

Effect of green coconut water kombucha on hematological parameters among adolescents with mild anemia

Pengaruh Kombucha Air Kelapa Hijau terhadap Parameter Hematologi pada Remaja dengan Anemia Ringan

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ABSTRACT

Background: Anemia remains a major public health problem in Indonesia, particularly among adolescent girls. Mild anemia is often overlooked despite its negative effects on learning ability, concentration, productivity, and quality of life.

Objective: This study aimed to analyze the effect of green coconut water kombucha on the hematological profile of adolescents with mild anemia.

Methods: This pilot study used a quasi-experimental one-group pretest–posttest design without a control group. Of 30 adolescents screened, 12 aged 17–21 years with hemoglobin levels of 10.0–11.9 g/dL met the inclusion criteria, and all were enrolled (total sampling of eligible participants). Participants consumed 150 mL of green coconut water kombucha daily for 14 days. White blood cell (WBC), red blood cell (RBC), hemoglobin (Hb), hematocrit (HCT), and platelet (PLT) counts were measured before and after the intervention. Normality of the paired differences was assessed using the Shapiro–Wilk test, and the paired t-test or Wilcoxon signed-rank test was applied accordingly.

Results: All parameters increased after the intervention. Mean Hb increased from 10.52 ± 0.36 to 12.03 ± 1.13 g/dL and HCT from $31.55 \pm 1.08\%$ to $36.10 \pm 3.40\%$ (both $p < 0.001$; paired t-test), and WBC from 6.63 ± 1.50 to $7.46 \pm 1.41 \times 10^3/\mu\text{L}$ ($p = 0.007$). RBC showed a small increase (median 4.65 to $4.79 \times 10^6/\mu\text{L}$; $p = 0.037$; Wilcoxon) that was sensitive to one participant with a large individual change. PLT increased (median 307.5 to $324.0 \times 10^3/\mu\text{L}$; $p = 0.002$) with wide inter-individual variation.

Conclusion: Within the limits of an uncontrolled pilot design, green coconut water kombucha showed potential to support improvement in hematological parameters, particularly Hb and HCT, in adolescents with mild anemia. These findings are preliminary and do not establish a causal effect; randomized controlled trials with larger samples, longer intervention periods, and control of dietary iron intake are needed.

Keywords: coconut water, hematological profile, mild anemia

ABSTRAK

Latar Belakang: Anemia masih menjadi masalah kesehatan masyarakat dengan prevalensi yang tinggi pada remaja di Indonesia, terutama pada remaja putri. Anemia ringan sering kali terabaikan meskipun dapat berdampak pada kemampuan belajar, konsentrasi, produktivitas, dan kualitas hidup.

Tujuan: Penelitian ini untuk menganalisis pengaruh kombucha air kelapa hijau terhadap profil hematologi pada remaja dengan anemia ringan.

Metode: Penelitian ini merupakan pilot study dengan desain quasi-experimental one-group pretest–posttest tanpa kelompok kontrol. Dari 30 remaja yang diskriminasi, 12 remaja berusia 17–21 tahun dengan kadar hemoglobin 10,0–11,9 g/dL memenuhi kriteria inklusi dan seluruhnya diikutsertakan (total sampling terhadap subjek yang memenuhi kriteria). Responden mengonsumsi kombucha air kelapa hijau 150 mL per hari selama 14 hari. Leukosit (WBC), eritrosit (RBC), hemoglobin (Hb), hematokrit (HCT),

dan trombosit (PLT) diukur sebelum dan sesudah intervensi. Normalitas selisih data berpasangan diuji dengan Shapiro–Wilk, kemudian dianalisis menggunakan paired t-test atau Wilcoxon signed-rank test sesuai distribusi data.

Hasil: Seluruh parameter meningkat setelah intervensi. Rerata Hb meningkat dari $10,52 \pm 0,36$ menjadi $12,03 \pm 1,13$ g/dL dan HCT dari $31,55 \pm 1,08\%$ menjadi $36,10 \pm 3,40\%$ (keduanya $p < 0,001$; paired t-test), serta WBC dari $6,63 \pm 1,50$ menjadi $7,46 \pm 1,41 \times 10^3/\mu\text{L}$ ($p = 0,007$). RBC meningkat kecil (median $4,65$ menjadi $4,79 \times 10^6/\mu\text{L}$; $p = 0,037$; Wilcoxon) dan hasil ini sensitif terhadap satu responden dengan perubahan individual yang besar. PLT meningkat (median $307,5$ menjadi $324,0 \times 10^3/\mu\text{L}$; $p = 0,002$) dengan variasi antarresponden yang lebar.

