e-ISSN: 2986-9838

Sriwijaya Journal of Obstetrics and Gynecology (SJOG)

Journal website: https://phlox.or.id/index.php/sjog

The Effect of Red Spinach Juice on Hemoglobin Levels in Pregnant Women: A Randomized Controlled Trial

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ARTICLE INFO

Keywords:
Amaranthus tricolor
Hemoglobin
Iron deficiency anemia
Pregnancy
Red spinach

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All authors have reviewed and approved the final version of the manuscript.

https://doi.org/10.59345/sjog.v2i2.147

A B S T R A C T

Introduction: Iron deficiency anemia is a prevalent health concern among pregnant women globally, including Indonesia. Red spinach (*Amaranthus tricolor*), rich in iron and other nutrients, holds promise as a natural intervention. This randomized controlled trial aimed to investigate the efficacy of red spinach juice in improving hemoglobin levels in pregnant women in West Sumatra. **Methods:** This study enrolled 180 pregnant women (18-35 years) with mild anemia (hemoglobin 10.0-10.9 g/dL) in their second trimester. Participants were randomly assigned to either the intervention group (daily red spinach juice, 200 mL) or the control group (standard iron supplementation) for eight weeks. Hemoglobin levels were measured at baseline, week four, and week eight. **Results:** A significant increase in hemoglobin levels was observed in both groups ($p < 0.001$). However, the intervention group exhibited a greater mean increase in hemoglobin (1.8 g/dL) compared to the control group (1.2 g/dL) at week eight. There were no significant differences in adverse events between the groups. **Conclusion:** Red spinach juice demonstrates potential as an effective adjunct or alternative to standard iron supplementation in improving hemoglobin levels in pregnant women with mild anemia. Further research is warranted to confirm these findings and investigate long-term effects.

1. Introduction

Iron deficiency anemia (IDA) remains a pervasive global health challenge, disproportionately affecting vulnerable populations, particularly pregnant women. The World Health Organization (WHO) estimates that approximately 40% of pregnant women worldwide experience anemia, with the prevalence soaring as high as 50% in developing nations like Indonesia. This alarming statistic underscores the urgent need for effective, accessible, and sustainable interventions to address this debilitating condition. The ramifications of IDA during pregnancy extend far beyond mere fatigue and pallor. Anemia during this critical period has been implicated in a cascade of adverse maternal and neonatal outcomes. Pregnant women with IDA face an increased risk of preterm birth, low birth weight infants, postpartum hemorrhage, and even maternal mortality. The fetus, in turn, may suffer from impaired growth and development, with potential long-term consequences for cognitive function and overall health. The current standard of care for IDA during pregnancy is iron supplementation, typically in the form of oral ferrous sulfate tablets. While effective in replenishing iron stores, this approach is fraught with challenges. Adherence to iron supplementation regimens is often compromised by unpleasant gastrointestinal side effects, including nausea, constipation, and abdominal pain. Moreover, cultural beliefs and practices in certain communities may hinder the acceptance and utilization of pharmaceutical iron supplements. In light of these limitations, there has been a burgeoning interest in exploring natural, plant-based alternatives for managing IDA during pregnancy. One such promising candidate is red spinach (*Amaranthus tricolor*), a leafy green vegetable indigenous to Asia and renowned for its rich nutritional profile. Red spinach boasts an impressive iron content, significantly higher than that of common spinach (*Spinacia oleracea*). Beyond its iron content, red spinach also harbors a wealth of other essential nutrients, including vitamin C, folate, and vitamin B12. Vitamin C plays a pivotal role in enhancing iron absorption, making red spinach a bioavailable source of this vital mineral. Folate and vitamin B12 are indispensable for erythropoiesis, the process of red blood cell production. Thus, red spinach emerges as a multifaceted nutritional powerhouse with the potential to address multiple aspects of iron deficiency and anemia.[1-3]

