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The Effect of Sea Urchin Gonad-Enriched *Baruasa* Snacks Combined with Iron Supplementation on Hemoglobin Levels in Adolescent Girls: A Non-Blinded Randomized Controlled Trial

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Abstract

Adolescent girls are highly vulnerable to iron deficiency anemia, which poses long-term risks to their growth and reproductive health. This quasi-experimental study aimed to evaluate the effectiveness of a local food-based intervention, specifically *baruasa* snacks enriched with sea urchin gonads combined with iron supplementation, compared to iron supplementation alone, in improving hemoglobin levels among adolescent girls. A total of 70 female students aged 15–17 years were equally divided into an intervention group receiving both the enriched *baruasa* and iron tablets, and a control group receiving only iron tablets. Hemoglobin levels, body mass index (BMI), and mid-upper arm circumference (MUAC) were measured before and after the intervention, with data analyzed using paired and independent t-tests. The results demonstrated a highly significant improvement in the intervention group, where mean hemoglobin levels increased from 10.43 ± 1.39 g/dL to 12.34 ± 1.27 g/dL ($p < 0.001$, mean delta = 1.91 ± 1.57 g/dL). In contrast, the control group exhibited a marginal increase from 11.76 ± 1.71 g/dL to 11.84 ± 1.52 g/dL ($p < 0.001$, mean delta = 0.07 ± 0.33 g/dL). Furthermore, secondary nutritional indicators, including BMI and MUAC, showed greater improvements in the combination group. In conclusion, supplementing iron tablets with sea urchin gonad-enriched *Baruasa* provides a synergistic nutritional effect that significantly outperforms iron supplementation alone. This integrated approach serves as a promising, culturally acceptable, and sustainable strategy for preventing adolescent anemia.

Keywords: Adolescent girls; Anemia; Iron supplementation; *Baruasa* traditional food; Dietary intervention.

Abbreviations: Directly Observed Treatment (DOT); Iron-Folic Acid (IFA); Body Mass Index (BMI); Mid-Upper Arm Circumference (MUAC)

INTRODUCTION

Anemia remains a pervasive nutritional disorder, particularly among adolescent girls. It is clinically characterized by hemoglobin (Hb) concentrations that fall below age- and sex-specific normal thresholds. As a critical public health challenge in developing nations, including Indonesia (Anwar et al., 2020), persistent anemia exerts detrimental effects on physical well-being. It diminishes productivity, concentration, and cognitive function, thereby compromising the overall trajectory of adolescent development (Kementerian Kesehatan, 2018).

Adolescent girls constitute a highly vulnerable demographic, primarily due to regular menstrual blood loss coupled with the physiological demands of rapid growth. This critical developmental window necessitates elevated intakes of energy, high-quality protein, iron, and other essential micronutrients to sustain optimal growth and replenish depleted iron stores. National epidemiological data highlight the severity of this issue, indicating that the highest anemia prevalence is found among out-of-school adolescents (30.6%) and urban populations (25%) (Gardner & Kassebaum, 2020).

The etiology of adolescent anemia is predominantly linked to inadequate dietary intakes of bioavailable iron and protein (Jumiyati et al., 2023). These deficiencies frequently stem from poor dietary patterns and limited access to nutrient-dense foods. A diet lacking in both quantity and quality not only impairs hematological status but also stunts somatic growth. Furthermore, iron deficiency is often compounded by concurrent shortages of synergistic micronutrients—such as folate, vitamin A, and vitamin B12—which are prevalent in developing regions (Food and Agriculture Organization of the United Nations & World Health Organization, 2018; Gardner & Kassebaum, 2020).

To mitigate this public health burden, the Indonesian Ministry of Health has instituted national prevention programs, notably the weekly provision of iron-folic acid (IFA) supplementation alongside balanced nutrition

advocacy (Kementerian Kesehatan, 2023). However, programmatic coverage and efficacy remain constrained. Recent evidence by Helmyati et al. (2023) highlights suboptimal compliance and limited uptake of IFA supplements among adolescents. Consequently, complementary and sustainable strategies are urgently required to optimize the outcomes of government-led supplementation programs.