Kesimpulan: Dalam keterbatasan desain pilot tanpa kelompok kontrol, kombucha air kelapa hijau menunjukkan potensi mendukung perbaikan parameter hematologi, terutama Hb dan HCT, pada remaja dengan anemia ringan. Temuan ini masih bersifat pendahuluan (preliminary) dan belum dapat membuktikan hubungan kausal; uji acak terkontrol dengan sampel lebih besar, durasi intervensi lebih panjang, dan pengendalian asupan zat besi diperlukan.

Kata kunci: *air kelapa, anemia ringan, profil hematologi*

INTRODUCTION

Anemia remains a major public health problem with a high prevalence, including in Indonesia, where approximately 32% of adolescents or about 3 to 4 out of every 10 adolescents suffer from anemia. The Indonesian Ministry of Health reported that 26.8% of adolescents aged 5–14 years and 32% of those aged 15–24 years experience anemia.¹ This condition is particularly common among adolescent girls, with a prevalence of 48.9%, primarily due to increased iron requirements during growth and blood loss during menstruation. The impact of anemia, even in mild cases, extends beyond reduced physical capacity; it also affects learning concentration, productivity, and the overall quality of life of adolescents.^{2,3}

Adolescents, particularly girls, are highly vulnerable to mild anemia due to their increased iron requirements during rapid growth and, in females, menstrual blood loss. Although mild anemia is often overlooked because of its subtle symptoms, untreated cases may progress to more severe anemia and adversely affect cognitive function, academic performance, physical productivity, and quality of life. Moreover, anemia during adolescence may have long-term consequences, including reduced work readiness and an increased risk of adverse pregnancy outcomes in adulthood. Therefore, effective, affordable, and acceptable preventive strategies are needed. Functional foods and beverages, such as green coconut water kombucha, may represent a promising nutritional approach to improving hemoglobin levels and overall hematological profiles.^{4,5}

Kombucha is a fermented beverage produced using a symbiotic culture of bacteria and yeast (SCOBY). During fermentation, it generates various bioactive compounds, including organic acids, vitamins, antioxidants, and probiotics, which contribute to its functional properties. These compounds may enhance mineral bioavailability, including iron, thereby supporting hematological health. Although kombucha is traditionally prepared from tea, coconut water can be used as an alternative fermentation medium because of its naturally high content of electrolytes, minerals, vitamins, and antioxidants, resulting in a beverage with enhanced nutritional value^{6,7,8,9,10,11,12} Previous studies have demonstrated the potential health benefits of coconut water-based kombucha. Nabila (2025) and Sipahutar (2024) reported that coconut water kombucha exhibited higher antioxidant activity and vitamin C content than conventional tea kombucha, suggesting

a greater potential to support iron metabolism and hematological status. Furthermore, Bastian (2025) found that roselle tea kombucha supplemented with nipa fruit significantly increased hemoglobin levels and reduced the risk of anemia among prospective brides after 7 days of consumption^{13,14,15}

Jakubczyk (2025)¹⁶ reported that herbal-based kombucha fermentation can increase mineral levels, including iron, up to twofold after fermentation. This finding demonstrates kombucha's ability to enrich essential minerals important for hemoglobin formation. Hematological parameters, including hemoglobin (Hb), hematocrit (Hct) are important indicators in assessing anemia status.^{17,18}

Changes in these hematological parameters may reflect improvements in anemia status, making them appropriate outcome measures for evaluating nutritional interventions. Previous studies have demonstrated that kombucha, particularly tea-based kombucha or kombucha supplemented with other plant materials, possesses antioxidant activity and may improve hemoglobin levels and hematological status. Coconut water kombucha has also been reported to contain higher antioxidant activity and vitamin C than conventional tea kombucha, suggesting its potential as a functional beverage.

Adolescents, as a population at high risk of anemia, require nutritional interventions that are effective, affordable, and acceptable to encourage long-term adherence. However, despite these promising findings, previous studies have not specifically evaluated the effects of green coconut water kombucha on comprehensive hematological parameters in adolescents with mild anemia. Most available studies have focused on the physicochemical properties of kombucha, antioxidant activity, or changes in hemoglobin levels in other populations, leaving the effects on hematological profiles including WBC, RBC, Hb, HCT, and PLT in adolescents with mild anemia largely unknown. Consequently, it remains unclear whether the nutritional and bioactive components of green coconut water kombucha can produce measurable improvements in hematological status within this vulnerable population. Addressing this knowledge gap is important because early nutritional interventions may contribute to preventing the progression of mild anemia and provide evidence for the development of affordable, food-based preventive strategies for adolescents. Therefore, this study aimed to evaluate the effect of green coconut water kombucha supplementation on hematological profile parameters, including white blood cell count (WBC), red blood cell count (RBC), hemoglobin (Hb), hematocrit (HCT), and platelet count (PLT), in adolescents with mild anemia.