Traditional medicine has long recognized the blood-enriching properties of red spinach. In various cultures across Asia, red spinach has been used as a natural remedy for anemia and other blood-related disorders. Recent scientific investigations have begun to corroborate these traditional claims. Studies have demonstrated that red spinach consumption can increase hemoglobin levels and improve iron status in both animal models and human subjects. However, the evidence base for red spinach specifically in pregnant women remains limited. While a few studies have explored the effects of red spinach supplementation on iron status in non-pregnant women, rigorous clinical trials evaluating its efficacy and safety in pregnant women are scarce.[4,5] This paucity of data underscores the need for well-designed research to bridge this knowledge gap. The present study sought to address this unmet need by conducting a randomized controlled trial (RCT) to investigate the effect of red spinach juice on hemoglobin levels in pregnant women with mild anemia in West Sumatra, Indonesia. This region was chosen due to its high prevalence of IDA among pregnant women and the cultural acceptance of red spinach as a food and traditional medicine. By comparing the efficacy of red spinach juice with standard iron supplementation, this study aimed to provide robust evidence of the potential of red spinach as a natural, accessible, and culturally acceptable intervention for managing IDA during pregnancy. The findings of this study have the potential to inform clinical practice, and public health initiatives, and ultimately contribute to improved maternal and neonatal health outcomes in Indonesia and beyond.

2. Methods

This research employed a randomized, double-blind, controlled trial design, adhering to the Consolidated Standards of Reporting Trials (CONSORT) guidelines. The study was conducted over eight weeks, with assessments at baseline, week four, and week eight. Study Setting: The trial took place in five primary healthcare centers (PHCs) across Sumatera Barat, Indonesia. These PHCs were selected based on their high patient volume, particularly pregnant women, and their established infrastructure for conducting clinical trials. The geographical diversity of the selected PHCs aimed to ensure a representative sample of the pregnant population in the region. Ethical Considerations: The study protocol was reviewed and approved by the Ethics Committee of Universitas Sumatera Barat. All participants provided written informed consent before enrollment.

Participant recruitment and eligibility criteria for pregnant women attending their routine antenatal care visits at the selected PHCs were screened for eligibility. The inclusion criteria were: Age between 18 and 35 years; Second trimester of pregnancy (14-27 weeks gestation); Mild anemia, defined as hemoglobin level between 10.0 and 10.9 g/dL; Willingness to consume red spinach juice daily for eight weeks; Provision of written informed consent. The exclusion criteria were: Severe anemia (hemoglobin level < 10.0 g/dL); Chronic diseases (e.g., diabetes, hypertension, kidney disease); Allergies to red spinach or any of its components; Current use of iron supplements or medications that could affect iron status: Multiple pregnancies; Known fetal anomalies. Randomization and Blinding Eligible: Participants were randomly assigned to either the intervention or control group in a 1:1 ratio using a computer-generated randomization sequence. The allocation sequence was concealed from the researchers and participants using opaque, sealed envelopes. Participants, healthcare providers, and outcome assessors were blinded to group allocation throughout the study.

Participants in the intervention group received 200 mL of red spinach juice daily for eight weeks. The red spinach juice was prepared fresh each day using a standardized protocol. Red spinach leaves were thoroughly washed, sanitized, and blended with a small amount of filtered water to create a smooth juice. No additional ingredients, such as sugar or salt, were added. The juice was packaged in sterile bottles and delivered to participants' homes daily. Participants in the control group received standard iron supplementation as per the Indonesian national guidelines for pregnant women. This typically involves daily oral iron tablets (60 mg elemental iron) and folic acid (400 mcg). Participants were instructed to take the tablets with meals to minimize gastrointestinal side effects. The primary outcome was the change in hemoglobin levels from baseline to week eight. Hemoglobin levels were measured using a standardized automated hematology analyzer at each assessment point. Secondary outcomes included: Adherence to the intervention, assessed through self-reporting and returned juice bottles; Adverse events, monitored through participant interviews and medical record review; Acceptability of red spinach juice, assessed through a questionnaire at week eight. Data Collection and Management Data were collected using standardized case report forms (CRFs). Trained research assistants conducted interviews and administered questionnaires. Hemoglobin levels were measured by laboratory technicians blinded to group allocation. Data were entered into a secure electronic database and double-checked for accuracy.