Addressing this gap, the utilization of fortified, culturally acceptable local foods presents a promising adjunctive nutritional strategy. Previous formulations have successfully enriched *baruasa* (also known as *bagea*)—a nutrient-dense, traditional cassava or sago-based snack endemic to Eastern Indonesia—with sea urchin gonads (*Diadema setosum*). Sea urchin gonads serve as a highly potent marine protein source; proximate analyses reveal significant nutritional density, comprising 58.96% protein and 20.31% fat on a dry basis (db), alongside essential trace minerals (Karnila et al., 2022). Consequently, each formulated serving delivers substantial energy (228.1 kcal), protein (3.9 g), and lipids (10.96 g), transforming a simple carbohydrate snack into a functional food (Banudi et al., 2021).

While *baruasa* is widely recognized for its biscuit-like characteristics and high acceptability (Dubey et al., 2020), its functional modification utilizing marine resources has not been clinically evaluated as an anemia intervention. Building upon prior food technology research, this study aimed to investigate the synergistic efficacy of sea urchin gonad-enriched *baruasa* combined with standard iron supplementation on hemoglobin levels in adolescent girls. By integrating local dietary wisdom with public health initiatives, this intervention seeks to provide an evidence-based, sustainable model for combating adolescent anemia.

MATERIALS AND METHODS

Study Design

This study was a non-blinded, parallel-group, randomized controlled trial (RCT) designed in strict adherence to the CONSORT (Consolidated Standards of Reporting Trials) guidelines. The objective was to evaluate the efficacy of a functional local food intervention on hematological and nutritional outcomes. The trial was conducted on June to August 2024 for over a four-week period at SMA Negeri 1 Soropia, Southeast Sulawesi, Indonesia.

Sample Size Determination

The sample size was calculated using the formula for testing the difference between two independent population means, based on previous related studies. Assuming a 95% confidence interval ($\alpha = 0.05$), a statistical power of 80% ($\beta = 0.20$), and accounting for a potential 10% dropout rate, the minimum required sample size was determined to be 35 participants per group, resulting in a total sample of 70 adolescent girls.

Randomization and Allocation

Following baseline screening and informed consent, the 70 eligible participants were randomly allocated (1:1 ratio) into either the intervention group or the control group. The randomization sequence was generated by an independent data manager using a computer-generated simple randomization list. Because of the nature of the dietary intervention (visible snack consumption), blinding of the participants and field researchers was not feasible (non-blinded).

Intervention and Compliance Assessment

The intervention was administered over a consecutive four-week period. The intervention group received six pieces of sea urchin gonad-enriched *baruasa* weekly alongside one standard iron-folic acid (IFA) tablet. The control group received the standard national care of one IFA tablet weekly. To ensure strict protocol adherence, the administration of both the snacks and IFA tablets was directly supervised by the primary research team assisted by trained school health coordinators using the Directly Observed Treatment (DOT) method. Compliance was meticulously assessed and documented through personalized weekly logbooks; participants were required to consume the supplements and snacks on-site, and any unconsumed portions were recorded.

Outcomes and Measurements

The primary outcome of this trial was the change in hemoglobin concentration, measured via capillary blood sampling using a validated point-of-care digital hemoglobinometer at baseline and week four. To provide a comprehensive clinical picture of the participants' growth and nutritional status, secondary outcomes were explicitly evaluated. These included changes in Body Mass Index (BMI) and Mid-Upper Arm Circumference (MUAC), which were measured using calibrated stadiometers, digital scales, and standard measuring tapes.

Ethical Considerations

The trial protocol was reviewed and approved by the Health Research Ethics Committee of Poltekkes Kemenkes Kendari. Written informed consent was obtained from all participants and their legal guardians prior to randomization.

RESULTS AND DISCUSSION

Table 1. Participants Characteristics.

