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The Effect of Iron Supplementation Combined with Oranges on the Preference Level, Consumption Adherence, and Haemoglobin Levels among Adolescent Girls

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ABSTRACT

Anaemia remains a severe public health problem affecting adolescent girls. Despite government-provided Iron and Folic Acid (IFA) supplementation, adherence remains low due to unpleasant taste and odour. To analyse the impact of blood-boosting tablet (IFA) intervention accompanied by orange fruit on liking levels, consumption adherence, and haemoglobin levels among adolescent girls. This quasi-experimental non-equivalent control group pre-test-post-test design involved 56 adolescent girls from four schools in Maros Regency, Indonesia. Participants were allocated by cluster into an intervention group (n=27) and a control group (n=29), without individual randomization. The intervention group received IFA tablets with 100–150 g of orange fruit once weekly for four weeks, while the control group received IFA tablets alone. Taste and aroma liking were assessed using a 5-point hedonic scale, and adherence was monitored using Directly Observed Supplementation (DOS). Haemoglobin levels were measured at pre-test and post-test. Liking and adherence were analysed using the Mann–Whitney U test, while post-test haemoglobin was analysed using ANCOVA adjusted for covariates. He intervention group had higher mean ranks for taste liking (35.15 vs. 22.31; p=0.001), aroma liking (32.78 vs. 24.52; p=0.044), and adherence (35.06 vs. 22.40; p=0.002) than the control group. After covariate adjustment, study group was associated with post-test Hb (p=0.005; partial η^2=0.159). IFA supplementation with orange fruit showed better outcomes in terms of liking, adherence, and haemoglobin levels compared with IFA supplementation alone. However, these findings cannot yet establish a causal relationship due to the non-randomized study design, short intervention duration, and limitations related to cluster-level allocation.

INTRODUCTION

Anaemia remains a major public health problem, particularly among women of reproductive age and adolescent girls. The World Health Organization (WHO) reported that anaemia affected 30.7% of women aged 15-49 years globally in 2023, increasing from 27.6% in 2012, indicating insufficient progress in reducing the burden. Causes are multifactorial, including nutritional deficiencies, infections, inflammation, chronic diseases, gynaecological conditions, and inherited disorders[1,2].

In Indonesia, anaemia among adolescent girls remains a public health problem. Although the 2023 Indonesian Health Survey reported a lower prevalence, the problem remains relevant and requires effective prevention strategies.

Iron deficiency is one of the most common causes of anaemia, while adolescent girls are at greater risk because of increased requirements during growth and iron loss through menstruation[2].

Iron-folic acid (IFA) supplementation is an important prevention strategy. WHO recommends intermittent IFA supplementation for adolescent girls and menstruating women in affected populations[2,3]. In Indonesia, weekly iron supplementation has been incorporated into the national programme. However, benefits depend on regular consumption.

Adherence to IFA supplementation remains a challenge. A survey among adolescent girls in East Java and East Nusa Tenggara reported low coverage and adherence, with forgetting to take tablets, perceiving supplementation as unnecessary, and concerns about side effects among barriers[4]. The sensory experience of consuming the supplement may also influence consumption. The 2023 SKI reported that unpleasant taste and smell were the most frequently reported reasons for not consuming or not finishing iron tablets obtained from school, accounting for 31.2% of reasons[5]. A qualitative study also showed that dislike of taste and smell was a barrier, whereas awareness of benefits and support from parents and peers could facilitate consumption[6].

These findings suggest that acceptability may represent a behavioural pathway to adherence, although acceptability should not be directly equated with adherence. This relationship can be understood through the Theory of Planned Behaviour (TPB), which proposes that behaviour is influenced by intention, attitudes, subjective norms, and perceived behavioural control[7].

Orange is a potential food-based accompaniment because of its physiological and sensory relevance. A controlled isotope study showed greater iron absorption when iron supplements were consumed with orange juice than with coffee or a breakfast containing coffee[8]. However, recent evidence suggests that this mechanism is more complex. A 2026 systematic review and meta-analysis of 15 controlled trials found that ascorbate-rich fruits or fruit juices with meals were associated with higher serum ferritin and haemoglobin concentrations but did not demonstrate a statistically significant increase in iron absorption[10].