METHODS

Study design

This pilot study employed a quasi-experimental one-group pretest–posttest design without a control group. All participants received the same intervention, and each participant served as their own comparison (baseline versus post-intervention values). The study was conducted in a laboratory and community setting over approximately two weeks, including the intervention and measurement phases, with controlled preparation of kombucha and standardized hematological examinations before and after the intervention.

Data source and sampling procedure

The data were primary data obtained directly from participants through laboratory examinations. The study population consisted of adolescents aged 17–21 years with mild anemia. Inclusion criteria were a hemoglobin level of 10.0–11.9 g/dL, willingness to participate, and good general health. Exclusion criteria were chronic disease, current medication affecting hematological status, or unwillingness to complete the study. Thirty

adolescents underwent hemoglobin screening, of whom 12 met the eligibility criteria. All eligible adolescents were enrolled using a total sampling technique, forming a single intervention group of 12 participants (coded A1–A12). No control group was formed, and all 12 participants completed the pretest, intervention, and posttest.

Variables of the study

The independent variable in this study was the administration of coconut water kombucha. The dependent variables were hematological profile parameters, including Hb, WBC, RBC, Ht, and PLT. Other relevant variables included age and baseline health condition of participants. All variables were operationally defined and measured using standardized laboratory procedures.

Measurement and instruments

The instruments used in this study included laboratory equipment such as EDTA tubes, micropipettes, centrifuge, and a hematology analyzer for measuring hematological parameters. The preparation of kombucha involved fermentation tools such as glass jars, pH meter, measuring cylinders, and sterile cloth covers. Hematological measurements were conducted using calibrated and standardized laboratory instruments to ensure validity and reliability of the results.

Data collection

Data collection was carried out in two stages: pretest and posttest. At the pretest stage, baseline hematological parameters were measured. All participants then consumed 150 mL/day of green coconut water kombucha for 14 days. After the intervention period, posttest measurements were performed using the same procedures and instruments. All data collection was conducted by trained laboratory personnel following standardized protocols.

Ethical considerations

This study obtained ethical approval from the Institutional Ethics Committee under approval number No: 005571/KEP Universitas Muhammadiyah Ahmad Dahlan Palembang/2025 prior to implementation. All participants and/or their guardians provided informed consent before participation. Confidentiality of participant data was strictly maintained, and all procedures were conducted in accordance with ethical standards for research involving human subjects.

Data analysis

All descriptive and inferential statistics were calculated from the same final verified dataset of 12 participants presented in Table 3, using [software name and version]. Data are presented as mean $\pm$ standard deviation (SD) and, for non-normally distributed differences, as median (interquartile range, IQR). Normality was assessed using the Shapiro–Wilk test, which is appropriate for samples smaller than 50, applied to pretest values, posttest values, and paired differences (posttest – pretest). Because paired tests evaluate within-subject change, the choice of test was based on the distribution of the paired differences: the paired t-test was used when differences were normally distributed ($p > 0.05$), and the Wilcoxon signed-rank test was used otherwise. Extreme values were identified using the $1.5 \times \text{IQR}$ rule and checked against the original hematology analyzer records. Verified values were retained, and a sensitivity analysis excluding the participant concerned was performed when an extreme paired difference was present. Statistical significance was set at $p < 0.05$.

RESULT

This study was declared to have met the ethical requirements and was approved for implementation. The research participants consisted of 12 adolescents diagnosed with mild anemia who underwent hematological profile examinations before and after the

administration of green coconut water kombucha. The laboratory results obtained, categorized by the participants' age, are presented in Table 1.

Table 1. Characteristics of The 12 Adolescent Respondents with Anemia Who Underwent Hematological Profile Examination Based on Age

Age (Year)	Frequency	Percentage (%)
17	1	8.3
18	5	41.7
19	3	25,0
20	2	16.7
21	1	8.3

Based on the age table, the majority of respondents were 18 years old, with a frequency of 5 individuals (41.7%), followed by 19 years old with 3 individuals (25.0%), 20 years old with 2 individuals (16.7%), while 17 and 21 years old were each represented by 1 individual (8.3%). This indicates that most respondents were in the late adolescent age range. To evaluate improvements in anemia among adolescents, green coconut water kombucha fermented for 14 days was administered. The phytochemical test results of the kombucha are presented in Table 2, followed by pretest and posttest hematological profile examinations to assess changes after the intervention (Table 3).