Variable	Intervention			
	***Baruasa* + IFA**		**IFA**	
	n	**%**	**n**	**%**
Age (year)				
15	11	31.43	2	5.71
16	20	57.14	17	48.57
17	4	11.43	16	45.72
Father's education				
Primary school	3	8.57	1	2.86
Junior high school	21	60.00	28	80.00
Senior high school	11	31.43	4	11.42
University degree	0	0	2	2.71
Mother's education				
Primary school	4	11.42	2	2.71
Junior high school	22	62.86	26	74.29
Senior high school	9	25.71	4	11.42
University degree	0	0	3	8.57
Mother's employment				
Homemaker	35	100	29	82.86
Self-employed	0	0	1	2.86
Civil servant/Military/Police	0	0	5	14.29
Father's employment				
Self-employed	7	20.00	18	51.43
Fishermen	21	60.00	3	8.57
Farmer	7	20.00	3	8.57
Civil servant/Military/Police	0	0	11	31.43

The baseline demographic characteristics of the participants, distributed between the intervention group (sea urchin gonad-enriched *baruasa* + IFA) and the control group (IFA only) (Table 1). Most participants in the intervention group were 16 years of age (57.14%), whereas the control group predominantly consisted of 16-year-olds (48.57%) and 17-year-olds (45.72%). Regarding parental education, the highest proportion of both fathers and mothers across both groups had attained a junior high school education. Parental attainment of tertiary education was minimal, with no parents in the intervention group holding a university degree. Occupationally, all mothers in the intervention group were homemakers, while a small proportion in the control group was formally employed (17.14%). Fathers in the intervention group were primarily employed as fishermen (60.00%), reflecting the study's coastal setting, whereas those in the control group were predominantly self-employed (51.43%) or employed in the public sector (31.43%).

Table 2. Nutritional and Health Status of Girls Adolescent.

Variable	Intervention			
	***Baruasa* + IFA**		**IFA**	
	n	**%**	**n**	**%**
Body Mass Index				
Underweight	10	28.57	3	8.57
Normal	23	65.71	31	88.57
Overweight	1	2.86	0	0
Obese	1	2,86	1	2.86
Baseline MUAC				
CED	17	48.57	18	51.43
Normal	18	51.43	17	48.57
Post-intervention MUAC				
CED	18	51.43	23	65.71
Normal	17	48.57	12	34.29
Baseline Anemia Status				
Anemic	22	62.86	9	25.71
Normal	13	37.14	26	74.29
Post-intervention Anemia Status				
Anemic	3	8.57	9	25.71
Normal	32	91.43	26	74.29

Result on table 2 delineates the secondary nutritional outcomes, specifically Body Mass Index (BMI) and Mid-Upper Arm Circumference (MUAC), before and after the intervention. At baseline, most respondents exhibited a normal BMI status (65.71% in the intervention group and 88.57% in the control group). However, a higher baseline prevalence of underweight individuals was observed in the intervention group (28.57%) compared to the control (8.57%). Assessment of MUAC revealed that approximately half of the participants in both groups were at risk of chronic energy deficiency (CED) at baseline (48.57% in the intervention group and 51.43% in the control group). Post-intervention, the proportion of participants categorized as having CED risk showed a slight increase, notably reaching 65.71% in the control group.

Regarding categorical anemia status, a notable baseline disparity was observed; 62.86% of participants in the intervention group were classified as anemic, compared to 25.71% in the control group. Following the four-week trial, the prevalence of anemia in the intervention group experienced a precipitous decline to 8.57%. Conversely, the anemia prevalence in the control group remained completely stagnant at 25.71%. Consequently, the proportion of participants achieving normal hemoglobin levels in the intervention group surged to 91.43%, indicating a robust clinical response to the combined dietary and pharmacological supplementation.

Table 3. Haemoglobin Levels Before and After Intervention.

Intervention	Hemoglobin level		p value	Delta	p value
	Baseline	Post-intervention			
Baruasa + IVA	10,43 ± 1,39	12,34 ± 1,27	0,000	1,91 ± 1,57	0,000
TTD	11,76 ± 1,71	11,84 ± 1,52	0,000	0,07 ± 0,33	

The result present within-group and between-group analyses of mean hemoglobin concentrations. In the intervention group, the mean hemoglobin level demonstrated a highly significant increase from a baseline of 10.43 ± 1.39 g/dL to 12.34 ± 1.27 g/dL post-intervention ($p < 0.001$). While the control group also exhibited a statistically significant within-group increase ($p < 0.001$), the absolute change was clinically marginal, rising only from 11.76 ± 1.71 g/dL to 11.84 ± 1.52 g/dL.

