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ORIGINAL ARTICLE

Grewia tenax fruits as a traditional remedy for iron deficiency anemia: A comparative clinical study with ferrous salt

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Abstract

Background: Iron deficiency anemia (IDA) remains a significant global public health concern, particularly among vulnerable populations such as children and menstruating women. Although standard oral iron supplements are effective in replenishing iron stores, their use is often limited by gastrointestinal side effects that negatively impact adherence. *Grewia tenax* fruits, a traditional Sudanese remedy, are widely used for managing IDA; however, their clinical efficacy has not been rigorously evaluated. **Method:** This open-label study compared *G. tenax* chewable tablets with ferrous gluconate in 34 adult females (18–50 years) with confirmed IDA (hemoglobin <12 g/dL). Participants received either *G. tenax* (five tablets twice daily) or ferrous gluconate (one tablet twice daily) for a period of 4 weeks. Hematological parameters were monitored weekly, and iron profile markers were assessed at baseline and at week 4. **Results:** Ferrous gluconate produced significantly greater increases in hemoglobin and serum iron levels. Although *G. tenax* showed more modest hemoglobin improvements, it yielded higher post-treatment ferritin levels (7.82 vs. 7.43 μg/L) and greater reductions in total iron-binding capacity, suggesting enhanced iron storage and regulation. A transient rise in reticulocyte counts observed in the *G. tenax* group indicates early erythropoietic stimulation. Variability in individual response to *G. tenax* may be attributed to differences in absorption or metabolism, underscoring the need for personalized approaches. **Conclusion:** These findings challenge the usual iron dose, highlighting the unique pharmacological effects of *G. tenax*. Further research is warranted to explore its mechanisms, long-term benefits, and role as a culturally acceptable adjunct or alternative in the management of IDA. **Relevance for patients:** The study population reflects women who are disproportionately affected by IDA in Sudan, making the findings highly relevant to communities that traditionally rely on *G. tenax* as a culturally rooted remedy.

Keywords: Iron deficiency anemia; *Grewia tenax*; Iron bioavailability; Iron supplementation; Traditional practice in Sudan

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1. Introduction

Iron is an essential mineral required for erythropoiesis and oxidative metabolism.[1] Its absorption is complex and tightly regulated by multiple physiological factors,

making iron supplementation a delicate balance between correcting deficiency and avoiding overload. As such, considerable research has been devoted to understanding the mechanisms governing gastrointestinal iron absorption and systemic iron metabolism.[1,2]

Iron deficiency is the most common cause of anemia worldwide,[3] with iron deficiency anemia (IDA) affecting approximately one-quarter of the global population.[4] Vulnerable groups include young children, pregnant women, and menstruating females,[5] and high prevalence has been reported in both developing and developed countries.[6]

Accurate diagnosis of IDA relies on laboratory evaluation, including complete blood count, serum iron, serum ferritin, total iron-binding capacity (TIBC), and transferrin saturation.[7] The diagnostic hemoglobin thresholds are <12 g/dL for menstruating women, <11 g/dL for pregnant women, and <13 g/dL for men.[8]

Iron hemostasis is critical for effective iron supplementation.[8] Iron absorption occurs primarily in the duodenum and proximal jejunum,[9] where dietary iron is transported across enterocytes and exported to the plasma through ferroportin.[8] However, oral iron has limited bioavailability, as only a small proportion of iron absorbed by enterocytes is released into the circulation and incorporated into hemoglobin.[9,10]

The regulation of iron absorption is tightly controlled at both cellular and molecular levels.[9] At the cellular level, iron is sequestered within enterocytes by ferritin, transferrin, and transferrin receptors, while at the molecular level, hepcidin plays a central regulatory role.[11]

The first-line treatment for IDA typically involves oral iron supplementation to replenish depleted iron stores. A commonly recommended regimen consists of an oral iron salt providing 60 mg of elemental iron daily for 3 months.[5] However, this conventional approach has been criticized for gastrointestinal adverse effects, inconsistent efficacy, and, most seriously, toxicity.[12] These limitations have spurred exploration into safer, more tolerable alternatives, including herbal therapies.[12-14]

