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Impact of fortified rice on hemoglobin levels in adolescent girls from BPL households: A study in Balasore district

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Abstract

Iron deficiency anemia is among the most widespread nutritional deficiencies globally and continues to be a significant public health issue in India, especially affecting adolescent girls. The present study was conducted in Balasore district of Odisha during the year 2024-2025 entitled "Impact of fortified rice on hemoglobin levels in adolescent girls from BPL households: A study in Balasore district". A total of 120 respondents were selected by the purposive sampling method for the study, of which 90 were from BPL households and 30 from Non-BPL households. The main two objectives of the study were to access the acceptability and knowledge of fortified rice among the adolescent girls and to know the effect of fortified rice on the nutritional status of adolescent girls. Statistical analysis was carried out to assess the association between fortified rice consumption and improvement in hemoglobin, vitamin B₁₂ and folic acid levels. The results revealed that with regular consumption of fortified rice the biochemical parameters haemoglobin (12.9 ± 0.3), vitamin B₁₂ (422.3 ± 20.1), folic acid (8.2 ± 0.4) was higher in BPL adolescent girls in comparison to Non-BPL adolescent girls parameters hemoglobin (10.8 ± 0.4), vitamin B₁₂ (220.3 ± 15.0), folic acid (4.1 ± 0.3). The study concludes that fortified rice has a considerable impact in combating iron deficiency anemia among vulnerable groups. The findings suggest that fortified rice can serve as a sustainable nutritional strategy to improve the health and nutritional status of adolescent girls in Odisha.

Keywords: Fortified rice, adolescent girls, hemoglobin, vitamin b₁₂, folic acid, iron deficiency anemia, nutritional status, BPL households, public health nutrition

1. Introduction

Iron deficiency anemia (IDA) remains one of the most prevalent nutritional deficiencies worldwide and a major public health issue in India, especially among adolescent girls (WHO, 2023). The National Family Health Survey (NFHS-5, 2021) reported that 59.1% of adolescent girls in India are anemic, emphasizing the need for effective interventions. Micronutrient malnutrition in this age group arises from poor dietary diversity, low intake of iron-rich foods, and socioeconomic disparities (UNICEF, 2020). Food fortification has emerged as a sustainable strategy to combat micronutrient deficiencies (FAO, 2017). Among

these, fortified rice—enriched with iron, folic acid, and vitamin B₁₂—has been promoted under India's Rice Fortification Programme through the Public Distribution System (PDS) and Mid-Day Meal schemes (FSSAI, 2022). Studies have demonstrated that fortified rice improves micronutrient status and cognitive performance among vulnerable populations (Della Lucia *et al.*, 2017) [6]. Balasore district of Odisha, with high anemia prevalence and active fortified rice implementation, provides an ideal setting to evaluate its impact. Hence, this study was undertaken to assess the acceptability of fortified rice and its effect on the nutritional status of adolescent girls.

The specific objectives of the study are as follows:

1. To access the acceptability and knowledge of fortified rice among the adolescent girls.
2. To know the effect of fortified rice on the nutritional status of adolescent girls.

2. Materials and Methods

A cross-sectional study entitled “Impact of fortified rice on hemoglobin levels in adolescent girls from BPL households: A study in Balasore district” was conducted during 2024-2025 in selected rural areas of Balasore district, Odisha. The methodology included the following components:

2.1 Location

The study was carried out in the Remuna block of Balasore district, which consists of 361 villages. Three villages—Bampada, Saraswatipur, and Samalpur—were selected using a purposive sampling method based on their representative rural population and active implementation of government nutrition programs such as the Mid-Day Meal Scheme and ICDS. These villages provided an appropriate setting for assessing the nutritional impact of fortified rice among adolescent girls.

