Efficacy of biofortified rice variety CR Dhan 310 on the anthropometric and nutritional status of rural farm women of Shahdol district, Madhya Pradesh

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ABSTRACT

Rice is a major staple food in rural India, where its nutritional quality can directly influence household nutrition. The present study evaluated the effect of regular consumption of the biofortified, high-protein rice variety CR Dhan 310 on the nutritional intake and anthropometric status of rural farm women. A six-month randomized controlled trial was conducted among 120 farm women aged 20-45 years in Shahdol district, Madhya Pradesh. Participants were randomly divided into an experimental group (n = 60), consuming CR Dhan 310 and a control group (n = 60), consuming MTU 1010, with both groups consuming 350 g rice per day. Dietary protein, calcium and energy intake along with body weight, height and body mass index (BMI) were assessed at baseline and after six months. Consumption of CR Dhan 310 significantly increased daily protein intake from 23.80 to 36.05 g, representing a net increase of 12.25 g per day ($p < 0.01$), while calcium intake increased by 10.50 mg per day ($p < 0.01$). Energy intake showed no significant change. The experimental group also recorded greater improvements in body weight (+1.85 kg) and BMI (+0.65 kg/m²) compared with the control group, which recorded increases of 1.10 kg and 0.32 kg per m² respectively. The findings indicate that replacing conventional rice with CR Dhan 310 can improve protein and calcium intake and may contribute to better nutritional status among rural farm women. Promoting nutrient-rich rice varieties through agricultural extension and nutrition education could, therefore, support household nutritional security in rice-dependent communities.

Keywords: Biofortified rice; CR Dhan 310; Protein intake; Nutritional security; Farm women; Anthropometric status; BMI

INTRODUCTION

Rice (*Oryza sativa* and *Oryza glaberrima*) is one of the most widely consumed staple foods globally and serves as a major source of dietary energy for approximately 3.5 billion people, particularly in Asia, Africa and Latin America. Its adaptability to diverse climatic conditions, high production potential and culinary versatility make rice a fundamental crop for global food security (Mohidem et al 2022, Rezvi et al 2023). Asia accounts for nearly 90 per cent of global rice production and consumption, with rice providing up to three-fourths of the dietary calorie requirement of about 520 million people in the region (Priya et al 2019).

Rice holds particular importance in India, where it is a major staple food as well as an important source of livelihood for millions of small and marginal farmers. India produced 150.18 million tonnes of rice from an area of 51.27 million ha, with an average productivity of 2,929 kg per ha (Anon 2026). Rice has been cultivated in Asia for thousands of years and is deeply embedded in the region's culture, cuisine and agricultural systems. Its ability to grow under diverse soil and climatic conditions, together with its affordability, storability and ease of transportation, has contributed to its widespread adoption. Rice is also an important source of carbohydrates, protein, fibre, vitamins and minerals, thereby, contributing substantially to household food and nutritional security.

Notwithstanding its importance, rice exhibits nutritional deficiencies. Although it serves as an excellent energy source through carbohydrates, it is comparatively deficient in vital micronutrients, including iron, zinc and vitamin A (Mohidem et al 2022, Wasan et al 2022, Siregar et al 2024).

Millions of small farmers and resource-poor households depend on rice not only for their livelihood but also for household food security (Chaturvedi et al 2023, Nain et al 2019).

Despite the importance of rice in food security, nutritional insecurity and malnutrition remain major public health concerns, particularly among vulnerable populations. Protein-energy malnutrition (PEM) is a serious public health problem in India, particularly among preschool children below six years of age. Its consequences include impaired physical and cognitive development and increased susceptibility to infections, with the potential for long-term effects on health and well-being (Shekar et al 2005, Park 2015). More broadly, malnutrition continues to be one of the most persistent global public health challenges despite considerable progress in agriculture, healthcare and socioeconomic development (Basu et al 2025). Poverty and rising food prices restrict access to diverse and nutrient-rich diets, while climate change further aggravates food and nutritional insecurity by disrupting crop cycles, reducing agricultural productivity and increasing seasonal fluctuations in food availability (Swaminathan et al 2019).

In rice-dependent populations, improving the nutritional quality of rice can, therefore, provide an important opportunity to address nutrient deficiencies. Conventional approaches such as dietary supplementation and industrial fortification have achieved measurable improvements but often face challenges related to sustainability, affordability and accessibility, particularly among rural and low-income communities. Biofortification, which involves increasing the bioavailable concentration of essential nutrients in staple crops through agronomic practices, conventional breeding or modern biotechnological approaches such as genetic engineering and genome editing, offers a cost-effective and sustainable strategy for improving nutritional outcomes among populations with limited dietary diversity (Nayak et al 2022). Biofortification incorporates enhanced nutritional traits directly into crops during production, allowing the benefits to reach rural and resource-poor populations, including those with limited access to formal food distribution systems.