Moreover, supplementing iron poses challenges for healthcare providers, particularly in striking a balance between iron replenishment and preventing the elevation of the free labile iron pool.[15-17] When the labile iron pool exceeds the transport capacity of ferroportin, it participates in a cascade of reactions that generate oxidative stress, a major pathogenic factor in IDA.[18]

Recently, radical scavenging activity has emerged as supporting evidence for the protective role of antioxidants against oxidative stress.[19-22] Therefore, the incorporation of antioxidants as adjunctive therapy in the management of IDA has been proposed as a safer and more effective approach in both iron deficiency and iron overload.[23]

In Sudan, IDA is highly prevalent, especially among women of childbearing age (35.5%).[24] A widely used traditional remedy is the fruit of *Grewia tenax*, commonly consumed as juice or porridge by pregnant and lactating women.[25] *G. tenax* is native to western Sudan, particularly in the Darfur and Kordofan regions.[26] The plant is considered to have multifaceted economic value, serving as a food source and exhibiting various pharmacological properties, such as tissue healing and bone strengthening.[27]

Several animal studies have demonstrated the positive effects of *G. tenax* fruits on iron absorption and hemoglobin synthesis.[28,29] An important *in vitro* experiment using the everted rat gut sac technique investigated the intestinal transport of iron across the intestinal membrane, and subsequent studies in rats demonstrated that the fruits possess significant hematinic effects.[30]

The traditional use of natural products as therapeutic agents has increasingly been recognized as a valid basis for scientific investigation, potentially leading to the discovery of new treatment mechanisms or novel bioactive compounds.[31] In line with this, advances in the understanding of the pathogenesis and treatment of IDA[14] prompted previous researchers to screen *G. tenax* fruits for primary and secondary metabolites and to assess their antioxidant activity, correlating these findings with their ability to improve hemoglobin levels and reverse IDA.[32] Phytochemical analysis revealed 22 secondary metabolites in the aqueous extract of *G. tenax* fruits, most of which are known to exhibit potent antioxidant and pharmacological effects.[32] For example, flavonoids exhibit dual actions by chelating excess iron and serving as antioxidants.[16] Iron chelators have been shown to protect the body from iron overload and inhibit oxidative reactions.[12] These findings coincide with the paradoxical role of iron as both an essential and potentially detrimental micronutrient.[11]

Although the ability of *G. tenax* fruits to reverse IDA has been widely reported in the literature,[33-36] the relatively low iron content of the fruits (4.5 mg/100 g) suggests that their therapeutic effects may be attributed more to their bioactive constituents than to direct iron supplementation.[37]

Therefore, the current clinical trial aimed to evaluate the clinical effectiveness of *G. tenax* fruits in women with IDA, while exploring their possible mechanisms of action.

2. Materials and methods

2.1. Materials

2.1.1. Study population

A total of 44 eligible adult menstruating females, aged between 18 and 50 years and previously diagnosed with IDA with hemoglobin levels below 12 mg/dL, were voluntarily recruited for the study. Of the initial 44 participants in the cohort, 34 completed the clinical trial. The participants were randomly assigned to one of two groups: one group received *G. tenax* chewable tablets (n = 20), while the other group received ferrous gluconate tablets (n = 14) for a period of 1 month. The flow of participant recruitment and retention throughout the study stages is presented in Figure 1.

(a) Inclusion criteria
Females aged ≥18 years, previously diagnosed with IDA, and with baseline hemoglobin levels ≤ 12 g/dL were included.

(b) Exclusion criteria
Individuals with a history of gastrointestinal disorders that may interfere with oral iron absorption, known gastrointestinal bleeding, anemia of causes other than IDA, or pregnancy were excluded from the study.

2.1.2. Interventions

G. tenax was administered in the form of chewable tablets containing 500 mg of extracts derived from the fruit pericarp.

2.1.3. Tablet authentication

(a) *G. tenax* chewable tablets

The crude *G. tenax* fruits were imported from Sudan (Batch No. D101001), donated by Dellas Natural Products Factory, Amman, Jordan (H/Reg 139), and registered by the Jordanian Ministry of Health and healthcare registration No. 5N/2000.

The tablets passed quality control test No. 08/05/04 NA, conducted by the Division of Organic Materials Food Laboratory in Jordan. Analysis of inorganic materials and constituents was also conducted. The ascorbic acid content was 0.1 mg/g, quantified using liquid chromatography against a standard ascorbic acid solution. Test for uniformity of weight, tablet diameter, and friability complied with Dellas Natural Products quality requirements.