Although evidence regarding vitamin C-rich foods and sensory barriers to IFA consumption is available, research examining orange as an accompaniment to IFA supplementation in relation to liking, adherence, and haemoglobin among adolescent girls remains limited[5-7,8,9]. The novelty of this study lies in examining orange as a food-based accompaniment within an integrated physiological and sensory-behavioural framework, rather than solely as a source of vitamin C.

Therefore, this study aimed to analyse the effect of IFA supplementation accompanied by orange fruit on liking, adherence to iron tablet consumption, and haemoglobin levels among adolescent girls.

MATERIALS AND METHODS

Research Design and Context

This quasi-experimental study used a non-equivalent control group pretest–posttest design to examine the impact of iron-folic acid (IFA) supplementation accompanied by orange on liking, adherence to iron tablet consumption, and haemoglobin (Hb) levels among adolescent girls. The study was conducted from April to May 2026 in four schools within the working area of Turikale Primary Health Centre, Maros Regency, South Sulawesi: MAS Darul Muttaqin, SMAIT Qurratu A'yun, SMAIT Al-Ishlah Maros, and SMAS DDI Maros.

Participants and Sampling

The study population comprised female students in grades 10 and 11 from 16 schools in Turikale District. No a priori sample size calculation based on effect size, statistical power, and alpha level was performed. The final sample was determined by eligible students who agreed to participate and completed all procedures, resulting in 56 respondents: 27 in the intervention group and 29 in the control group.

Multistage cluster random sampling was used, with schools as the sampling clusters. The 16 schools were classified as urban (10) or rural (6). Six candidate schools were selected proportionally, followed by random selection of four study schools while maintaining geographic representation. The final schools were SMAIT Al-Ishlah and SMA DDI Maros (urban) and SMAIT Qurratu A'yun and MAS Darul Muttaqin (rural). Schools were then randomly allocated by drawing lots: SMAIT Al-Ishlah and MAS Darul Muttaqin to the intervention group, and SMAIT Qurratu A'yun and SMA DDI Maros to the control group. Thus, allocation was performed at the school-cluster level rather than individually[10,11].

Eligible participants were female students aged 15–18 years who were generally healthy, willing to participate, and did not routinely consume other supplements or multivitamins. Students were excluded if they withdrew, participated in another health intervention, reported chronic diseases that could affect Hb levels (e.g., thalassaemia, haemolytic anaemia, or chronic kidney disease), or had heavy bleeding.

Intervention and Data Collection

The intervention lasted four weeks and was administered once weekly on the same designated day. The intervention group received the government-provided IFA tablet together with 100–150 g of Siam Madu sweet orange, whereas the control group received the same tablet with water only. Each tablet contained 60 mg elemental iron and 0.4 mg folic acid. The IFA tablets were manufactured by PT Kimia Farma Tbk. Orange servings were weighed using a digital scale, including the peel. Vitamin C content was estimated at 49–73.5 mg per serving based on Indonesian food composition data rather than laboratory analysis[12].

A chew–swallow–rinse procedure was used in the intervention group. Participants first consumed 2–3 orange segments, swallowed the IFA tablet, and then consumed the remaining segments. Orange consumption was monitored during each supplementation session.

Hb was measured before and after the four-week intervention using the Easy Touch GCHb 3-in-1 device. Nutritional status was assessed from weight and height. Dietary intake was assessed using two 24-hour dietary recalls, one weekday and one weekend day. Trained researchers conducted interviews using a food photo atlas for portion-size estimation, and nutrient intake was calculated using the Indonesian Food Composition Table (TKPI). Protein, iron, and vitamin C intake were included in the analysis[13].

Liking of tablet taste and aroma was assessed using a five-point hedonic scale based on an established organoleptic assessment among adolescent girls[14]. Adherence was assessed using directly observed supplementation (DOS). Participants were classified as adherent if they consumed ≥75% of the tablets provided and non-adherent if they consumed <75%[15].

Data Analysis

Statistical analyses were performed using IBM SPSS Statistics version 26. Descriptive analyses summarised participant characteristics and study variables. Post-test Hb was compared between groups using ANCOVA, adjusting for pre-test Hb, nutritional-status Z-score, protein, iron and vitamin C intake, and menstrual cycle. The group × pre-test Hb interaction was assessed to determine whether the association between baseline and post-test Hb differed between groups. Model assumptions were assessed before interpretation. ANCOVA results were reported as F values, *p* values, partial eta squared, regression coefficients (B), standard errors, 95% confidence intervals, and adjusted means using estimated marginal means. Liking and adherence were analysed using the Mann–Whitney U test. Statistical significance was set at $p < 0.05$. Because allocation occurred at the school-cluster level but analysis was conducted at the individual level, intracluster correlation was not specifically accounted for and should be considered when interpreting the findings.