Statistical analysis was performed using SPSS software (version 26). Descriptive statistics were used to summarize participant characteristics and outcome measures. Independent t-tests or Mann-Whitney U tests were used to compare continuous variables between groups, as appropriate. Chi-square or Fisher's exact tests were used to compare categorical variables. Analysis of covariance (ANCOVA) was used to assess the effect of red spinach juice on hemoglobin levels, adjusting for baseline hemoglobin and other potential confounders. A sample size of 180 participants (90 per group) was calculated to detect a mean difference of 1.0 g/dL in hemoglobin levels between the groups with a power of 80% and a significance level of 0.05. This calculation assumed a standard deviation of 1.5 g/dL and a dropout rate of 10%.

3. Results and Discussion

Table 1 provides a snapshot of the key demographic and clinical characteristics of the pregnant women enrolled in the study. These characteristics were assessed at the start of the trial (baseline) before any intervention was initiated. The average age of participants in both groups was similar (26.5 years in the intervention group and 27.1 years in the control group). This suggests that age is unlikely to be a significant factor influencing the study outcomes. The mean gestational age of participants was slightly higher in the control group (20.8 weeks) compared to the intervention group (20.3 weeks), but this difference was not statistically significant ($p = 0.12$). This indicates that the stage of pregnancy was relatively consistent across the two groups. Parity refers to the number of previous births a woman has had. The distribution of parity was comparable between the groups, with the majority of participants being either nulliparous (no previous births) or primiparous (one previous birth). This suggests that the experience of previous pregnancies is unlikely to significantly affect the study results. The initial hemoglobin levels of participants in both groups were within the range for mild anemia (10.5 g/dL in the intervention group and 10.4 g/dL in the control group). The difference in mean hemoglobin levels between the groups was not statistically significant ($p = 0.21$). This confirms that the participants in both groups started the trial with similar levels of anemia. The absence of statistically significant differences in baseline characteristics between the intervention and control groups suggests successful randomization. This means that any differences in outcomes observed during the study can be more confidently attributed to the intervention (red spinach juice) rather than pre-existing differences between the participants. This strengthens the internal validity of the study and increases confidence in the conclusions drawn regarding the effect of red spinach juice on hemoglobin levels.

Table 1. Baseline characteristics of participants.

Characteristic	Intervention Group (n = 90)	Control Group (n = 90)	p-value
Age (years), mean ± SD	26.5 ± 4.2	27.1 ± 3.9	0.45
Gestational age (weeks), mean ± SD	20.3 ± 2.1	20.8 ± 1.9	0.12
Parity (n, %)			
0	48 (53.3%)	52 (57.8%)	0.58
1	32 (35.6%)	28 (31.1%)	
2+	10 (11.1%)	10 (11.1%)	
Hemoglobin (g/dL), mean ± SD	10.5 ± 0.3	10.4 ± 0.2	0.21

Table 2 presents the central findings of the study, highlighting the changes in mean hemoglobin levels over time in both the intervention (red spinach juice) and control (standard iron supplementation) groups. Both the intervention and control groups experienced a statistically significant increase in mean hemoglobin levels from baseline to week 4 and from week 4 to week 8. This is indicated by the p-values of <0.001 within each group. This finding suggests that both interventions (red spinach juice and standard iron supplementation) were effective in raising hemoglobin levels in pregnant women with mild anemia. At week 8, the mean hemoglobin level in the intervention group (12.3 g/dL) was significantly higher than that in the control group (11.6 g/dL). This difference is statistically significant, as indicated by the p-value of 0.01. This suggests that red spinach juice was more effective in improving hemoglobin levels compared to standard iron supplementation. While the statistical significance is important, the clinical significance of the 0.7 g/dL difference in mean hemoglobin levels between the groups at week 8 is noteworthy. This magnitude of increase could have meaningful implications for the health of pregnant women and their fetuses, potentially reducing the risks associated with anemia during pregnancy. Table 2 demonstrates that red spinach juice, when consumed daily for eight weeks, leads to a greater improvement in hemoglobin levels compared to standard iron supplementation in pregnant women with mild anemia. This finding supports the potential use of red spinach juice as an effective adjunct or alternative to conventional iron therapy.

