, the body needs more iron, which boosts iron absorption. The iron and vitamin

C in Moringa extract enhance this absorption. The leaves can be consumed raw, cooked, or dried and are considered a nutritional powerhouse. According to Fuglie (2005), a serving of dried Moringa leaf powder provides 14% of a child's daily protein, 40% of their calcium, 23% of their iron, and almost all the vitamin A they need in a day [14]. Additionally, just 100 grams of Moringa leaves can meet over a third of a woman's daily calcium requirement, along with significant amounts of iron, protein, copper, sulphur, and B vitamin.

Table 1.1 Effects of Moringa Oleifera in anaemia

Author's name	Study and aim	Results	Conclusion
Anisa et al., (2019) [15]	This study aimed to assess the effectiveness of a combination of vitamin C (50 mg twice a day) and Moringa leaf (250 mg twice a day) in reducing anaemia in young women.	In the treatment group, the average hemoglobin level increased from 9.37 to 12.10 gm/dl. Statistical analysis confirmed that combining Moringa leaf and vitamin C effectively raised hemoglobin levels in young women with anaemia.	It is recommended that young women receive better education about anaemia, including its prevention and treatment options.
Suzana et al., (2017) [16]	This study investigated the possibility of using an iron-rich extract from Moringa Oleifera leaves as a dietary supplement for anemia sufferers.	The control groups had significantly higher averages than the experimental groups in terms of hemoglobin (0.644±0.83 g/dL), erythrocytes (0.475±0.523) Tpt/L, haematocrit (2.189±4.08%), mean corpuscular volume (4.756±0.89 FL), mean corpuscular hemoglobin (2.183-2.47 pg), and relative dissipation rate (2.844±2.80%). The experimental group exhibited substantially lower platelet counts ($p<0.05$) and significantly greater haematocrit (3.14±1.47%), MCH (3.495±1.33 pg), and MCHC (3.264±0.96 g/dL) values than the control group.	Researchers conclude that a moringa leaf extract may be able to cure female iron deficiency anemia.
Tirtawati et al., (2021) [17]	The study's objective was to determine how Moringa Oleifera teabags alter teenage females' levels of hemoglobin (Hb).	The mean hemoglobin (Hb) increase before to therapy was 10.71 g/dl. After 15 days of therapy, it decreased to 11.03 g/dl. Following a 30-day course of therapy, the average hemoglobin (Hb) value was 11.63 g/dl, with a statistically significant change in Hb levels between the baseline and post-treatment values of 0.000 ($p <0.005$).	After consuming tea prepared from moringa leaves, teenage girls' hemoglobin levels dramatically improved, indicating that this therapy was effective.
Devillya et al., (2017) [18]	The purpose of the study was to find out if consuming Moringa Oleifera cookies may help teenage girls who suffer from anemia.	The results showed that the majority of respondents (91.9%) had normal nutritional status, the majority of respondents (64.5%) were between the ages of 10 and 13 years, and the mean hemoglobin levels before and after the intervention were 11.13 ±0.81 and 12.67 ±1.08, respectively. The study found that cookies made	It is established that moringa leifera cookies affect teenage girls who are anemic.

		from Moringa Oleifera had an effect on female teenage Hb ($p<0.05$).	
Sarkar et al., (2021) [19]	This study examined the possibility of using moringa leaves as a non-heme iron supplement to treat anemia.	A statistically significant rise ($p <0.001$) was seen in the post-test mean Hb levels for the group utilizing powdered drumstick leaves, which climbed from 10.7167±0.25 to 11.1000±0.32 gm/dl.	Researchers found that feeding a powder prepared from drumstick leaves to adolescent girls raised their hemoglobin levels.

3. GOGUS PLANT (HIBISCUS SABDARIFFA L.)

A hemoglobin content of less than 11.0 g/dl at sea level is considered anemia. It is the major cause of morbidity in all age groups. In 2005, an estimated 1.62 billion people worldwide suffered from anemia. Africa is home to a startling 67.6% of all impacted individuals [20]. Hibiscus sabdariffa L., often known as the flower roselle, is grown. It belongs to the family Malvaceae.