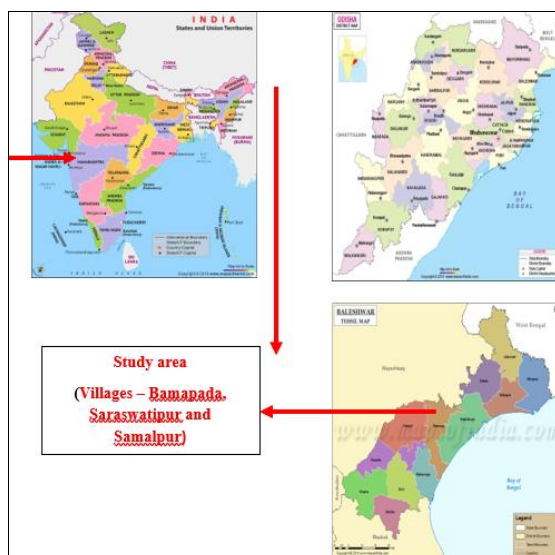


Fig 1: Map of Selected villages of Balasore district for survey

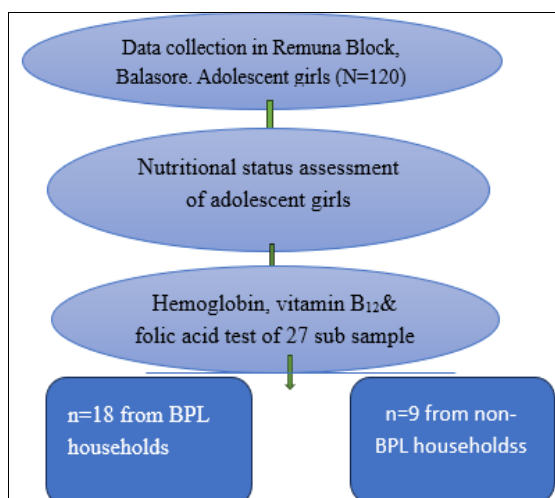


Fig 2: plan of work

2.2 The nutritional assessment

The nutritional status of adolescent girls was assessed using anthropometry, biochemical parameters, clinical signs and symptoms, and diet survey. Measurements such as height, weight, BMI, waist and hip circumference, MUAC, and WHR were recorded. Biochemical analysis included Hemoglobin, Vitamin B₁₂, and Folic Acid levels, while clinical signs like pallor and fatigue were observed. Dietary assessment was done using the 24-hour recall method, and nutrient adequacy was calculated as:

$$\text{Food adequacy} = (\text{Actual Food Intake} / \text{RDA of Food}) \times 100$$

$$\text{Nutrient adequacy} = (\text{Actual Nutrient Intake} / \text{RDA of Nutrient}) \times 100.$$

2.3 Anthropometric measurements

In this case such as height, weight, waist and hip circumference, MUAC, and skinfold thickness were recorded following the procedure of Majumder *et al.* (2024). Height and weight were measured using standard tools, and Waist-Hip Ratio (WHR) was calculated. BMI was computed using the formula:

$$\text{BMI} = \text{Weight (kg)} / \text{Height (m}^2\text{)}$$

2.4 Biochemical parameters

The study assessed three biochemical parameters—hemoglobin, vitamin B₁₂, and folic acid levels—to evaluate micronutrient deficiencies and anemia among adolescent girls. Using purposive sampling, 27 girls (18 BPL and 9 Non-BPL) were selected. Hemoglobin was tested using a standard kit; levels ≥ 12 g/dL were normal, and 10.0-11.9 g/dL indicated mild/moderate anemia. Blood samples collected by an NABL-accredited technician were analyzed for vitamin B₁₂ and folic acid. Vitamin B₁₂ levels ≥ 200 pg/mL were normal, < 200 pg/mL indicated mild/moderate anemia. Folic acid levels ≥ 5.5 ng/mL were normal, and ≤ 5.4 ng/mL indicated mild/moderate anemia.

2.5 Clinical assessment

It is a evaluated visible and reported signs of anemia and micronutrient deficiencies using a structured checklist. Symptoms recorded included pale skin, fatigue, dizziness, shortness of breath, brittle nails, irregular heartbeat, headache, and menstrual irregularities.

2.6 Diet survey

IT used the 24-hour recall method, where participants reported all foods and drinks consumed in the previous day. Standardized cups and bowls ensured accurate portion measurement and consistent food intake estimation.

2.7 Statistical analysis

The collected data was organized, tabulated and analysed statistically by conducting a paired t-test.