Table 2. Phytochemical Test Results of Coconut Water Kombucha 14 days of Fermentation

Test Parameters	Analysist Results	
	7 Days	14 Days
Flavonoid (mg QE/g)	0.058	0.071
Fenol (mg QE/g)	0.06	0.06
Antioksidan (ppm)	0.031	0.034

Based on the parameter test results, there was an increase in flavonoid levels from 0.058 mg QE/g on day 7 to 0.071 mg QE/g on day 14, indicating an accumulation or enhancement of bioactive compounds during the storage or fermentation process. Total phenol levels remained relatively stable at both observation times (0.06 mg QE/g), suggesting that the phenolic compound content did not undergo significant changes within this period. Meanwhile, antioxidant activity showed a slight increase from 0.031 ppm on day 7 to 0.034 ppm on day 14, which is consistent with the rise in flavonoid levels and may contribute to improved free radical scavenging capacity.

Overall, these findings suggest that extending the fermentation time to 14 days tends to enhance antioxidant activity, particularly influenced by flavonoid content. Furthermore, the characteristics of the 12 study subjects and the results of hematological profile examinations before and after the administration of green coconut water kombucha are presented in Table 3 below.

Verification of participant A10. During data checking, the posttest RBC of participant A10 was flagged because the value entered in the preliminary data file ($7.27 \times 10^6/\mu\text{L}$) appeared as an extreme value in the box plot and was inconsistent with the participant's other results. This value was therefore re-checked against the original hematology analyzer printout for the same sample. The printout showed a posttest RBC of $5.27 \times 10^6/\mu\text{L}$, confirming that the earlier value was a transcription error (the first digit entered as 7 instead of 5), whereas the other parameters of A10 matched the printout. The verified value is also biologically consistent. It represents a change of $+0.05 \times 10^6/\mu\text{L}$ (+1.0%) from the pretest value of $5.22 \times 10^6/\mu\text{L}$, whereas $7.27 \times 10^6/\mu\text{L}$ would imply an implausible 39% increase within 14 days. Moreover, the verified value yields a calculated

mean corpuscular hemoglobin ($MCH = Hb/RBC \times 10$) of 22.6 pg, comparable to the participant's pretest MCH of 19.5 pg, whereas the erroneous value would correspond to 16.4 pg. The same procedure identified a similar transcription error for A2 (7.68 corrected to $5.68 \times 10^6/\mu L$). After correction, A10 was no longer an outlier (upper $1.5 \times IQR$ fence for posttest RBC: $6.22 \times 10^6/\mu L$) and was retained in all analyses. The corrections changed the posttest RBC from 5.17 ± 1.13 to $4.83 \pm 0.46 \times 10^6/\mu L$ and the Shapiro–Wilk p-value of posttest RBC from 0.003 to 0.937. Accordingly, all RBC statistics presented in Tables 3–5 and Figure 1 are based on the verified values.

Table 3. Individual Hematological Values Before (Pretest) and After (Posttest) 14 Days of Green Coconut Water Kombucha Administration (Final Verified Dataset, n = 12)

Sample/ ID	Examination Parameters									
	Pre test	Post test	Pre test	Post test	Pre test	Post test	Pre test	Post test	Pre test	Post test
	WBC	WBC	RBC	RBC	HB	HB	HCT	HCT	PLT	PLT
A1	6.5	7.3	4.93	4.81	10.6	13.6	31.8	40.8	352	381
A2	6	7.8	4.87	5.68	11	12.7	33	38.1	366	387
A3	4.6	5.1	4.54	4.63	10.3	10.6	30.9	31.8	269	271
A4	8.6	7.3	4.54	4.43	11.0	12.9	33	38.7	316	317
A5	9	10.5	4.68	5.08	10.4	11.6	31.2	34.8	242	245
A6	7.4	7.9	4.33	4.53	11.0	13.3	33	39.9	340	370
A7	5.2	5.9	4.7	4.79	10.3	11.4	30.9	34.2	459	514
A8	7.2	7.9	5.23	5.32	10.1	11.2	30.3	33.6	308	331
A9	5.1	7.4	4.62	4.79	10.8	13.6	32.4	40.8	275	389
A10	5.1	6.2	5.22	5.27	10.2	11.9	30.6	35.7	256	295
A11	6.4	7.2	3.82	3.93	10.5	10.9	31.5	32.7	307	312
A12	8.4	9	4.55	4.74	10	10.7	30	32.1	240	309
Mean	6.63	7.46	4.67	4.83	10.52	12.03	31.55	36.10	310.8	343.4
SD	1.50	1.41	0.38	0.46	0.36	1.13	1.08	3.40	62.8	71.0