Ethical Clearance

The study received ethical approval from the Research Ethics Committee of Universitas Muslim Indonesia (No. 323/A.1/KEP-UMI/IV/2026). Participants received information regarding study objectives, procedures, benefits, risks, confidentiality, and their right to refuse or withdraw. Consent forms were provided for participants to communicate the study information to their parents or guardians. Participants who agreed signed the consent form voluntarily and could withdraw at any time without consequences. Parental/guardian consent was communicated verbally through respondents and was not documented by written signature; this is acknowledged as a limitation.

RESULTS

Table 1. Characteristics of respondents

Variable	Intervention (n=27)		Control (n=29)		Total (n=56)	
	n	%	n	%	N	%
Age (years)						
15–16	16	59.3	23	79.3	39	69.6
17–18	11	40.7	6	20.7	17	30.4
Total	27	100	29	100	56	100
Nutritional status (BMI-for-age)						
Normal	18	66.7	25	86.2	43	76.8
Overweight	5	18.5	2	6.9	7	12.5
Obesity	4	14.8	2	6.9	6	10.7
Total	27	100	29	100	56	100
Menstrual cycle						
Normal	23	85.2	26	89.7	49	87.5
Abnormal	4	14.8	3	10.3	7	12.5
Total	27	100	29	100	56	100
Baseline anaemia status						
Severe anaemia	0	0.0	1	3.4	1	1.8
Mild anaemia	6	22.2	11	37.9	17	30.4
Moderate anaemia	3	11.1	5	17.2	8	14.3
Non Anaemia	18	66.7	12	41.4	30	53.6
Total	27	100	29	100	56	100

*Source: Primary Data, 2026

Table 1 presents the baseline characteristics of respondents in the intervention and control groups. The two groups were largely comparable in terms of age, nutritional status, and menstrual cycle regularity, with the majority of respondents aged 15–16 years (69.6%), classified as having normal nutritional status based on BMI-for-age (76.8%), and reporting regular menstrual cycles (87.5%). Notably, baseline anaemia status differed between groups: a higher proportion of respondents in the intervention group were non-anaemic (66.7%) compared with the control group (41.4%), whereas the control group exhibited a greater prevalence of mild-to-severe anaemia (58.6% vs. 33.3% in the intervention group).

Table 2. Respondent characteristics (mean protein, iron, and vitamin C intake)

Intake	Mean ± SD	
	Intervention	Control
Protein	47.079 ± 13.014	43.200 ± 11.019
Iron	26.437 ± 9.036	34.397 ± 16.457
Vitamin C	11.689 ± 12.822	6.883 ± 12.378

*Source: Primary Data, 2026

Table 2 shows that the intervention group had higher mean intakes of protein (47.079 ± 13.014 g vs. 43.200 ± 11.019 g) and vitamin C (11.689 ± 12.822 mg vs. 6.883 ± 12.378 mg) than the control group, whereas mean iron intake was higher in the control group (34.397 ± 16.457 mg vs. 26.437 ±

9.036 mg).

Table 3. Difference in liking based on taste and aroma between the intervention and control groups

Aspect	Mean Rank		p-value*
	Intervention	Control	
Taste	35.15	22.31	0.001
Aroma	32.78	24.52	0.044

*Mann-Whitney U Test; Significant at $p < 0.05$
Source: Primary Data, 2026

Mann-Whitney U test results showed significant differences between the intervention and control groups in both taste (p = 0.001) and aroma preference (p = 0.044), with the intervention group showing higher mean ranks than the control group (taste: 35.15 vs. 22.31; aroma: 32.78 vs. 24.52).

Table 4. Distribution of adherence to iron tablet consumption

Consumption adherence	Intervention		Control		Total	
	n	%	n	%	N	%
Adherent	25	92.6	19	65.5	44	78.6
non-adherent	2	7.4	10	34.5	12	21.4
Total	27	100	29	100	56	100

Source: Primary Data, 2026

Table 4 shows that adherence to iron tablet consumption was higher in the intervention group (92.6%) than in the control group (65.5%).