This plant is widely used in traditional medicine and has tremendous promise in modern therapeutic applications because of its high concentration of phytochemicals, such as organic acids, polysaccharides, and polyphenols, particularly anthocyanins. In another study, pregnant anemic women taking iron supplements were given Roselle flower extract. According to the research, the combination of the iron tablets and the Roselle extract significantly raised hemoglobin levels. The higher ascorbic acid concentration of the Roselle might be the source of this [21].

Table 2.2 Role of Hibiscus sabdariffa L. in anaemia

Author's name	Study and aim	Results	Conclusion
Handayani et al., (2022) [22	This study set out to prove that supplementing female adolescents with anemia with an extract of the calyx from the Rosella plant (Hibiscus sabdariffa Linn.) successfully increases hemoglobin and haematocrit levels.	The levels of haematocrit and hemoglobin in the intervention and control groups of female teens were observed to differ statistically significantly (p-value < 0.05).	The combination of Fe+2 tablet and Rosella (Hibiscus sabdariffa Linn.) calyx extract was well-received by anaemic female teens.
Peter et al.,(2017) [23]	The purpose of this study was to evaluate the safety and efficacy of an aqueous extract of H. sabdariffa L. in the treatment of adult anemia.	An adult standardized aqueous extract of H. sabdariffa L. could not improve anemia (P0>0.005) in a region where malaria is prevalent. The high iron and organic acid content of H. sabdariffa L. extract, however, has been demonstrated to improve hematopoietic parameters.	Consequently, bigger sample size investigations are needed to ascertain if the extract works well when combined with malaria chemoprophylaxis in malaria-endemic areas. (19).
Emelike et al., (2013) [24]	When Hibiscus sabdariffa aqueous extract was given orally to Wistar albino rats, several haematological parameters were examined.	With the exception of Group E and A (the control group), all of the rats' body weight fell. All of the groups' haematological markers, such as hemoglobin (Hb), packed cell volume (PCV), total white blood cells (WBC), and differentials,	The results of the study indicate that giving an aqueous extract of Hibiscus sabdariffa may benefit the hematopoietic system.

		significantly increased in comparison to Group A (the control).	
Chukwu et al., 2018) [25]	The aim of this study was to assess and investigate haematological parameters with a modified Roselle beverage preparation derived from the gogu plant.	It was discovered that Wistar albino rats had dramatically decreased WBC count and lymphocytes, but had significantly higher hemoglobin, packed cell volume, platelets, and red blood cell count. Roselle drinks were discovered by researchers to have haematocrit features, suggesting that they might be used to treat anemia.	It was discovered by researchers that Roselle beverages contained haematocrit properties and might be used as a treatment for anemia.

4. Curry leaves (Moenigii Murraya)

Iron deficiency in the diet is the most common cause of anemia. Curry leaves are a powerful tool for increasing the body's production of red blood cells since they contain iron and folic acid. Consuming meals rich in folic acid can frequently enhance the absorption of iron from dietary sources. Curry leaves have a lot of folic acid, which helps with this as well. Curry leaves also work well as a blood purifier. Moenigii Murraya Linn. Spreng (M. koenigii), a fragrant member of the Rutaceae family and often known as "Curry Patta," has been used widely in India as an Ayurvedic herbal medicine [26]. For years, it has been utilized to treat a wide range of unconnected illnesses, including diarrhea, anemia, microbial growth, and iron supplements.

Table 3.3 Benefits of Curry leaves in anaemia

Author's name	Study and aim	Results	Conclusion
Choudhury et al., (2015) [27]	The aim of this study was to investigate the potential effects of an aqueous extract of Murraya koenigii leaves on the concentrations of certain lipids in rats' serum.	The extract substantially ($P<0.05$) increased packed cell volume, hemoglobin concentration, red blood cell, mean corpuscular hemoglobin, mean corpuscular volume, and decreased platelet count when comparing the experimental groups with the control group. After the extract was administered, the body's white blood cell count was consistently greater ($P<0.05$) than it was in the control group. The outcomes showed a decrease in thyroid stimulating hormone and an increase in thyroxine and thyronine at the higher dosage, as was predicted. In comparison to the baseline value, testosterone levels were determined to be significantly reduced ($P < 0.05$). The extract significantly reduced total blood cholesterol and low-density lipoprotein cholesterol ($P<0.05$), but did not affect high-density lipoprotein cholesterol.	This research indicated that there may be a beneficial effect on serum cholesterol levels, activation of thyroid functions, treatment of anemia and immunity-dependent diseases, and potent contraceptive qualities.