The mineral content per 100 g was as follows: Potassium 750.9 mg, calcium 332.3 mg, sodium 12.3 mg, iron 2.95 mg,

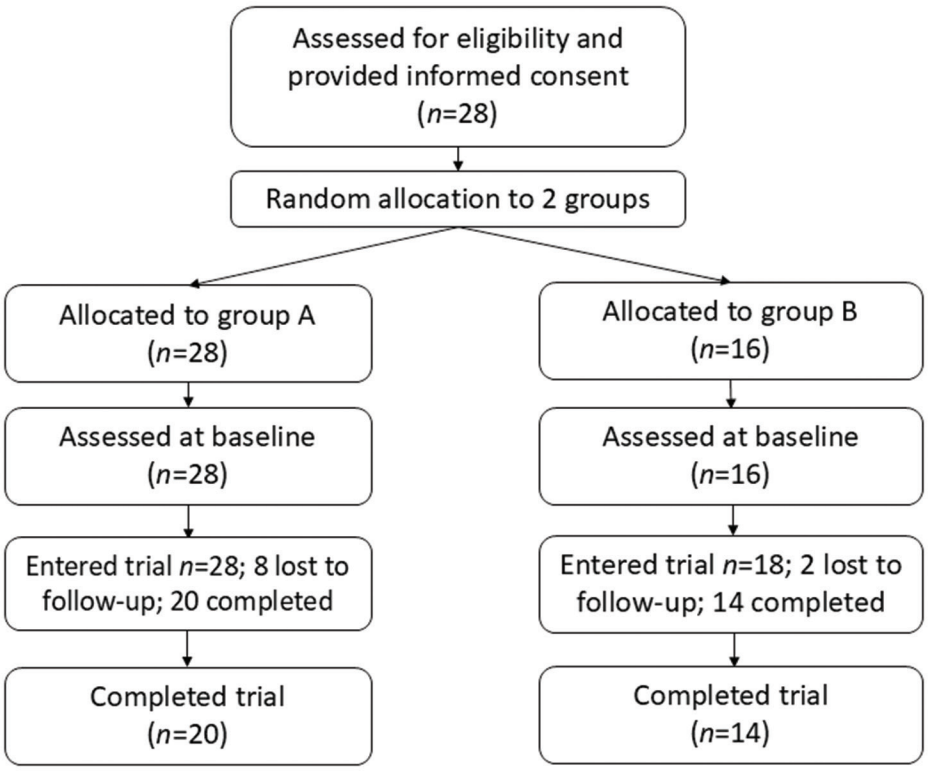

Figure 1. Flowchart of participant enrollment, allocation, follow-up, and completion

zinc 0.74 mg, manganese 0.49 mg, copper 0.39 mg, and chromium 0.25 mg.

Analysis of heavy metals and contaminants revealed that arsenic, mercury, cadmium, lead, and fluorine were each present at <0.01 mg/100 g, and no aflatoxins were detected.

(b) Ferrous gluconate tablets

The ferrous gluconate tablets were sugar-coated and manufactured by Chemical Industries Development Co., Giza, Arab Republic of Egypt (G.C.R. No. 19717). Each tablet contained 300 mg of ferrous gluconate, equivalent to 36 mg of elemental iron (Batch No. 103065T).

2.1.4. Sample size estimation

The study aimed to detect a 1–2 g/dL rise in hemoglobin over 1 month. The required sample size was calculated using Equation (1):

$$n = \frac{2(Z_{\frac{\alpha}{2}} + Z_{\beta})^2}{\Delta^2} \quad (1)$$

where:

- $\alpha = 0.05$ (two-sided), therefore $Z_{\alpha/2} = 1.96$
- Power = 80%, therefore $Z_{\beta} = 0.84$
- Δ = Expected mean difference in hemoglobin (1–2 g/dL in 1 month).

The calculated sample size was 35 participants per group. However, due to logistical constraints, the total sample size was limited to 34 participants, divided into two unequal groups.

2.1.5. Data analysis

Changes in hemoglobin levels over time were analyzed using SPSS version 25 (IBM, United States), employing analysis of variance (ANOVA). A $p<0.05$ was considered statistically significant.