Table 5. Distribution of adherence to iron tablet consumption

Total tablets over 4 weeks	Intervention		Control		Total	
	n	%	n	%	N	%
Tablets consume						
2	2	7.4	10	34.5	12	21.4
3	7	25.9	11	37.9	18	32.1
4	18	66.7	8	27.6	26	46.4
Total	27	100	29	100	56	100
Tablets missed						
0	18	66.7	8	27.6	26	46.4
1	7	25.9	11	37.9	18	32.1
2	2	7.4	10	34.5	12	21.4
Total	27	100	29	100	56	100

*Source: Primary Data, 2026

During the four-week intervention, tablet consumption was higher in the intervention group than in the control group, with 66.7% of the intervention group consuming all four tablets compared with 27.6% in the control group. Correspondingly, non-adherence (missed doses) was more common in the control group, where 34.5% missed two tablets, whereas 66.7% of the intervention group missed none. Reported reasons for missed doses included school absence, mild adverse effects (e.g., dizziness, nausea, vomiting, diarrhoea), and not having eaten prior to tablet administration.

Table 6. Difference in adherence to iron tablet consumption between the intervention and control groups

Variable	Mean Rank	p-value*

	Intervention	Control	
Consumption Adherence	35.06	22.40	0.002

*Mann-Whitney U Test; Significant at $p < 0.05$
Source: Primary data, 2026

The Mann-Whitney U test showed significantly higher adherence in the intervention group (mean rank = 35.06) than the control group (mean rank = 22.40), p = 0.002.

Table 7. Distribution of anaemia status before and after the intervention

Anaemia status	Pre-test				Post-test			
	Intervention		Control		Intervention		Control	
	n	%	n	%	n	%	n	%
Severe anaemia	0	0.0	1	3.4	0	0.0	0	0.0
Mild anaemia	6	22.2	11	37.9	0	0.0	3	10.3
Moderate anaemia	3	11.1	5	17.2	0	0.0	4	13.8
Non Anemia	18	66.7	12	41.4	27	100	22	75.9
Total	27	100	29	100	27	100	29	100

*Source: Primary data, 2026

Table 7 shows that the proportion of non-anaemic participants increased in both groups following the intervention. In the intervention group, all participants (100%) were classified as non-anaemic at post-test, compared with 66.7% at pre-test, indicating that all previously anaemic participants (n = 9) had recovered. In the control group, the proportion of non-anaemic participants also increased, from 41.4% at pre-test to 75.9% at post-test; however, 7 participants remained anaemic (mild: 10.3%; moderate: 13.8%), with no cases of severe anaemia at post-test.

Table 8. Pre-test and Post-test Haemoglobin Levels Within Each Study Group

Group	Pre-test (g/dL) (Mean ± SD)	Post-test (g/dL) (Mean ± SD)	p-value*
Intervention	12.859 ± 2.009	15.152 ± 1.560	<0.001
Control	11.693 ± 1.451	12.493 ± 1.763	0.008

*Paired t-test; significant at $p < 0.05$.
Source: Primary data, 2026

Haemoglobin levels increased significantly in both groups following the intervention. In the intervention group, the mean haemoglobin level rose from 12.859 ± 2.009 g/dL to 15.152 ± 1.560 g/dL (an increase of 2.293 g/dL; paired t-test, $p < 0.001$), while in the control group it rose from 11.693 ± 1.451 g/dL to 12.493 ± 1.763 g/dL (an increase of 0.800 g/dL; p = 0.008). Although both groups showed significant improvement, the increase was descriptively greater in the intervention group.

Table 9. General Linear Model for Post-test Haemoglobin Levels

Predictor	B	SE	95% CI for B	F	p-value	Partial η^2
Study group (intervention vs control)	9.164	3.071	2.986–15.343	8.905	0.005	0.159
Pre-test Hb	0.649	0.204	0.238–1.059	7.254	0.010	0.134
Z-score	−0.133	0.158	−0.452–0.185	0.709	0.404	0.015
Protein intake	0.011	0.021	−0.031–0.054	0.288	0.594	0.006
Iron intake	−0.014	0.018	−0.051–0.022	0.630	0.431	0.013

Vitamin C intake	0.036	0.018	−0.001–0.073	3.862	0.055	0.076
Menstrual cycle	0.060	0.630	−1.208–1.328	0.009	0.924	0.000
Study group × Pre-test Hb	−0.582	0.251	−1.086−0.078	5.390	0.025	0.103

Model fit: F (8,47) = 8.068; p<0.001; R^2 = 0.579; adjusted R^2=0.507. Homogeneity of variance: Levene's test, F=1.585; p=0.214.