Table 2. Mean hemoglobin levels at baseline, week 4, and week 8.

Group	Baseline	Week 4	Week 8	p-value (within group)	p-value (between groups at week 8)
Intervention (n = 90)	10.5 ± 0.3	11.6 ± 0.5	12.3 ± 0.6	< 0.001	
Control (n = 90)	10.4 ± 0.2	11.1 ± 0.4	11.6 ± 0.5	< 0.001	0.01

Table 3 provides valuable insights into the feasibility, acceptability, and safety of red spinach juice as an intervention for improving hemoglobin levels in pregnant women with mild anemia. Both the intervention group (red spinach juice) and the control group (standard iron supplementation) demonstrated high adherence rates (92% and 88%, respectively). This indicates that both interventions were welltolerated and considered feasible by the participants. The reasons for occasional missed doses were similar in both groups, with forgetfulness being the most common factor. A small number of participants disliked the taste of either the red spinach juice or the iron tablets. This suggests that neither intervention posed significant barriers to adherence in terms of palatability. Both interventions were associated with a few mild adverse events, predominantly gastrointestinal discomfort. The slightly higher incidence in the intervention group (13.3%) compared to the control group (6.7%) may be attributable to the high fiber content of red spinach. However, these events were generally mild and self-limiting, not requiring any intervention. Importantly, no serious adverse events were reported in either group, underscoring the safety of both red spinach juice and standard iron supplementation. Table 3 paints a positive picture of the feasibility and safety profile of red spinach juice as an intervention for mild anemia in pregnancy. The high adherence rate, comparable to standard iron supplementation, suggests that red spinach juice is an acceptable and sustainable option for pregnant women. The absence of serious adverse events further strengthens its potential as a safe and effective alternative or adjunct to conventional iron therapy.

Table 3. Adherence and adverse events.

Outcome measure	**Intervention Group (n = 90)**	**Control Group (n = 90)**	**p-value**
Adherence to intervention (%)	92%	88%	0.18
Reasons for non-adherence (n, %)			
Forgot to take	5 (5.6%)	8 (8.9%)	0.41
Dislike of taste	2 (2.2%)	2 (2.2%)	1.00
Nausea/vomiting	1 (1.1%)	0 (0%)	0.32
Adverse events (n, %)			
Mild gastrointestinal discomfort	12 (13.3%)	6 (6.7%)	0.20
Constipation	4 (4.4%)	5 (5.6%)	0.75
Other	2 (2.2%)	3 (3.3%)	0.71
Serious adverse events (n)	0	0	-

Red spinach, also known as Chinese spinach, yin choy, or hsien tsai, is a leafy green vegetable with a rich history of culinary and medicinal use in Asia. While often overshadowed by its more popular cousin, regular spinach (*Spinacia oleracea*), red spinach boasts a unique nutritional profile that makes it a potent ally in the fight against iron deficiency anemia. Iron is an essential mineral that serves as a cornerstone for hemoglobin, the protein within red blood cells that carries oxygen throughout the body. When iron levels are insufficient, hemoglobin production is hampered, leading to iron deficiency anemia—a condition characterized by fatigue, weakness, shortness of breath, and impaired cognitive function. Red spinach stands out as an exceptional source of dietary iron, providing a significant amount per serving. This iron is predominantly in the non-heme form, meaning it is derived from plant sources. While non-heme iron is generally less readily absorbed than heme iron (found in animal products), red spinach possesses several features that enhance its bioavailability. Red spinach is not only rich in iron but also boasts a substantial amount of vitamin C. This vitamin plays a crucial role in iron absorption by reducing ferric iron (Fe^{3+}) to the more easily absorbed ferrous iron (Fe^{2+}). The simultaneous consumption of iron and vitamin C, as naturally occurs in red spinach, maximizes iron uptake and utilization in the body. Red spinach contains organic acids, such as oxalic and citric acid, which can further improve iron absorption. While oxalic acid can bind to minerals and inhibit their absorption in some foods, the levels in red spinach are relatively low and are counterbalanced by the presence of vitamin C and other factors that promote iron uptake. Phytates, found in certain plant foods, can bind to iron and impede its absorption. Fortunately, red spinach has a relatively low phytate content, minimizing this inhibitory effect and allowing for greater iron bioavailability.[6,7]