2.2. Methods

This open-label clinical trial was conducted in adult female participants to compare the effects of *G. tenax* formulated as chewable tablets with ferrous gluconate tablets over 1 month.

Participants were randomly allocated into two groups:

- GT group ($n = 20$): Received *G. tenax* chewable tablets at a dose of five tablets twice daily, to be chewed after meals
- FG group ($n = 14$): Received ferrous gluconate tablets at a dose of one tablet twice daily for 4 weeks.

Each participant in the GT group received six packages of *G. tenax* chewable (Tonigrow®, Jordan), each containing 50 tablets, sufficient for the 4-week duration of the trial. Each participant in the FG group was supplied with 60 ferrous gluconate tablets for the same duration.

2.2.1. The outcome measures

The primary outcome measures included hematological parameters and iron profile indices:

- Hematological parameters (hemoglobin levels and reticulocyte count) were measured at baseline (week 0) and at weeks 1, 2, 3, and 4.
- Iron profile parameters (serum iron, serum ferritin, and TIBC) were measured at baseline (week 0) and at week 4.

Participants were instructed to maintain their regular diet, to discontinue the use of any tonics, nutritional supplements, or vitamin preparations, and to report any adverse reactions experienced during the 4-week duration.

2.2.2. Determination of the G. tenax daily dose

The daily dose of *G. tenax* chewable tablets was determined based on an ethnopharmacological survey carried out using a questionnaire administered to traditional users. The typical preparation method reported corresponded to approximately 5 g of *G. tenax* extract per day. This was standardized to 10 Tonigrow® chewable tablets, administered as 5 tablets twice daily after meals. This dose is equivalent to 5 g of *G. tenax* extract, containing approximately 0.9 mg of elemental iron.

2.2.3. Ethical clearance

Ethical approval for the trial was granted by the University of Science and Technology Ethics Committee (Reference No. UST/EC/2025/045).

All participants provided written informed consent upon enrollment and were informed of their right to withdraw from the trial at any time.

3. Results

3.1. Reported causes of IDA

Participants reported several causes of IDA, including heavy menstrual bleeding, poor nutrition, and unknown etiologies. The distribution of these reported causes is shown in Figure 2. Heavy menstrual bleeding accounted for approximately one-third of cases, while dietary factors and unknown causes comprised the remainder.

3.2. Hemoglobin response

Treatment response differed significantly between the two groups. In the *G. tenax* group, 10 out of 20 participants

(50%) exhibited a rise in hemoglobin levels, with changes ranging from 0.2 g/dL to 1.1 g/dL. In comparison, 11 out of 14 participants (79%) in the ferrous gluconate group responded to treatment, with a higher mean increase of approximately 1.2 g/dL (Figure 3).

Weekly mean hemoglobin levels increased from approximately 10.3 g/dL at baseline to 11.5 g/dL at week 4 in the GT group, and from 9.8 g/dL to 11.8 g/dL in the FG group (Figure 4).

A two-way repeated measures ANOVA (group × time) showed a significant between-group effect (F = 35.17, p<0.0001), a significant but small time effect (F = 2.46, p=0.048), and no significant group × time interaction (F = 1.65, p=0.166) (Table S1). Week-by-week analysis (Table S2) showed that significant between-group differences emerged at week 2 (p=0.009) and persisted through week 4 (p=0.005). These findings indicate that ferrous gluconate produced a more pronounced hemoglobin response compared to *G. tenax*, although the latter still resulted in modest, clinically meaningful improvements.