3. Results and Discussion

3.1 General information

The study was conducted among 120 adolescent girls aged 12-20 years from the villages of Bampada, Saraswatipur and

Samalpur in Remuna block of Balasore district, including 90 girls from BPL households and 30 from Non-BPL households. Most respondents belonged to the 15-18 years age group. Educational status showed that a majority had completed middle school (classes 6-8), followed by high school (classes 9-10), with fewer girls having only primary education or pursuing higher secondary studies; education levels were slightly higher among Non-BPL girls. Caste distribution revealed that most belonged to OBC, followed by General and SC, with few from ST groups. Hindu

religion was predominant, with smaller representation of Muslims and Christians in both groups. Most girls lived in nuclear families, while joint families were more common among Non-BPL households. Family size varied, with 49.2% belonging to small families (≤ 4 members), 36.7% to medium families (5-6 members), and 14.1% to larger families (≥ 7 members). Housing conditions differed notably: kutcha houses were more common among BPL families, whereas semi-pucca and pucca houses were more frequent among Non-BPL households.

Table 1: General informations of the respondents.

Variables	Categories	BPL (n=90)		Non-BPL (n=30)		Total (N=120)	
		f	%	f	%	f	%
Age (years)	12-15	28	31.1	08	26.7	36	30.0
	15-18	40	44.5	14	46.6	54	45.0
	18-20	22	24.4	08	26.7	30	25.0
	Total	90	100	30	100	120	100
Education	Middle (6-8)	34	37.8	9	30.0	43	35.8
	High School (9-10)	31	34.4	12	40.0	43	35.8
	Higher Secondary	25	27.8	09	30.0	34	28.4
	Total	90	100	30	100	120	100
Caste	General	14	15.6	08	26.7	22	18.3
	OBC	26	28.9	10	33.3	36	30.0
	SC	30	33.3	06	20.0	36	30.0
	ST	20	22.2	06	20.0	26	21.7
	Total	90	100	30	100	120	100
Religion	Hindu	84	93.4	30	100	108	90.0
	Muslim	04	04.4	-	-	04	03.3
	Christian	02	02.2	-	-	02	01.7
	Total	90	100	30	100	120	100
Family Type	Nuclear	52	57.7	16	53.3	68	56.7
	Joint	38	42.2	14	46.7	52	43.3
	Total	90	100	30	100	120	100
Family Size	Small	44	48.9	15	50.0	59	49.2
	Medium	33	36.7	11	36.7	44	36.7
	Large	13	14.4	04	13.3	17	14.1
	Total	90	100	30	100	120	100
House Type	Kutcha	52	57.7	06	20.0	58	48.4
	Semi-pucca	28	31.1	12	40.0	40	33.3
	Pucca	10	11.1	12	40.0	22	18.3
	Total	90	100	30	100	120	100

3.2 Anthropometric status of respondents

The results showed no significant difference in anthropometric measurements between BPL and Non-BPL girls. Mean height was 152.2 ± 4.7 cm for BPL and 153.4 ± 5.2 cm for Non-BPL; mean weight was 45.3 ± 6.0 kg and 47.5 ± 6.1 kg, respectively. BMI values were similar (19.6 ± 2.2 vs. 20.1 ± 2.1 kg/m²), indicating normal BMI and no major nutritional gap. Waist-hip ratio was slightly higher in

Non-BPL (0.78 ± 0.05) than BPL (0.74 ± 0.04), suggesting lifestyle differences but statistically non-significant. About 30% of girls were underweight, higher among BPL (34.4%) than Non-BPL (16.7%), while most fell within normal BMI (60.8%)—more in Non-BPL (73.3%). Fortified rice consumption, rich in iron, folic acid, and vitamin B₁₂, likely improved nutritional outcomes and reduced anemia risk (Della Lucia *et al.*, 2017) [6].