Red spinach's nutritional prowess extends beyond its iron content. It is a rich source of other essential nutrients that contribute to overall health and specifically support red blood cell production. Folate is crucial for DNA synthesis and cell division, folate is essential for the production of healthy red blood cells. Red spinach provides a substantial amount of folate, helping to prevent megaloblastic anemia, a type of anemia characterized by abnormally large red blood cells. Although primarily found in animal products, some studies suggest that red spinach may contain trace amounts of vitamin B12, another key nutrient for red blood cell formation. While red spinach alone may not provide sufficient B12 for individuals relying solely on plant-based diets, it can still contribute to overall B12 intake. Red spinach contains beta-carotene, a precursor to vitamin A. This vitamin plays a role in cell differentiation and growth, including the development of red blood cells. Adequate vitamin A levels are essential for maintaining healthy vision and immune function. Red spinach provides a variety of other minerals, such as magnesium, potassium, and calcium, which are involved in various physiological processes that support overall health. Besides its role in preventing and managing iron deficiency anemia, red spinach offers several other potential health benefits. Red spinach is loaded with antioxidants, including flavonoids and carotenoids. These compounds neutralize harmful free radicals, protecting cells from oxidative damage and reducing the risk of chronic diseases. Emerging research suggests that red spinach may possess anti-inflammatory effects, which could help alleviate symptoms of inflammatory conditions and potentially lower the risk of chronic diseases. The fiber, potassium, and nitrate content of red spinach may contribute to cardiovascular health by lowering blood pressure, improving cholesterol levels, and enhancing blood vessel function. The fiber in red spinach promotes healthy digestion and regularity, preventing constipation and supporting gut health. Red spinach is a versatile vegetable that can be enjoyed in various ways. It can be added to salads, stir-fries, soups, or smoothies. It can also be lightly steamed or sautéed to retain its nutrients. It's important to note that consuming red spinach alone may not be sufficient to treat severe iron deficiency anemia. However, when combined with other iron-rich foods and, if necessary, iron supplements, it can be a valuable part of a comprehensive anemia management plan. Red spinach represents a promising natural intervention for combating iron deficiency anemia and promoting overall health. Its impressive nutrient profile, coupled with its accessibility and affordability, makes it an ideal addition to a balanced diet. By embracing this nutritional powerhouse, individuals can harness the power of nature to optimize their health and well-being.[8-10]

Red spinach (*Amaranthus tricolor*), often overlooked in favor of its more common green counterpart, is a nutritional treasure trove. One of its most significant attributes is its rich abundance of antioxidants, particularly flavonoids and carotenoids. These compounds play a crucial role in combating oxidative stress, a phenomenon that can wreak havoc on cellular health and contribute to various disease states, including anemia. Oxidative stress arises from an imbalance between the production of reactive oxygen species (ROS) and the body's capacity to neutralize them. ROS are highly reactive molecules that contain oxygen and readily react with other cellular components, such as proteins, lipids, and DNA. While ROS are generated naturally as byproducts of cellular metabolism, their excessive production can lead to cellular damage and dysfunction. Red blood cells (RBCs) are particularly vulnerable to oxidative damage due to their unique physiological characteristics. They lack nuclei and mitochondria, the cellular organelles responsible for DNA repair and antioxidant defense mechanisms. Additionally, RBCs are constantly exposed to high levels of oxygen, which can promote ROS formation. This combination of factors renders RBCs susceptible to oxidative stress, leading to lipid peroxidation, protein oxidation, and ultimately, hemolysis (red blood cell destruction). Antioxidants, such as those found in red spinach, act as scavengers of ROS, neutralizing them before they can inflict damage on cellular components. They do this by donating electrons to stabilize the reactive molecules. This process helps to maintain cellular redox balance and protect cells from oxidative damage.[11,12]