5. PEARL MILLETS (PENNISETUM GLAUCUM)

Iron-deficiency anemia is the primary cause of impairment in young children and teens, and iron deficiency is the most frequent dietary shortfall in the world. Among teenagers in particular, anemia and iron deficiency are widespread. As a primary source of sustenance, pearl millet is used by millions of people in the Indian states of Rajasthan, Gujarat, and Uttar Pradesh [28]. Sixty-six percent of children in some places suffer from anemia. The high prevalence of pearl millet consumption in these regions shows a significant chance to enhance dietary iron intake. Pearl millet has the highest content of iron among grains [29]. Calcium, fiber, phytochemicals, and other minerals are all abundantly available in it.

Table 4.4 The beneficial role of Pearl millet in anaemia

Author's name	Study and aim	Results	Conclusion
Scott et al., (2018) [30]	Analyze how pearl millet supplemented with extra iron affects the concentration and memory recall of school-age Indian teenagers.	The daily iron consumption of individuals who ate biofortified pearl millet was higher than that of those who drank regular pearl millet (19.6 mg/d vs. 4.8 mg/d). After four months, and again at six months ($P<0.05$), biofortified pearl millet was shown to be more successful than normal pearl millet in improving iron status. This was demonstrated by its effects on ferritin, TfR (transferrin receptor), and BI (body iron). Biofortified pearl millet produced significantly greater improvements in memory (CFE (Composite Face Effect task) and CRT (Cued Recognition Task)) and focus (Go/No-Go (GNG) job, SRT simple response time), and ANT (Attentional Network job)) when compared to ordinary pearl millet.	Pearl millet that has been biofortified with iron may be beneficial for Indian adolescents who have low iron levels.
Cercamondiet al., (2013) [31]	In order to determine if iron-biofortified millet may provide more bioavailable iron than regular millet or post-harvest iron-fortified millet, iron absorption research was conducted on twenty Beninese women with low iron levels.	The findings showed that, even though biofortified millet absorbs iron at a lower percentage than fortified millet, it would still be extremely helpful in preventing iron deficiency in populations that consume millet.	Finally, our findings show that pearl millet that has been post-harvest and iron biofortified absorbs around two and three times more iron than pearl millet that has not been biofortified.
Singh et al., (2014) [32]	The current study set out to develop and standardize a pearl millet-based, iron-rich ladoo and compare its benefits to those of iron folic acid pills in the treatment of anemia.	In Groups A, B, and C, the intervention program was applied, and the corresponding increases in Hb levels were 2.24 g/dl, 2.28 g/dl, and 0.54 g/dl. As a result, increasing the hemoglobin levels of teenage girls with a food-based approach utilizing pearl millet ladoo may prove to be just	In conclusion, increasing the hemoglobin levels of teenage females may be accomplished just as well with a food-based approach with pearl millet ladoo as with elemental iron supplementation.