Table 2: Anthropometric status of respondents

Parameters	BPL (n=90) Mean $\pm$ SD	Non-BPL (n=30) Mean $\pm$ SD	Total (N=120) Mean $\pm$ SD	t-value
Height (cm)	152.2 $\pm$ 4.7	153.4 $\pm$ 5.2	152.5 $\pm$ 4.9	0.92 ^{NS}
Weight (kg)	45.3 $\pm$ 5.6	47.5 $\pm$ 6.1	45.9 $\pm$ 5.8	1.55 ^{NS}
BMI (kg/m ²)	19.6 $\pm$ 2.2	20.1 $\pm$ 2.1	19.8 $\pm$ 2.2	1.05 ^{NS}
Waist Circumference (cm)	67.0 $\pm$ 4.1	69.2 $\pm$ 4.5	67.6 $\pm$ 4.3	1.95 ^{NS}
Hip Circumference (cm)	87.2 $\pm$ 5.0	89.0 $\pm$ 5.3	87.7 $\pm$ 5.1	1.42 ^{NS}
WHR	0.74 $\pm$ 0.04	0.78 $\pm$ 0.05	0.75 $\pm$ 0.05	2.05 ^{NS}

Values are expressed in terms of Mean $\pm$ SD

*Significant at $p < 0.05$, **Significant at $p < 0.01$, NS - Not Significant.

BMI classifications of respondents

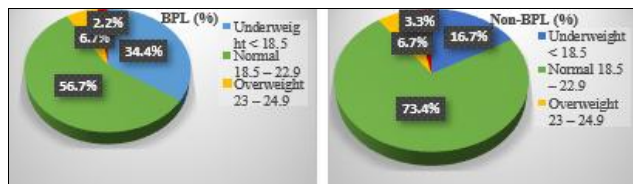


Fig 3: Comparison of BMI status

3.3 Biochemical measurements of the respondents

The biochemical analysis showed significant differences between BPL and Non-BPL girls in hemoglobin, vitamin B₁₂, and folic acid levels. Normal hemoglobin (≥ 12 g/dL)

was found in 77.8% of BPL girls and only 33.3% of Non-BPL, with BPL showing a higher mean (12.9 ± 0.3 g/dL) ($t = 6.12$, $p < 0.05$). Vitamin B₁₂ levels were normal in 72.2% of BPL and 55.6% of Non-BPL, with mean concentrations almost double in BPL (422.3 ± 2.01 pg/mL vs. 220.3 ± 1.50 pg/mL) ($t = 9.45$, $p < 0.01$). Folic acid adequacy (≥ 5.5 ng/mL) was higher among BPL (83.3%) than Non-BPL (66.7%), with mean values of 8.2 ± 0.4 ng/mL and 4.1 ± 0.3 ng/mL, respectively ($t = 7.88$, $p < 0.01$). These results align with findings by Thankachan *et al.* (2012) [24] and Della Lucia *et al.* (2017) [6], indicating that fortified rice significantly improved hemoglobin, vitamin B₁₂, and folic acid levels, thereby reducing anemia among BPL adolescents.

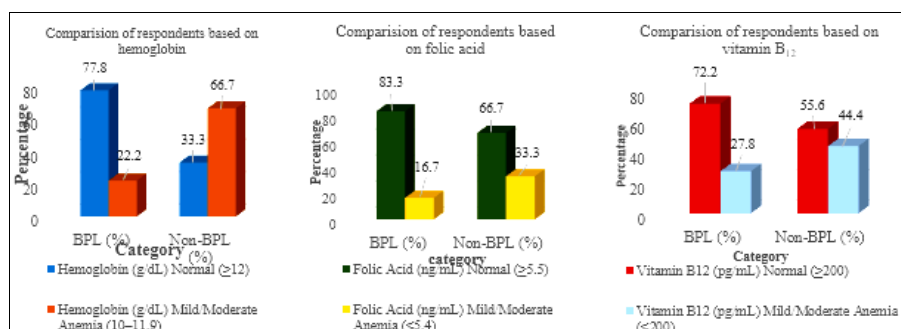


Fig 4: Biochemical profiles of respondents

3.4 Comparison of mean biochemical parameters between BPL and Non-BPL respondents

The comparison of mean biochemical parameters highlights a consistent difference between BPL and Non-BPL respondents.