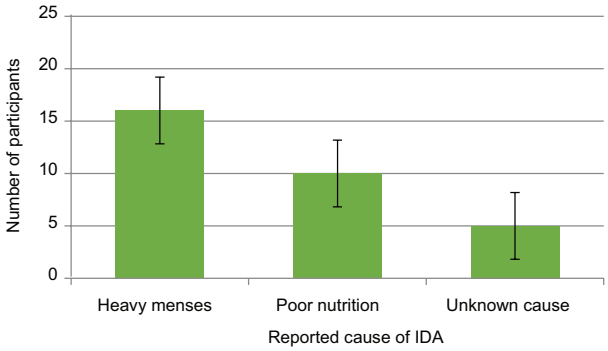

Figure 2. Distribution of reported causes of iron deficiency anemia

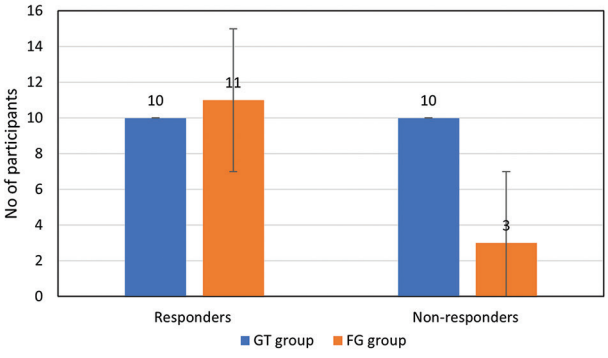

Figure 3. Comparisons of treatment responders and non-responders between the GT (receiving *Grewia tenax* chewable tablets) and FG (receiving ferrous gluconate tablets) groups (Chi-square = 2.8464, p=0.09; not statistically significant)
Note: Responders were defined as participants who demonstrated an increase in hemoglobin levels; non-responders showed no increase.

3.3. Reticulocyte counts

Reticulocyte counts peaked early in the GT group and subsequently declined, whereas the FG group exhibited a gradual decrease over time (Figure 5 and Table S3). Within-group analysis using the Friedman test revealed no significant change over time in the GT arm (χ^2 = 7.56, p=0.109). A mixedeffects model showed no significant main effects or interaction between groups. Although *G. tenax* appeared to stimulate an early erythropoietic response, neither treatment resulted in statistically significant changes in reticulocyte counts over the 4-week period.

3.4. Serum iron

Serum iron levels increased in both groups; however, the responses diverged by week 4. Baseline values did not differ significantly (p=0.119), but by week 4, the FG group exhibited a significantly greater increase (F = 4.218,

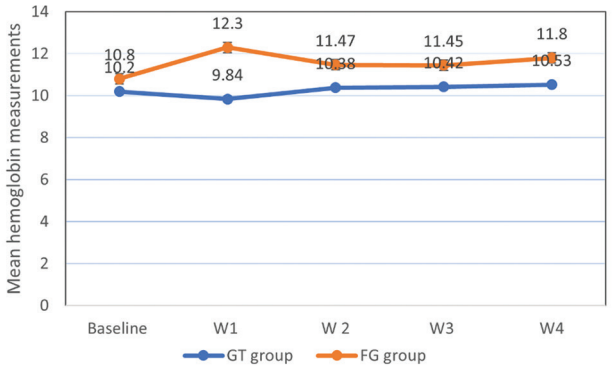

Figure 4. Mean hemoglobin levels in the GT (receiving *Grewia tenax* chewable tablets) and FG (receiving ferrous gluconate tablets) groups among treatment responders (two-way repeated measures ANOVA)
Note: Responders were defined as participants who demonstrated an increase in hemoglobin levels.

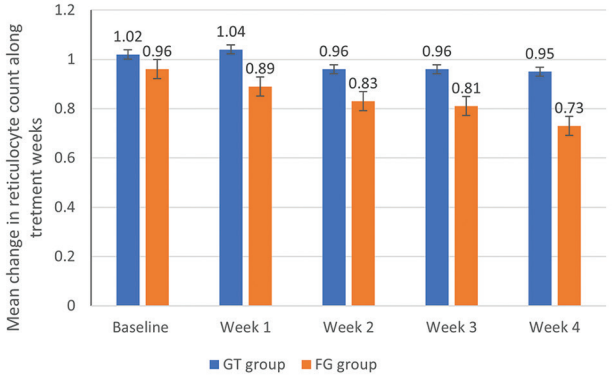

Figure 5. Changes in reticulocyte counts over the 4-week treatment period in the GT (receiving *Grewia tenax* chewable tablets) and FG (receiving ferrous gluconate tablets) groups

p=0.048). As illustrated in Figure 6 (data corresponding to Table S4), ferrous gluconate more effectively replenished circulating iron, whereas *G. tenax* also produced a clinically meaningful increase of approximately 27 µg/dL in 65% of participants.