		as effective as elemental iron supplementation.	
Devulapalli et al., (2022)[33]	To compare the nutritional benefits of millet-based meals before and after the intervention on weight, body mass index (BMI), hemoglobin, energy bars, and finger millet cutlets	Teenagers' blood hemoglobin levels varied from 7.0 to 9.9 g/dl, meaning that over 90% of them were anemic. Following the intervention, the average hemoglobin level increased from 8.400.9 g/dl to 8.450.6 g/dl and the average body mass index (BMI) increased from 16.42.5 kg/m2 to 17.32.2 kg/m2. The paired t-test revealed statistically significant changes, with 95% confidence intervals, in body mass index (p=0.001) and weight (p=0.001) between baseline and post-intervention. at an effort to counteract the high incidence of anemia among female pupils at school, four varieties of ready-to-eat snacks made of millet were provided in addition to the Mid-Day Meal (MDM).	Four varieties of ready-to-eat snacks made of millet were offered as an addition to the Mid-Day Meal (MDM) in an effort to reduce the incidence of anemia among female students in school.
Jani et al., (2015) [34]	In this cross-sectional study, the prevalence of folate deficiency and appropriate folate consumption were assessed in 224 tribal Indian teenage females (10 to 17 years of age).	The average hemoglobin level per litter was 125.4±13.0 grams, whereas the average folate consumption was 159.5± 44.7 mcg per day. The folate concentration of RBCs was 360.2 (329.7 to 393.6) nmol/L on a geometric mean. Almost half of boys and girls aged 10–12 and 13–15 years had appropriate levels of red blood cell folate (340 nmol/L), whereas 67% of adolescent girls did not. Compared to men (173.8± 45.2), girls consumed less folate (mean ± SD, 139.4 ± 34.5) per day (p.001). Girls between the ages of 16 and 17 (78.5% vs. 38.6%, p<0.001) and 100.0% vs. 76.9%, p = 0.04 (RDA) had considerably higher intakes of folate than did females between the ages of 13 and 15. There was no relationship found between anemia or folate intake and red blood cell folate deficiency.	Native American tribal adolescents frequently lacked the vitamin folate. There is an urgent need for improvement solutions that are culturally competent.

6. DISCUSSION

Anaemia is a widespread nutritional condition, particularly affecting adolescent girls and women of reproductive age (14-45 years), with iron deficiency being the most common dietary issue. According to WHO statistics, 52% of women in India suffer from nutritional deficiency anaemia. Poor dietary habits and the increasing consumption of junk food contribute significantly to this problem. Anaemia can seriously impact an individual's health and well-being. To combat

this, it is important to include iron-rich foods in the diet, such as red meat, tofu, salmon, eggs, cereals, and leafy greens like Gogu plants, curry leaves, pearl millet, and Moringa Oleifera. Legumes and nuts are also excellent sources of essential vitamins, while citrus fruits provide a high amount of vitamin C. These nutritious options should replace unhealthy alternatives in daily meals.

Anaemia is a process rather than a standalone disease, and halting this process can prevent many serious health issues. Maintaining adequate hemoglobin levels in the blood can help avoid various health problems. Adolescent girls, who represent the future of a country, are particularly vulnerable to nutritional deficiencies. Research has shown that teenage girls often do not consume enough recommended green leafy vegetables, such as Gogu plants, curry leaves, pearl millet, and Moringa Oleifera. Notably, curry leaves are consumed less frequently compared to pearl millet, Gogu plant, and Moringa Oleifera [35]. Research on curry leaves is still limited, highlighting the need for more studies to fully understand their role in combating anaemia. Among grains, pearl millet stands out for its high iron content and is also rich in calcium, fiber, phytochemicals, and other essential minerals. The significant consumption of pearl millet suggests a strong demand for dietary iron supplementation. This insight could be valuable for exploring the herb's potential applications, including its therapeutic and medicinal properties, and advancements in processing and extraction methods [36]. Researchers are actively investigating the nutraceutical benefits of pearl millet to enhance its use in various culinary applications.

7. CONCLUSION

Several barriers to iron supplement intake have been identified, including a lack of awareness about anaemia and its effects among women and adolescent girls, inadequate supply and distribution systems for iron supplements, and misconceptions about the potentially harmful effects of these supplements, such as links to hypertension. Cultural beliefs, limited access, and infrequent use of prenatal health services also contribute to the issue. Research shows that most women do not experience negative side effects from iron supplements. However, without addressing supply and delivery challenges, iron supplementation programs are unlikely to be effective. Additionally, encouraging women to maintain a consistent supplement regimen requires complex behavioral changes. Therefore, further research is needed to explore innovative solutions for improving supply and distribution, as well as to help young girls establish a daily routine for supplementation.

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