For hemoglobin, the mean value among the BPL group was 12.9 ± 0.3 g/dL, which was significantly higher than the Non-BPL group (10.8 ± 0.4 g/dL). The t-value (6.12) confirmed a statistically significant difference, suggesting a greater prevalence of anemia in the Non-BPL group. In the case of vitamin B₁₂, BPL respondents recorded a mean of 422.3 ± 20.1 pg/mL compared to 220.3 ± 15.0 pg/mL in the

Non-BPL group. The observed difference was highly significant ($t = 9.45$), indicating a better vitamin B₁₂ status among the BPL respondents. For folic acid, the BPL group again showed a higher mean concentration (8.2 ± 0.4 ng/mL) compared to Non-BPL (4.1 ± 0.3 ng/mL). The difference was statistically significant ($t = 7.88$), reinforcing the relatively better folate profile in BPL respondents. The analysis shows that BPL individuals exhibited comparatively better mean biochemical profiles for hemoglobin, vitamin B₁₂, and folic acid than their Non-BPL counterparts, with all parameters showing statistically significant differences.

Table 3: Comparison of mean biochemical parameters

Parameters	Range / Class	Mean $\pm$ SD (BPL, n=18)	Mean $\pm$ SD (Non-BPL, n=9)	t-value
Hemoglobin (g/dL)	12.1-15.1	12.9 ± 0.3	10.8 ± 0.4	6.12*
Vitamin B ₁₂ (pg/mL)	180-914	422.3 ± 20.1	220.3 ± 15.0	9.45**
Folic Acid (ng/mL)	3.5-17	8.2 ± 0.4	4.1 ± 0.3	7.88**

*Significant at $p < 0.05$, **Significant at $p < 0.01$.

3.5 Hemoglobin levels of selected BPL adolescent girls before and after fortified rice consumption

This table presents the hemoglobin levels of 18 selected adolescent girls from BPL households before and after the introduction of fortified rice through the Public Distribution System (PDS). The before hemoglobin values for comparison were obtained from Primary Health Centre (PHC) Remuna, Balasore District (secondary health records-2023). The dataset was provided by Dr. Banaja Priyadarshini Biswal, Medical Officer (PHC Remuna, Balasore District Health Office,). These values reflected the

prevalence of mild/moderate anemia, with a mean hemoglobin concentration of 10.9 ± 0.4 g/dL. After two years of fortified rice consumption, the same girls were reassessed by collecting blood samples, and their hemoglobin levels showed a significant improvement, with a mean of 12.9 ± 0.3 g/dL. This indicates the positive effect of fortified rice in improving hemoglobin levels. The comparative analysis highlights that the majority of girls were in the mild anemia range (< 12 g/dL), after consumption of fortified rice, most of them had shifted into the normal range (≥ 12 g/dL).

Table 4: Hemoglobin levels of selected BPL adolescent girls before and after fortified rice consumption

Sample No.	Before (g/dL)	After (g/dL)
1	10.2	12.5
2	10.5	12.7
3	11.3	12.9
4	10.8	13.1
5	11.0	12.8
6	10.6	12.0
7	11.2	11.4
8	10.4	12.7
9	11.1	13.2
10	10.9	11.2
11	10.7	12.8
12	11.0	11.3
13	10.5	12.6
14	11.3	11.5
15	10.8	12.9
16	11.2	13.1
17	10.6	12.8
18	11.1	13.0
Mean $\pm$ SD	10.9 $\pm$ 0.4	12.9 $\pm$ 0.3

3.6 Clinical assessment

The clinical assessment showed that anemia-related symptoms were more frequent among Non-BPL girls than BPL girls. Fatigue and weakness were reported by 46.6% of Non-BPL compared to 13.3% of BPL, while pale skin (43.3% vs. 8.9%), shortness of breath (50% vs. 5.6%), dizziness and headaches were also higher in Non-BPL. Menstrual irregularities were notably more common in Non-BPL (43.3%) than BPL (14.4%). Overall, BPL girls showed fewer anemia symptoms, likely due to fortified rice improving hemoglobin and reducing anemia (Mahapatra *et al.*, 2021) [17].