3.5. Serum ferritin

Serum ferritin levels increased significantly in both groups, indicating improved iron stores. Between-group differences were highly significant at both baseline and week 4 (F = 41.573 and F = 125.562, respectively; p<0.001 for both) (Table S5). The GT group exhibited a mean increase of 7.82 µg/L (45% of participants), whereas the FG group showed a mean increase of 7.43 µg/L (78% of participants). These results, depicted in Figure 7, suggest that *G. tenax* may enhance iron storage despite its relatively low elemental iron content.

3.6. TIBC

TIBC, an indicator of transferrin's iron-binding potential, typically ranges from 240 to 450 µg/dL. No significant between-group differences were observed at baseline (p=0.335) or at week 4 (p=0.137) (Table S6). However, the GT group showed a greater mean reduction from baseline (−37.2 µg/dL) compared with the FG group (−8.6 µg/dL), suggesting potentially greater transferrin saturation or regulatory feedback on iron absorption (Figure 8). Elevated TIBC is typically indicative of iron deficiency, whereas a decline suggests improving iron status or a physiological reduction in iron absorption.

3.7. Summary of key differences

Overall, ferrous gluconate produced greater and more rapid improvements in hemoglobin and serum iron levels. However, *G. tenax*, despite its low elemental iron content, still induced clinically meaningful hematological improvements in 50% of participants. It stimulated an early reticulocyte response, increased serum ferritin levels, and reduced TIBC more effectively than ferrous gluconate, as shown in Table S7. These findings highlight the potential of *G. tenax* to enhance iron bioavailability and stabilize iron storage through regulatory or antioxidant mechanisms, rather than through direct iron supplementation. Full numerical data are provided in Tables S1-S7.

4. Discussion

This open-label clinical trial was designed to compare the efficacy of *G. tenax* fruit extract in chewable tablet form with ferrous gluconate tablets for the treatment of IDA in menstruating females. The study included 34 participants, with 20 receiving *G. tenax* and 14 receiving ferrous gluconate for a duration of 4 weeks.

The response to iron supplementation varies considerably among individuals due to differences in baseline iron status, absorption efficiency, and other patient-specific factors.[5,38] This variability underscores the need for individualized treatment strategies in the management and monitoring of IDA.[39] Typically, hematological responses to iron supplementation begin to appear around day 14 following initiation of supplementation.[40]

In this study, hemoglobin levels were similar between the two groups at the baseline and remained comparable during the 1st week of intervention (p=0.154 and p=0.218, respectively). By weeks 2 (p=0.009) and 3 (p=0.019), the FG group showed significantly greater increases in hemoglobin levels compared with the GT group. This difference persisted at week 4 (p=0.005), indicating that ferrous gluconate produces faster and more robust improvements in hemoglobin levels. In contrast, *G. tenax* produced a modest increase that did not reach

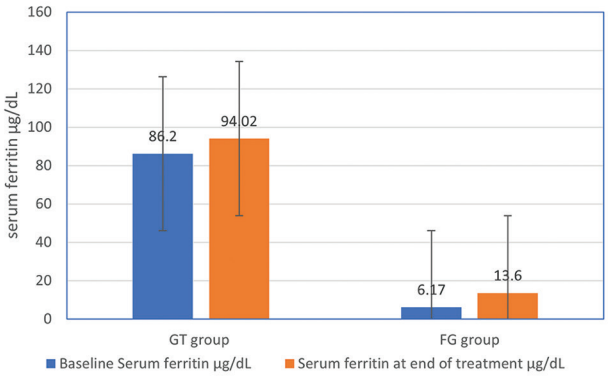

Figure 6. Changes in serum iron levels between baseline and week 4 in the GT (receiving *Grewia tenax* chewable tablets) and FG (receiving ferrous gluconate tablets) groups (p=0.119 for GT; p=0.048 for FG)

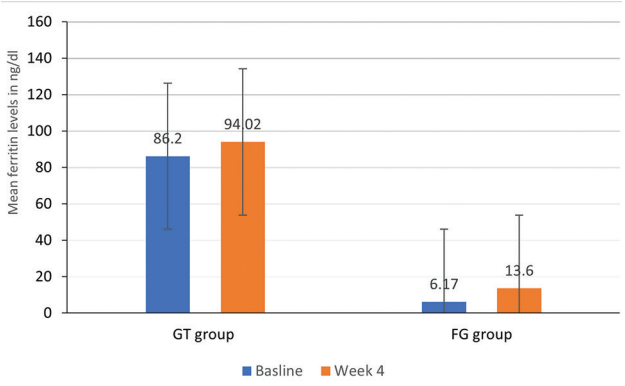

Figure 7. Mean serum ferritin levels at baseline and week 4 in the GT (receiving *Grewia tenax* chewable tablets) and FG (receiving ferrous gluconate tablets) groups (p<0.001 for both comparisons; mean increase of 7.82 µg/L in GT versus 7.43 µg/L in FG)