Table 3 presents the individual values that constitute the final dataset used for all subsequent analyses. Compared with baseline, the mean WBC count increased from 6.63 to $7.46 \times 10^3/\mu L$ (+12.6%), RBC from 4.67 to $4.83 \times 10^6/\mu L$ (+3.5%), Hb from 10.52 to 12.03 g/dL (+14.4%), HCT from 31.55% to 36.10% (+14.4%), and PLT from 310.8 to $343.4 \times 10^3/\mu L$ (+10.5%). The magnitude of change, however, varied between participants. Hb and HCT increased in all 12 participants, with Hb changes ranging from +0.3 g/dL (A3) and +0.4 g/dL (A11) to +2.8 g/dL (A9) and +3.0 g/dL (A1). WBC increased in 11 participants and decreased in A4 (8.6 to $7.3 \times 10^3/\mu L$); the posttest WBC of A5 ($10.5 \times 10^3/\mu L$) was the highest value in the dataset and was identified as an extreme value by the $1.5 \times IQR$ rule, but its paired change was not extreme and the WBC differences were normally distributed.

The distribution of each parameter before and after the intervention, including individual paired values and extreme values, is shown in Figure 1, and the Shapiro–Wilk normality test results are summarized in Table 4.

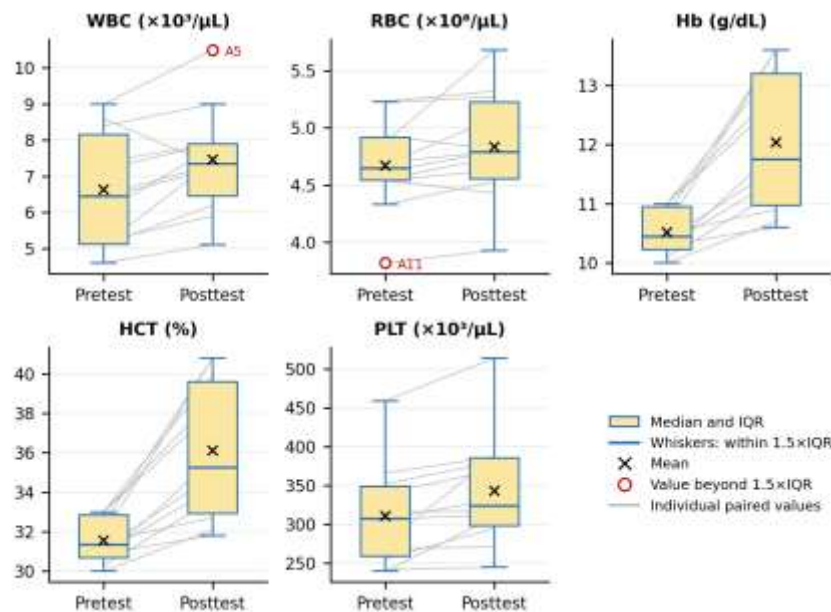


Figure 1. Distribution of Hematological Parameters Before (Pretest) and After (Posttest) 14 Days of Green Coconut Water Kombucha Administration (n = 12). Boxes show the median and IQR; whiskers extend to the most extreme values within $1.5 \times \text{IQR}$; red circles indicate values beyond $1.5 \times \text{IQR}$ (labelled by participant code); x indicates the mean; grey lines connect each participant's paired values.

The p-values in Table 4 were obtained from the Shapiro–Wilk test applied separately to the pretest values, posttest values, and paired differences of the dataset in Table 3; consequently, the means $\pm$ SDs reported in Tables 3 and 5 are identical. Pretest and posttest values of all parameters were normally distributed ($p > 0.05$). Because paired tests evaluate within-subject changes, the choice of test was based on the paired differences: WBC, Hb, and HCT differences were normally distributed and were analyzed using the paired t-test, whereas RBC ($p = 0.016$) and PLT ($p = 0.045$) differences were not normally distributed and were analyzed using the Wilcoxon signed-rank test.