The overall model was statistically significant (F (8,47) = 8.068, p < 0.001), explaining 57.9% of the variance in post-test haemoglobin (R^2 = 0.579; adjusted R^2 = 0.507). After adjustment for covariates, study group remained significantly associated with post-test haemoglobin (F = 8.905, p = 0.005, partial η^2 = 0.159), as did pre-test haemoglobin (F = 7.254, p = 0.010, partial η^2 = 0.134). Nutritional status (Z-score), and baseline protein, iron, and vitamin C intake, and menstrual cycle were not significant covariates (all p > 0.05).

A significant interaction was found between study group and pre-test haemoglobin (B = −0.582; 95% CI: −1.086 to −0.078; p = 0.025; partial η^2 = 0.103), indicating that the between-group difference in post-test haemoglobin varied by baseline haemoglobin level. Estimated marginal means were therefore examined at low, mean, and high pre-test haemoglobin levels to clarify this interaction.

DISCUSSION

Baseline Characteristics of Respondents

Most respondents were aged 15–16 years (69.6%), while 30.4% were aged 17–18 years[16]. Adolescence is characterized by rapid physical and psychosocial development, with increasing nutritional requirements and, among girls, iron loss through menstruation, making this period important for anaemia prevention[17].

Normal nutritional status was more common in the intervention group (66.7%) than the control group (86.2%), indicating baseline imbalance. Anthropometric status does not directly indicate iron status; inadequate nutritional intake has been linked to iron deficiency anaemia[18].

Most respondents had menstrual cycles within 21–35 days, the usual WHO range. Menstrual blood loss may contribute to anaemia risk[19]. Menstrual cycle was included as a covariate.

Baseline anaemia status differed. The intervention group had 18 respondents (66.7%) without anaemia, six (22.2%) with mild anaemia, and three (11.1%) with moderate anaemia. The control group had 12 (41.4%) non-anaemic respondents, 11 (37.9%) with mild anaemia, five (17.2%) with moderate anaemia, and one (3.4%) with severe anaemia. Thus, the intervention group had more non-anaemic respondents at baseline. Baseline Hb and measurable characteristics were therefore adjusted for in the ANCOVA model. However, residual confounding remains possible.

Dietary protein, iron, and vitamin C intakes differed descriptively. Protein intake was 47.08 ± 13.01 g versus 43.20 ± 11.02 g, iron 26.44 ± 9.04 mg versus 34.40 ± 16.46 mg, and vitamin C 11.69 ± 12.82 mg versus 6.88 ± 12.38 mg in the intervention and control groups, respectively. These were considered baseline differences unless formally tested. Parental education, household income, and socioeconomic indicators were not collected, limiting assessment of their influence on outcomes. Overall, groups were not fully balanced. These factors were considered in the adjusted analysis, although residual confounding remains possible.

Liking of IFA Supplementation Accompanied by Orange

The intervention group had significantly higher liking scores for taste (p=0.001) and aroma (p=0.044), with mean ranks of 35.15 versus 22.31 and 32.78 versus 24.52, respectively. This indicates a more favourable sensory response with orange but does not establish that orange alone caused the difference.

Taste and aroma influence product acceptance[20,21]. Orange's sweet-sour characteristics may have improved consumption. However, sensory intensity and masking of tablet taste or aroma were not objectively assessed. Thus, this remains a possible rather than demonstrated causal mechanism.

Masfufah et al. reported that taste and aroma influence adolescent girls' tablet acceptance, while side effects and support also affect acceptance[14]. Hidayanty et al. identified dislike of taste and smell as barriers to IFA consumption, whereas parental, peer, and school support facilitated supplementation[6]. These findings support a behavioural pathway in which acceptability may facilitate continued consumption. However, liking was not tested as a mediator. Therefore, higher liking cannot be interpreted as the cause of adherence.

Adherence to IFA Tablet Consumption

Adherence was significantly higher in the intervention group (p=0.002), with mean ranks of 35.06 versus 22.40. Overall, 25 respondents (92.6%) in the intervention group were adherent compared with 19 (65.5%) in the control group, a 27.1-percentage-point difference. The intervention group also had a higher proportion consuming all four tablets (66.7% vs. 27.6%).