Table 5: Frequency of anemia-related symptoms reported among respondents

Symptoms	Categories	BPL (n=90)		Non-BPL (n=30)		Total (N=120)	
		f	%	f	%	f	%
Fatigue & weakness	Never	78	86.7	16	53.3	94	78.3
	Occasionally	8	8.9	12	40.0	20	16.6
	Always	04	04.4	02	13.4	06	05.0
Pale skin	Never	82	91.1	17	56.7	99	82.5
	Occasionally	06	06.7	12	40.0	18	15.0
	Always	02	02.2	01	03.3	03	02.5
Shortness of breath	Never	85	94.4	15	50.0	100	83.3
	Occasionally	03	03.3	10	33.3	13	10.8
	Always	02	02.3	05	16.7	07	05.8
Menstrual irregularities	Never	72	80.0	25	83.3	97	80.8
	Occasionally	10	11.1	16	53.3	26	21.6
	Always	03	03.3	08	26.6	11	09.1
f =Frequency, % =Percentage							

3.7 Diet survey

The diet survey showed that while cereal intake was similar in both groups, Non-BPL girls had significantly higher consumption of pulses, milk/milk products, fruits, and fats/oils ($p < 0.05$), indicating better dietary diversity. Both groups, however, fell below the Recommended Dietary Allowances (RDA) for most nutrients. BPL participants had lower protein (41.2 g/day) and energy intake (2,115.4 kcal/day) compared to Non-BPL (44.6 g/day; 2,185.7 kcal/day). Micronutrient deficiencies were evident, with lower iron, calcium, vitamin A, vitamin C, and folic acid intake across both groups. BPL girls showed relatively better iron and vitamin B₁₂ levels, likely due to fortified rice through the Public Distribution System (PDS). These findings align with Putri *et al.* (2019) [21] and FAO (2017), emphasizing that fortified foods improve micronutrient intake but cannot fully address dietary inadequacy when overall diet diversity is low

Table 6: Gap analysis of nutrient intake vs RDA (%) of respondents

Nutrient (unit)	RDA	BPL (Mean $\pm$ SD)	%Gap (BPL)	Non-BPL (Mean $\pm$ SD)	%Gap (Non-BPL)	t-value
Energy (kcal/day)	2400	2115.4 $\pm$ 125.6	-11.90%	2085.7 $\pm$ 130.8	-13.10%	1.18 ^{NS}
Protein (g/day)	46	41.2 $\pm$ 3.5	-10.40%	44.6 $\pm$ 3.7	-3.00%	2.31*
Iron (mg/day)	30	25.2 $\pm$ 5.5	-16.00%	18.0 $\pm$ 5.8	-40.00%	2.45*
Calcium (mg/day)	1000	415.8 $\pm$ 55.7	-58.50%	305.3 $\pm$ 35.9	-69.50%	2.22*
Vitamin A (μ g/day)	800	325.6 $\pm$ 40.4	-59.40%	392.8 $\pm$ 48.2	-51.00%	2.10*
Vitamin C (mg/day)	65	28.2 $\pm$ 4.1	-56.60%	33.8 $\pm$ 4.5	-48.00%	2.55*
Folic Acid (μ g/day)	600	315.4 $\pm$ 22.6	-52.50%	240.7 $\pm$ 20.4	-60.00%	4.32**
Vitamin B12 (μ g/d)	2.4	2.5 $\pm$ 0.3	4.20%	1.6 $\pm$ 0.2	-33.30%	4.88**

Significance: ** $p < 0.01$; * $p < 0.05$; NS = not significant ($p \geq 0.05$)

4. Conclusion

The study concluded that fortified rice effectively improves hemoglobin, vitamin B₁₂, and folic acid levels while helping bridge nutritional gaps between socio-economic groups. Through systems like PDS, ICDS, and MDM, it ensures better micronutrient intake and nutritional security for adolescent girls, proving vital in reducing anemia and malnutrition.

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Future Recommendations

Expand fortified rice programs statewide, enhance nutrition education and awareness, promote dietary diversity and local food production, strengthen government-NGO collaboration, involve community leaders to build acceptance, conduct long-term impact studies, and develop evidence-based policies linking fortification with food security and women's empowerment.

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