Table 4. Shapiro–Wilk Normality Test Results for Pretest Values, Posttest Values, and Paired Differences of Hematological Parameters (n = 12)

Parameter	Pretest W (p)	Posttest W (p)	Difference W (p)	Distribution of differences	Test applied
WBC	0.931 (0.387)	0.947 (0.591)	0.880 (0.087)	Normal	Paired t-test
RBC	0.934 (0.422)	0.973 (0.937)	0.821 (0.016)	Not normal	Wilcoxon
Hb	0.912 (0.225)	0.902 (0.167)	0.953 (0.684)	Normal	Paired t-test
HCT	0.912 (0.225)	0.902 (0.167)	0.953 (0.684)	Normal	Paired t-test
PLT	0.910 (0.216)	0.915 (0.245)	0.858 (0.045)	Not normal	Wilcoxon

W, Shapiro–Wilk statistic; p, Shapiro–Wilk p-value ($p > 0.05$ indicates normal distribution). Difference = posttest – pretest. All values were calculated from the dataset in Table 3.

RBC counts varied between participants, ranging from 3.82 to $5.23 \times 10^6/\mu\text{L}$ at pretest and from 3.93 to $5.68 \times 10^6/\mu\text{L}$ at posttest (Table 3; Figure 1). Ten participants showed

an increase (median change $+0.10 \times 10^6/\mu\text{L}$; IQR 0.06–0.20), whereas A1 ($-0.12 \times 10^6/\mu\text{L}$) and A4 ($-0.11 \times 10^6/\mu\text{L}$) showed slight decreases. After verification of A10 and A2 (described above), no posttest RBC value was classified as an outlier. Two extreme values remained according to the $1.5 \times \text{IQR}$ rule: the pretest RBC of A11 ($3.82 \times 10^6/\mu\text{L}$) and the paired change of A2 ($+0.81 \times 10^6/\mu\text{L}$; $+16.6\%$). Both were verified measurements and were retained. However, the A2 change was considerably larger than that of the other participants and contributed to the non-normal distribution of RBC differences; therefore, the Wilcoxon signed-rank test, which is less sensitive to extreme values, was applied. In a sensitivity analysis excluding A2, the direction of change was unchanged (mean change $+0.11 \times 10^6/\mu\text{L}$), but the difference was no longer statistically significant (Wilcoxon $p = 0.071$). The RBC finding is therefore not robust and should be interpreted with caution.

Table 5. Comparison of Hematological Parameters Before and After 14 Days of Green Coconut Water Kombucha Administration in Adolescents with Mild Anemia (n = 12)

Parameter	Pretest	Posttest	Mean change (95% CI)	Test	Statistic	p
WBC ($\times 10^3/\mu\text{L}$)	6.63 ± 1.50	7.46 ± 1.41	$0.83 (0.28 \text{ to } 1.39)$	t-test	$t = 3.29$	0.007
RBC ($\times 10^6/\mu\text{L}$)	4.67 ± 0.38 $4.65 (4.54\text{--}4.92)$	4.83 ± 0.46 $4.79 (4.56\text{--}5.22)$	$0.16 (0.01 \text{ to } 0.32)$	Wilcoxon	$Z = -2.08$	0.037
Hb (g/dL)	10.52 ± 0.36	12.03 ± 1.13	$1.52 (0.96 \text{ to } 2.08)$	t-test	$t = 5.97$	< 0.001
HCT (%)	31.55 ± 1.08	36.10 ± 3.40	$4.55 (2.87 \text{ to } 6.23)$	t-test	$t = 5.97$	< 0.001
PLT ($\times 10^3/\mu\text{L}$)	310.8 ± 62.8 $307.5 (259.3\text{--}349.0)$	343.4 ± 71.0 $324.0 (298.5\text{--}385.5)$	$32.6 (11.3 \text{ to } 53.8)$	Wilcoxon	$Z = -3.06$	0.002

t-test, paired t-test (df = 11); Wilcoxon, Wilcoxon signed-rank test. Values are mean $\pm$ SD; for parameters analyzed with the Wilcoxon signed-rank test, median (IQR) is shown on the second line. CI, confidence interval; the Z statistic is based on the normal approximation.

As shown in Table 5, all five parameters differed significantly between pretest and posttest. The largest and most consistent changes were observed for Hb and HCT, which increased in every participant (both $p < 0.001$). WBC increased significantly ($p = 0.007$), although one participant (A4) showed a decrease. RBC showed the smallest relative change ($+3.5\%$; $p = 0.037$), and this result was sensitive to the exclusion of A2, as described above.