Furthermore, the mean difference (delta change) in hemoglobin levels was markedly superior in the intervention group (1.91 ± 1.57 g/dL) compared to the control group (0.07 ± 0.33 g/dL). This substantial disparity ($p < 0.001$) confirms that the adjunct administration of sea urchin gonad-enriched *baruasa* exerts a significantly greater hematological improvement than standard IFA supplementation alone.

Discussion

The present non-blinded randomized controlled trial demonstrated that complementing standard iron-folic acid (IFA) supplementation with sea urchin gonad-enriched *baruasa* significantly enhances hemoglobin levels in adolescent girls compared to standard care alone. The pronounced mean difference (*delta*) observed in the intervention group supports the hypothesis that the integration of culturally acceptable, nutrient-dense local foods acts synergistically with pharmacological interventions to combat adolescent anemia.

The superiority of the combined intervention can be attributed to the complex and highly bioavailable nutrient profile of the fortified snack. While IFA tablets directly supply exogenous iron and folate, their absorption and utilization are heavily dependent on the presence of supporting macronutrients (Azzahra et al., 2023). The protein derived from sea urchin gonads provides critical essential amino acids necessary for globin chain synthesis. Adequate dietary protein not only forms the structural basis of hemoglobin but also significantly enhances the intestinal absorption of non-heme and supplemental iron. This aligns with findings by Bordbar et al. (2021) and Toruntju et al. (2020), who highlighted that higher intake of marine-derived hemoglobin precursors, such as those found in sea urchins, directly correlate with improved hematological status.

The pathogenesis of anemia in adolescent girls extends beyond simple iron deficiency, it is often compounded by inadequate total energy intake and deficiencies in co-factors like vitamins C, B12, and folate (Glinz et al., 2017). The fortified *baruasa* addresses this multi-etiological challenge. According to Banudi et al. (2021), this formulation provides substantial macronutrient density, including 24.48 g of fat per 100 g. In the context of anemia, this fat content serves primarily as a concentrated energy reserve, helping to mitigate overall chronic energy deficiency without causing counterproductive metabolic stress. Additionally, the inherent micronutrients in the fortified food, such as vitamin C, act as reducing agents that maintain iron in its absorbable ferrous state (Fe^{2+}), while B-complex vitamins facilitate normal megaloblastic erythropoiesis and cellular proliferation (Morales et al., 2024; Fathimah et al., 2024).

By bridging the gap between clinical supplementation and local dietary habits, this intervention offers a sustainable, community-based strategy to improve adherence and nutritional outcomes (Onomu & Okuthe, 2024). However, several limitations must be

acknowledged. First, the relatively short four-week duration of the trial may capture immediate hematological responses but falls short of evaluating long-term sustainability or the replenishment of ferritin stores. Second, as observed in the baseline data, there was an incidental imbalance in initial anemia prevalence between the groups, an inherent risk in simple randomization with a modest sample size. Furthermore, the slight increase in the risk of Chronic Energy Deficiency (CED) observed post-intervention across both groups suggests that external confounding factors, such as erratic dietary diversity outside the intervention, academic stress, or unrecorded menstrual patterns were not fully controlled. Future multi-center trials with extended follow-up periods and rigorous dietary recall controls are warranted to validate these findings across broader demographics.

CONCLUSIONS

The provision of sea urchin gonad-enriched *baruasa* combined with standard iron-folic acid supplementation is remarkably more effective in elevating hemoglobin levels among adolescent girls than iron supplementation alone. The synergistic interaction between the marine-derived proteins, essential dietary fats, and catalytic micronutrients within the local snack significantly optimizes iron absorption and erythropoiesis. Integrating this culturally acceptable, functional food into existing public health frameworks represents a highly viable and sustainable strategy to accelerate the eradication of iron-deficiency anemia in vulnerable adolescent populations.

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