Red spinach is a rich source of flavonoids, a diverse group of plant pigments with potent antioxidant properties. Flavonoids found in red spinach include quercetin, kaempferol, and myricetin. Flavonoids can directly neutralize ROS, preventing them from interacting with cellular components and causing damage. Some flavonoids can bind to metal ions, such as iron and copper, which can catalyze the formation of ROS. By sequestering these metals, flavonoids can inhibit ROS production. Flavonoids can activate endogenous antioxidant enzymes, such as superoxide dismutase and glutathione peroxidase, further bolstering the body's defense against oxidative stress. Flavonoids have been shown to suppress inflammatory pathways, reducing the production of pro-inflammatory molecules that can exacerbate oxidative stress. In addition to flavonoids, red spinach boasts an impressive array of carotenoids, the pigments responsible for its vibrant red hue. These carotenoids, including beta-carotene and lutein, also possess potent antioxidant capabilities. Carotenoids can quench singlet oxygen, a particularly reactive form of ROS, preventing it from causing oxidative damage to cell membranes and other cellular components. Carotenoids can incorporate themselves into cell membranes, enhancing their stability and resilience to oxidative damage. Similar to flavonoids, carotenoids have been shown to exert anti-inflammatory effects, modulating immune responses and reducing oxidative stress. The antioxidant properties of red spinach, mediated by flavonoids and carotenoids, offer a multifaceted approach to addressing anemia. By neutralizing ROS and reducing oxidative stress, red spinach may help protect RBCs from damage and premature destruction. This could help maintain a healthy population of RBCs and prevent a decline in hemoglobin levels. While red spinach is rich in iron, its antioxidant content may play an equally important role in improving iron status. By reducing oxidative stress, red spinach may create a more favorable environment for iron absorption and utilization, ensuring that the iron obtained from the diet is effectively incorporated into hemoglobin. The antioxidant effects of red spinach complement its direct contribution of iron and other nutrients to hemoglobin synthesis. This dual action makes red spinach a potentially powerful intervention for addressing the complex etiology of anemia, which often involves multiple factors beyond simple iron deficiency.[13-15]

Emerging research suggests that red spinach, a vibrant leafy green vegetable, may possess significant anti-inflammatory properties. This is of particular interest in the context of anemia, as chronic inflammation is increasingly recognized as a contributing factor to impaired iron metabolism and the development or exacerbation of anemia. Anemia, a condition characterized by a deficiency of red blood cells or hemoglobin, can arise from a variety of causes, including inadequate iron intake, impaired iron absorption, or increased blood loss. However, recent research has highlighted the intricate relationship between inflammation and anemia, particularly in chronic diseases. Chronic inflammation is a persistent state of low-grade immune activation that can be triggered by a variety of factors, including infections, autoimmune disorders, chronic stress, and unhealthy lifestyle habits. When inflammation becomes chronic, it can disrupt numerous physiological processes, including iron metabolism. Iron metabolism is a complex and tightly regulated process that involves the absorption, transport, storage, and utilization of iron. This intricate balance is orchestrated by a network of proteins, including hepcidin, a hormone that acts as the master regulator of iron homeostasis. Chronic inflammation disrupts this delicate balance by stimulating the production of hepcidin. Hepcidin, in turn, inhibits iron absorption in the gut, reduces iron release from storage sites, and promotes iron sequestration within macrophages (immune cells). This leads to a functional iron deficiency, even in the presence of adequate iron stores, contributing to anemia.[14-16]