Platelet responses were heterogeneous at the individual level (Table 3). PLT increased in all 12 participants, but the magnitude of change ranged from $+1$ to $+114 \times 10^3/\mu\text{L}$ (median $+26 \times 10^3/\mu\text{L}$; IQR 3.5–51.0). Four participants (A3, A4, A5, and A11) showed virtually no change ($+1$ to $+5 \times 10^3/\mu\text{L}$; $\leq 1.6\%$), whereas A9 ($+114 \times 10^3/\mu\text{L}$; 275 to $389 \times 10^3/\mu\text{L}$; $+41.5\%$), A12 ($+69 \times 10^3/\mu\text{L}$; $+28.7\%$), and A7 ($+55 \times 10^3/\mu\text{L}$; $+12.0\%$) accounted for most of the mean increase. This right-skewed distribution of changes explains the non-normal PLT differences and the use of the Wilcoxon test; excluding A9 did not change the conclusion (Wilcoxon $p = 0.001$; mean change $+25.2 \times 10^3/\mu\text{L}$). Posttest PLT counts of 11 participants ranged from 245 to $389 \times 10^3/\mu\text{L}$, within the commonly used reference interval of 150–450 $\times 10^3/\mu\text{L}$, whereas A7 had counts above this interval both before ($459 \times 10^3/\mu\text{L}$) and after ($514 \times 10^3/\mu\text{L}$) the intervention.

DISCUSSION

The observed differences in various hematological parameters before and after the administration of coconut water kombucha are consistent with previous studies reporting the biological effects of fermented beverages on the hematopoietic system. Onsun (2025)⁶ reported that kombucha exhibits broad physiological activities due to its content of organic acids, polyphenols, and fermentation-derived microorganisms. These compounds are capable of influencing cellular metabolism and bone marrow function, leading to significant changes in blood parameters. This finding aligns with the present study, which demonstrated significant differences in hematological profiles after the administration of coconut water kombucha.

The increase in WBC levels after treatment is consistent with studies by Hananta et al. (2025) and Cheepchirasuk (2025)^{20,21}, which reported the immunomodulatory effects of kombucha. Their findings showed that kombucha consumption can increase leukocyte counts in response to immune system stimulation by probiotics and fermentation metabolites. This effect is attributed to immune cell activation through interactions between gut microbiota and the mucosal immune system. This mechanism explains the observed increase in WBC levels in the present study following coconut water kombucha administration.

The differences in RBC, Hb, and HCT values before and after treatment are in line with the study by Öztürko et al. (2025)²², which stated that kombucha supports erythropoiesis. Kombucha contains gluconic and glucuronic acids that enhance mineral solubility and bioavailability, particularly iron. Improved iron bioavailability may contribute to hemoglobin synthesis and maintenance of erythrocyte-related parameters; however, iron absorption and erythropoietic activity were not directly measured in the present study.

However, the RBC change observed in the present study was small (+3.5%) and was not robust in the sensitivity analysis excluding one participant with a large individual increase (A2). Given the approximately 120-day lifespan of erythrocytes, a 14-day intervention is unlikely to produce a large change in circulating red cell count, and this finding should be confirmed in longer studies that include erythrocyte indices and iron status markers.

The increase in hemoglobin levels is also associated with the vitamin content of kombucha. Fermented kombucha beverages are known to contain B-complex vitamins and vitamin C, which act as enzyme cofactors in heme synthesis. Vitamin C is known to enhance non-heme iron absorption in the intestine by reducing ferric iron (Fe³⁺) to the more absorbable ferrous form (Fe²⁺). Therefore, the observed improvement in hemoglobin levels may be associated with increased iron bioavailability and utilization, although these mechanisms were not directly evaluated in this study. Humairah (2025)²³ reported the antioxidant effects of kombucha on red blood cells. The polyphenol and flavonoid content in kombucha can protect erythrocyte membranes from oxidative damage, prolong red blood cell lifespan, and increase circulating erythrocyte volume.

The platelet (PLT) increase at the group level suggests that fermented beverages may help balance inflammatory responses rather than directly stimulate thrombopoiesis. Kombucha does not necessarily cause a drastic increase in platelet counts but may influence platelet regulation and homeostasis.^{24,25}

Interpretation of the PLT results should, however, take the individual data in Table 3 into account. Although the group mean increased from 310.8 to 343.4 ×10³/μL and all participants showed an increase, the response was highly heterogeneous: four participants showed virtually no change, whereas three participants (A9, A12, and A7)

accounted for most of the mean increase. Such variability is compatible with biological and pre-analytical variation in platelet counts, which may be influenced by hydration status, menstrual phase, recent infection or inflammation, physical activity, and sample handling, none of which were controlled in this study. Apart from A7, whose platelet count was already above the reference interval at baseline, all values remained within the reference interval, and no participant showed a change suggestive of clinically relevant thrombocytosis or thrombocytopenia. Therefore, the statistically significant PLT increase should not be interpreted as a clinically meaningful effect of kombucha on thrombopoiesis.