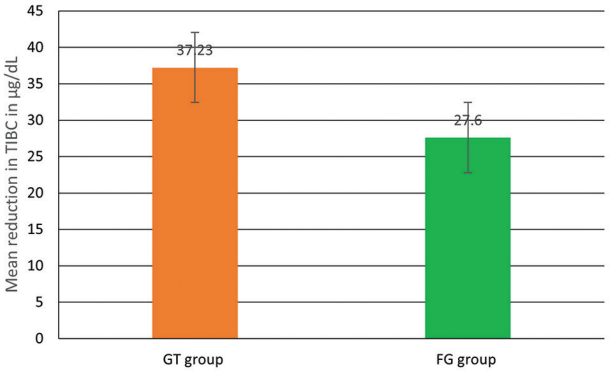

Figure 8. Comparison of mean total iron-binding capacity measurements before and after treatment in the GT (receiving *Grewia tenax* chewable tablets) and FG (receiving ferrous gluconate tablets) groups (p=0.335 at baseline; p=0.137 at week 4)

statistical significance, reflecting lower potency. However, the clinical improvement observed in some patients indicates potential bioactive mechanisms beyond iron supplementation alone.

Chi-square analysis revealed that 50% of participants in the GT group and 78% in the FG group responded positively to treatment (p=0.09). Although this difference did not reach statistical significance, the trend suggests greater efficacy of ferrous gluconate, which may be confirmed in future trials with larger sample sizes.

Reticulocyte dynamics further distinguished the two treatments. Participants receiving *G. tenax* displayed an early rise in reticulocyte counts within 5–10 days, followed by a decline, consistent with expected erythropoietic stimulation.[5] In contrast, reticulocyte counts declined steadily in the FG group. The early reticulocyte response in the GT group suggests a potential erythropoietic stimulus mediated by its phytochemical constituents—including flavonoids, β-carbolines, and ascorbic acid—which may enhance iron utilization and provide antioxidant protection. This potential of *G. tenax* to improve iron bioavailability and stabilize iron stores is an intriguing aspect that warrants further investigation and may offer new avenues in the treatment of IDA.

At baseline, serum iron levels were comparable between the two groups, with no statistically significant difference (p=0.119). At the end of treatment (4 weeks), the FG group demonstrated a significantly greater increase compared to the GT group (p=0.048), indicating that ferrous gluconate more effectively improves circulating serum iron.

At baseline, serum ferritin levels differed significantly between the two groups (p<0.001), with the GT group having significantly higher ferritin stores (approximately 81 µg/dL vs. 6 µg/dL in the FG group). This baseline imbalance may confound the interpretation of ferritin changes over time. At week 4 (end of treatment), serum ferritin levels remained significantly higher in the GT group, with mean increases of 7.82 µg/L in the GT group and 7.43 µg/L in the FG group (p<0.005). This suggests that participants in the GT group already had higher iron stores before treatment. While ferrous gluconate markedly improved hemoglobin levels, ferritin levels remained relatively low. Clinically, this indicates that *G. tenax* may contribute to maintaining or stabilizing iron stores, whereas ferrous gluconate primarily increases functional hemoglobin and circulating iron.

For TIBC, no significant differences were observed between the two groups at baseline (p=0.335 for the FG group; p=0.137 for the GT group), suggesting comparable initial iron-binding capacity. However, the GT group demonstrated a greater reduction in TIBC prior to full correction of hemoglobin levels, suggesting early suppression of iron absorption through increased transferrin saturation.[41,42] This finding raises the possibility that *G. tenax* not only enhances iron bioavailability but also exerts a regulatory effect to prevent excessive iron accumulation, in line with physiological iron homeostasis mechanisms.