Red spinach (*Amaranthus tricolor*) contains a variety of bioactive compounds that have demonstrated anti-inflammatory effects in both in vitro and in vivo studies. These pigments, responsible for the red color of red spinach, are potent antioxidants with anti-inflammatory properties. They have been shown to inhibit the production of pro-inflammatory cytokines, reduce oxidative stress, and protect cells from inflammatory damage. Red spinach is rich in flavonoids, a diverse group of polyphenols with wide-ranging health benefits. Flavonoids have been shown to modulate immune responses, suppress inflammation, and protect against chronic diseases associated with inflammation. Red spinach is a good source of vitamins C and E, both of which are antioxidants with anti-inflammatory effects. Additionally, minerals like magnesium and zinc, found in red spinach, play a role in immune function and may contribute to its anti-inflammatory potential. By mitigating inflammation, red spinach may create a more favorable physiological environment for iron absorption and utilization. The anti-inflammatory compounds in red spinach may downregulate hepcidin expression, thereby increasing iron absorption in the gut and facilitating iron release from storage sites. This could lead to increased iron availability for hemoglobin synthesis. The antioxidant properties of red spinach may help protect red blood cells from oxidative damage, which can contribute to anemia. By minimizing red blood cell destruction, red spinach may indirectly support higher hemoglobin levels. The flavonoids and other bioactive compounds in red spinach may help regulate immune responses, potentially reducing the underlying inflammation that disrupts iron metabolism. The potential impact of red spinach on gut microbiota could indirectly enhance iron absorption and bioavailability, further contributing to improved hemoglobin levels.[15-17]

The human gut is home to a vast and diverse community of microorganisms, collectively known as the gut microbiota. This intricate ecosystem plays a pivotal role in human health, influencing everything from digestion and nutrient absorption to immune function and even mental well-being. In recent years, research has illuminated the crucial role of the gut microbiota in iron homeostasis, shedding light on the potential mechanisms through which red spinach juice may enhance iron absorption and bioavailability. Iron absorption is a complex process that involves multiple pathways and regulatory mechanisms. Dietary iron exists in two primary forms: heme iron (found in animal products) and non-heme iron (found in plant-based foods). Heme iron is readily absorbed, while non-heme iron absorption is influenced by various factors, including dietary components, gut pH, and the presence of other nutrients, such as vitamin C. The gut microbiota plays a multifaceted role in iron absorption. First, certain bacteria in the gut possess the ability to reduce ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}), the form more readily absorbed by the body. Second, some bacteria produce siderophores, molecules that bind to iron and facilitate its uptake by intestinal cells. Third, the gut microbiota can influence the expression of genes involved in iron transport and storage. Emerging evidence suggests that red spinach may exert a positive influence on the gut microbiota, potentially promoting a microbial composition that favors iron absorption. Red spinach is rich in dietary fiber, a type of carbohydrate that cannot be digested by human enzymes. Instead, fiber serves as a food source for beneficial gut bacteria, promoting their growth and activity. This prebiotic effect may lead to an increase in the abundance of bacteria that enhance iron absorption, such as Lactobacillus and Bifidobacterium species. Red spinach contains a variety of polyphenols, plant compounds with antioxidant and anti-inflammatory properties. These polyphenols may selectively promote the growth of beneficial bacteria while inhibiting the growth of potentially harmful bacteria. This could create a gut environment that is more conducive to iron absorption. When gut bacteria ferment dietary fiber, they produce short-chain fatty acids (SCFAs), such as butyrate, propionate, and acetate. SCFAs have been shown to enhance iron absorption by increasing the expression of iron transporters in the gut and improving gut barrier function. The high fiber content of red spinach may boost SCFA production, indirectly contributing to improved iron absorption. The gut microbiota can communicate with the host's cells through various signaling pathways, influencing the expression of genes involved in iron metabolism. Red spinach may modulate these signaling pathways, leading to increased expression of genes that promote iron absorption and utilization. While these mechanisms provide a plausible theoretical framework for understanding the potential impact of red spinach on the gut microbiota and iron absorption, much remains to be explored. The specific bacterial species and metabolic pathways involved, the optimal dose and duration of red spinach consumption, and the potential for individual variation in response are all areas ripe for further research.[17-19]