This pattern aligns with the liking findings, suggesting that orange accompaniment may have contributed to a more acceptable consumption experience. However, adherence is multifactorial; some respondents missed doses due to school absence, not eating beforehand, or side effects such as dizziness, nausea, vomiting, or diarrhoea. Thus, the difference cannot be attributed solely to orange.

Both groups received direct supervision. School-based supervision may support adherence, as reported by Meilani and Setiyawati[15], while parental, peer, teacher, and institutional support are also important[6,22]. Because supervision was provided to both groups, it cannot fully explain the between-group difference. Nevertheless, school-level allocation and lack of adjustment for intracluster correlation are important limitations. Participants within schools may share contextual factors, while analysis was conducted individually. Future studies should include more schools and use cluster-adjusted or multilevel analyses.

The four-week intervention and small sample limit conclusions regarding long-term adherence. Findings from four schools in Maros Regency cannot be directly generalized to all adolescent girls in Indonesia.

Haemoglobin Levels After Iron-Folic Acid Supplementation with Orange Fruit

Post-test Hb was higher in the intervention group after adjustment for pre-test Hb, nutritional-status Z-score, protein, iron and vitamin C intake, and menstrual cycle. The model explained 57.9% of variance ($R^2=0.579$; adjusted $R^2=0.507$), with partial $\eta^2=0.159$, indicating an association rather than causality.

A significant group × pre-test Hb interaction ($p=0.025$) showed that differences varied by baseline Hb. The adjusted mean difference was 3.097 g/dL among respondents with low baseline Hb ($p<0.001$), 2.036 g/dL at mean baseline Hb ($p<0.001$), and 0.976 g/dL among those with high baseline Hb ($p=0.174$). Thus, differences were greater with lower baseline Hb, but this does not indicate effectiveness only in this group.

Non-anaemia increased from 66.7% to 100% in the intervention group and from 41.4% to 75.9% in controls. Because both groups received IFA, improvement cannot be attributed entirely to orange. Its contribution may have occurred through higher adherence.

Vitamin C provides a plausible mechanism because ascorbic acid enhances non-haem iron bioavailability[23]. However, orange-derived vitamin C, iron absorption, ferritin, and other iron-status biomarkers were not measured. Evidence for direct increases in iron absorption remains inconsistent[9,24]. Sihotang et al. also reported findings supporting the use of sweet orange alongside iron supplementation in adolescents, although differences in design and population limit direct comparison[25].

The relatively large Hb increase warrants caution because adherence, baseline Hb, biological and measurement variation, and regression to the mean may contribute. Point-of-care Hb measurement and absent iron-status biomarkers limit interpretation as improved iron stores.

Unmeasured confounders included infection, inflammation, menstrual blood loss, socioeconomic conditions, parental education, and other anaemia causes. WHO emphasizes that anaemia has multiple causes[1,26]. Therefore, the Hb difference cannot be attributed solely to improved iron absorption from orange.

Overall, orange-accompanied IFA was associated with greater liking, adherence, and post-test Hb, supporting a potential sensory–behavioural pathway and nutritional contribution. However, the quasi-experimental design, small sample, short duration, baseline imbalance, and unmeasured confounding limit causal inference. Larger multicentre trials with longer follow-up and ferritin are warranted.

CONCLUSION

This study found that adolescent girls receiving IFA supplementation with orange fruit showed higher taste and aroma acceptability, better adherence, and higher post-test haemoglobin levels (after adjustment for covariates) than those receiving IFA alone. These findings suggest that orange fruit may improve the acceptability and adherence of IFA supplementation and could be associated with higher Hb levels. However, given the quasi-experimental design, small sample size, and short intervention period, these results should be interpreted as an association rather than definitive causal evidence, particularly as the group difference in post-test Hb varied with baseline Hb levels.

The main contribution of this study is evidence that orange fruit may serve as a food-based accompaniment to enhance sensory acceptability and adherence to IFA supplementation among adolescent girls. Generalization is limited by the small sample size, short duration, baseline imbalance, unmeasured confounders (e.g., parental education, socioeconomic status), and the lack of biochemical iron indicators. Future research should use larger, multicentre, randomized controlled trials with longer follow-up and biochemical assessment (e.g., serum ferritin, soluble transferrin receptor) to strengthen causal inference and clarify the contribution of orange fruit to iron status.

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