Bastian et al. (2025)¹⁵ reported that roselle kombucha mixed with nipa fruit significantly increased hemoglobin levels in prospective brides with anemia ($p = 0.000$). The significant improvement was attributed to the bioactive components in roselle and nipa. Roselle kombucha tea contains vitamins B1, B2, and B3, which function as catalytic cofactors in carbohydrate, lipid, and protein metabolism, supporting enzymatic activity and contributing to hemoglobin synthesis.

The significant differences in hematological parameters are also consistent with studies emphasizing the role of gut microbiota in hematological regulation. Probiotics in fermented products can enhance nutrient absorption, reduce systemic inflammation, and improve the body's metabolic environment. These improvements may be associated with enhanced hematopoietic activity in the bone marrow. Coconut water kombucha may exert its beneficial effects through a combination of immunomodulatory properties, improved nutrient bioavailability, antioxidant activity, and possible interactions with gut microbiota regulation; however, these mechanisms were not directly evaluated in the present study.^{26,27,28}

This study has several limitations that should be considered when interpreting the findings. Most importantly, the one-group pretest–posttest design without a control group does not allow the observed changes to be separated from regression to the mean (participants were selected on the basis of low hemoglobin), time-related changes, or other concurrent factors. The relatively small sample size may limit the generalizability of the results to a broader population. Dietary intake and lifestyle factors of the participants were not strictly controlled, which may have influenced the observed changes in hematological parameters. In addition, this study did not evaluate specific biomarkers related to iron metabolism or inflammatory status, such as ferritin, transferrin, C-reactive protein (CRP), or gut microbiota composition. Therefore, the biological mechanisms underlying the observed hematological changes could not be directly confirmed and should be interpreted with caution.

Furthermore, dietary iron intake, iron supplementation, consumption of iron-rich foods (such as red meat), use of nutritional supplements, and menstrual status were not controlled during the study period. These factors may have influenced the observed changes in hemoglobin and other hematological parameters. Therefore, the increase in hemoglobin levels cannot be attributed solely to the administration of green coconut water kombucha.

The strengths of this study include the use of paired pretest–posttest measurements in which each participant served as their own comparison, which reduces the influence of between-individual differences in baseline hematological values. The study also employed standardized hematological measurements using calibrated laboratory instruments, and all statistics were derived from a single verified dataset with transparent reporting of individual values and extreme values. Furthermore, this research contributes to the limited scientific evidence regarding the use of coconut water kombucha as a functional beverage among adolescents with mild anemia.

The findings of this study have important implications. Coconut water kombucha shows potential as a natural, affordable, and accessible functional drink to improve hematological profiles and support anemia prevention efforts among adolescents. This study also suggests that fermented beverages may be associated with improvements in hematological parameters through nutritional, antioxidant, and gut microbiota-related pathways; however, these mechanisms require further investigation using specific biological markers. Future research is recommended to involve larger sample sizes, longer intervention periods, and the inclusion of more specific biomarkers to further strengthen and expand these findings.

Biological variation among participants should also be considered when interpreting the findings. Individual differences in nutritional status, baseline iron stores, menstrual patterns, daily dietary habits, physical activity, and physiological responses to fermented beverages may have contributed to the variability observed in hematological parameters. In addition, although no adverse events were formally assessed during this study, fermented beverages may cause mild gastrointestinal symptoms such as bloating, abdominal discomfort, or changes in bowel habits in some individuals. Future studies should monitor both biological variability and potential adverse effects to provide a more comprehensive evaluation of the safety and effectiveness of coconut water kombucha.

CONCLUSION

In this pilot study with a one-group pretest–posttest design, 14 days of green coconut water kombucha administration was associated with increases in hematological parameters among adolescents with mild anemia. The most consistent changes were observed in Hb and HCT, which increased in all participants, whereas the RBC increase was small and not robust in the sensitivity analysis, and PLT changes varied widely between individuals while remaining largely within the reference interval. These findings indicate the potential of green coconut water kombucha as a functional beverage to support hematological status in adolescents.

However, because no control group was included, the sample size was small, and dietary intake, iron supplementation, and menstrual status were not controlled, the observed changes cannot be causally attributed to kombucha consumption. The findings should therefore be regarded as preliminary.

Randomized controlled trials with larger samples, longer intervention periods, standardized dietary assessment, and markers of iron status (e.g., ferritin and transferrin saturation) and inflammation are needed to confirm these preliminary findings and to evaluate the underlying mechanisms and long-term safety of coconut water kombucha.

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