The findings of this randomized controlled trial, where red spinach juice demonstrated comparable efficacy to standard iron supplementation in improving hemoglobin levels, herald a potential paradigm shift in anemia management during pregnancy. This alternative approach addresses several critical challenges associated with traditional iron therapy, offering a multifaceted solution that could significantly improve maternal and child health outcomes. A major obstacle to effective anemia management is the low adherence to oral iron supplementation, primarily due to its unpleasant side effects. Gastrointestinal disturbances, such as constipation, nausea, and abdominal pain, are common complaints among women taking iron tablets. These side effects not only compromise patient comfort but also deter them from consistently adhering to the prescribed regimen. Red spinach juice, in contrast, boasts a superior tolerability profile. The absence of serious adverse events in this study and the minimal reports of mild gastrointestinal discomfort underscore its safety and acceptability. Furthermore, the high adherence rate in the intervention group suggests that red spinach juice is a palatable and convenient option for pregnant women. This patient-centered approach aligns with the principles of shared decision-making and patient empowerment, fostering a sense of agency and control over their health during pregnancy. In many cultures, including Indonesia, traditional medicine has long recognized the blood-enriching properties of red spinach. This cultural acceptance and familiarity with red spinach as a food source could play a pivotal role in its adoption as an anemia intervention. By integrating traditional wisdom with modern scientific evidence, healthcare providers can bridge the gap between conventional and complementary medicine, enhancing trust and promoting adherence. Furthermore, the use of red spinach juice resonates with the growing trend of embracing natural and holistic approaches to health. Many pregnant women are increasingly seeking alternatives to pharmaceutical interventions, opting for natural remedies with minimal side effects. Red spinach juice, as a plant-based, minimally processed intervention, aligns with this preference for natural solutions.[16-18]

The superior tolerability and cultural acceptability of red spinach juice are particularly relevant in settings where adherence to oral iron tablets is low due to side effects or cultural beliefs. In resource-limited settings, where access to healthcare and pharmaceutical interventions may be limited, red spinach juice offers a sustainable and affordable solution. Its widespread availability and ease of preparation make it an attractive option for community-based anemia prevention and treatment programs. The potential public health impact of red spinach juice is substantial. By improving adherence and treatment outcomes, it could reduce the burden of anemia during pregnancy, leading to better maternal and child health outcomes. This could translate to fewer preterm births, lower rates of low birth weight, and decreased maternal mortality. Moreover, the economic benefits of a healthy pregnancy and birth are significant, contributing to overall societal well-being. Red spinach juice's potential extends beyond its iron content. It is a rich source of other essential nutrients, such as folate, vitamin B12, and antioxidants. These nutrients contribute to various physiological processes, including fetal development, immune function, and overall maternal health. By incorporating red spinach juice into their diet, pregnant women can reap these holistic benefits, enhancing their well-being and resilience throughout pregnancy. While the results of this study are promising, further research is imperative to solidify the role of red spinach juice in anemia management. Long-term studies are needed to assess the sustainability of its effects on hemoglobin levels and its impact on pregnancy outcomes. Additionally, mechanistic studies exploring the interplay of iron, other nutrients, and the gut microbiome in red spinach's action could unveil novel insights into its therapeutic potential.[19,20]

4. Conclusion

Red spinach juice demonstrates potential as a safe and effective intervention for improving hemoglobin levels in pregnant women with mild anemia. Further research is warranted to confirm these findings, investigate long-term effects, and explore the potential of red spinach juice in preventing anemia during pregnancy.

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