Although ferrous gluconate demonstrated superior hematological response within 2–4 weeks, *G. tenax* produced clinically meaningful improvements despite delivering a substantially lower elemental iron dose (0.9 mg/day vs. 72 mg/day). This observation supports the concept that iron bioavailability, rather than absolute iron dose, plays a critical role in therapeutic outcomes, consistent with prior reports demonstrating an inverse relationship between iron dose and absorption efficiency.[43] Furthermore, while a higher proportion of responders in the FG group met the clinical response criteria (78% vs. 50%), this difference did not reach statistical significance (p=0.09), highlighting the need for larger studies to confirm these findings. The need for further research to investigate the therapeutic potential of *G. tenax* is therefore both urgent and highly relevant to the field of anemia treatment.

In summary, ferrous gluconate is more effective in rapidly increasing hemoglobin and serum iron levels, whereas *G. tenax* appears to enhance iron storage and regulate iron metabolism through mechanisms potentially independent of total iron content. The findings challenge the conventional assumption that efficacy is solely dependent on elemental iron dose and underscore the need for further investigation into the bioavailability-enhancing and regulatory properties of *G. tenax*. These results provide preliminary but clinically meaningful evidence supporting its therapeutic potential as an adjunct or alternative in the management of IDA.

5. Study limitation

This study has several limitations that should be acknowledged:

(i) The groups demonstrated markedly different baseline serum ferritin levels, which may confound the interpretation of treatment effects.
(ii) The small sample size reduces the statistical power of the study analyses.
(iii) The treatment duration (4 weeks) may be insufficient to observe the full hematinic effect of a natural product such as *G. tenax*, which may exert its benefits gradually.
(iv) Dietary iron consumption and nutrition variability among participants were not controlled, potentially influencing hematological measurements.

6. Conclusion

This exploratory clinical trial represents a significant milestone, providing the first human evidence that supports the potential efficacy of *G. tenax* fruits in the management of IDA. Although ferrous gluconate demonstrated greater potency in rapidly increasing hemoglobin and reticulocyte responses, *G. tenax* produced clinically meaningful hematological improvements despite its extremely low elemental iron content. These effects may be attributable to enhanced iron bioavailability through various mechanisms, early stimulation of erythropoietic activity, stabilization of iron stores, and modulation of iron absorption, as reflected by reductions in TIBC.

Importantly, ferrous gluconate demonstrated superior efficacy in raising hemoglobin and serum iron levels; however, *G. tenax* still produced clinically meaningful improvements, likely driven by enhanced bioavailability and antioxidant-mediated regulation. The greater reduction in TIBC observed in the GT group suggests more efficient transferrin saturation or feedback regulation of iron uptake, an effect not observed with ferrous gluconate. Reticulocyte kinetics also differed between the groups: participants receiving *G. tenax* showed an early rise followed by a decline, consistent with physiological erythropoietic patterns, whereas participants receiving ferrous gluconate exhibited a flat or declining trend, suggestive of potential oversaturation or oxidative stress. In addition, ferritin increases were higher in the GT group (≈7.78 ng/mL) compared with the FG group (≈ 7.43 ng/mL), highlighting its role in maintaining iron stores. The notable variability in hemoglobin and iron responses—especially among the GT group—further supports the need for individualized approaches to iron therapy.

Although the small sample size limits generalizability, this pilot study provides proof of concept and highlights the urgent need for larger, controlled clinical trials. If confirmed, *G. tenax* could represent a safe, natural, and potentially more tolerable alternative or adjunct to conventional iron supplements, particularly in resource-limited settings where plant-based remedies are readily accessible and culturally accepted.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: Sami Ahmed Khalid
Investigation: Randa Alsadig Almahdi
Methodology: Randa Alsadig Almahdi
Writing–original draft: Randa Alsadig Almahdi
Writing–review & editing: Sami Ahmed Khalid

Ethics approval and consent to participate

The ethics approval was granted by the IRB of the University of Science and Technology (Reference No: UST/EC/2025/045). Patients provided written informed consent before enrolling in the study.

Consent for publication

The data of the involved human subjects were anonymous and do not allow for identification of participants.

Availability of data

The data of this work are available upon request from the corresponding authors.

Further disclosure

This clinical trial was part of the work undertaken to complete a Ph.D. thesis; accordingly, it is archived at the University of Khartoum (http://khartoumpace.uok.edu).

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