Evidence from different crops demonstrates the potential of biofortification to improve nutritional health. Zinc-enriched rice varieties developed in India and Bangladesh have been shown to improve plasma zinc levels in children, while iron-rich pearl millet has been associated with reduced anaemia prevalence among school-aged children in Maharashtra. Similarly, provitamin A-rich sweet potato has contributed to reductions in vitamin A deficiency in African countries (Barua 2024). These findings highlight the potential of nutrient-dense staple crops as sustainable tools for improving nutritional security.

In this context, the development of nutritionally superior rice varieties is particularly relevant for rice-dependent populations. Based on higher grain protein content (GPC) and protein yield observed during multilocational testing, the high-yielding line CR2829-PLN-37 (CR Dhan 310), developed in the genetic background of cv Naveen, was released at the national level by ICAR –National Rice Research Institute (NRRI), Cuttack, Odisha. The variety recorded an average grain protein content of 10.2 per cent in polished rice. Its combination of high grain yield and elevated protein content has considerable potential to contribute to improved nutrition among underprivileged populations that depend heavily on rice as a major component of their diet (Chattopadhyay et al 2019).

Among the commonly cultivated rice varieties in India, MTU 1010 is widely preferred because of its adaptability and high productivity. However, its grain protein content is considerably lower than that of CR Dhan 310. Although several agronomic studies have compared rice varieties in terms of yield performance and grain quality, evidence regarding the effect of consuming high-protein rice on the nutritional status of rural consumers under field conditions remains limited. Recent findings further support the nutritional advantage of CR Dhan 310. Priyadarshini et al (2025) reported that CR Dhan 310 recorded higher grain yield, greater tillering capacity, higher returns and a better benefit-cost ratio than CR Dhan 311 and the farmers' variety Lalat. The study also reported higher protein content in CR Dhan 310 compared with CR Dhan 311 and Lalat (Priyadarshini et al 2025).

Therefore, the present study was undertaken by KVK, Shahdol, Madhya Pradesh, to evaluate the

impact of six months of regular consumption of CR Dhan 310 on nutrient intake and anthropometric indicators among rural farm women. The study was designed to generate field-based evidence on the potential of high-protein rice as a dietary intervention for improving nutritional security and addressing protein-energy malnutrition among rice-dependent rural communities.

MATERIAL and METHODS

The present study was conducted as a randomized controlled trial over a period of six months in year 2022-25 to evaluate the effect of consuming the biofortified rice variety CR Dhan 310 on the nutritional and anthropometric status of rural farm women. A total of 120 farm women aged 20-45 years were selected from rural households and randomly assigned to two groups: an experimental group (n = 60) and a control group (n = 60). Women receiving medical treatment for chronic illnesses or consuming nutritional supplements during the study period were excluded.

Participants in the experimental group consumed the biofortified rice variety CR Dhan 310, while those in the control group consumed the commonly cultivated rice variety MTU 1010. Both groups consumed an equal daily rice intake of 350 g per day, which represents the average rice consumption in the study area. Participants were instructed to use only the assigned rice variety throughout the six-month study period.

All participants provided written informed consent prior to the study's initiation. The purpose of the study was explained to each participant and confidentiality of personal information was maintained throughout the study. All data were anonymized using unique identification codes before analysis.

Nutrient intake was estimated using standard Indian food composition tables based on the daily quantity of raw rice consumed. Daily intake of protein, calcium and energy was calculated for each participant.

Anthropometric measurements, including body weight, height and body mass index (BMI), were recorded at the beginning of the study (baseline) and after six months. Body weight was measured using a calibrated digital weighing scale, while height was measured using a standard stadiometer. Body mass index (BMI) was calculated using the formula:

$$BMI\ (kg/m^2) = Body\ weight\ (kg)/Height^2\ (m^2)$$

The collected data were analysed using appropriate statistical methods. A paired Student's t-test was used to compare baseline and post-intervention values within each group, while an independent Student's t-test was used to compare changes between the experimental and control groups.

Results are presented as mean ± standard error of the mean (SEM). The 95 per cent confidence interval (CI) was calculated for all major outcome variables. Differences were considered statistically significant at $p < 0.05$ and highly significant at $p < 0.01$.

RESULTS and DISCUSSION

Socioeconomic and demographic profile

The baseline demographic and socioeconomic characteristics of the 120 selected rural farm women are summarized in Table 1.

The study population comprised actively working agricultural women aged 20 to 45 years, with an overall mean age of 33.8 ± 5.0 years. Age distribution was well-balanced between the groups; the majority of participants fell into the 31-40 years age bracket (45.0%), followed by 20-30 years (35.0%) and 41-45 years (20.0%). No statistically significant difference in age was observed between the experimental and control groups ($p = 0.450$).

Educational attainment was modest across the sample size, with 25.0 per cent of the women being illiterate, 45.0 per cent having attained primary education and 30.0 per cent completing middle or high school.

Socioeconomic vulnerability was evident in landholding profiles and household income patterns. More than half of the participants (51.7%) belonged to marginal farming households (<1.0 ha of land), while 31.7 per cent were landless agricultural labourers reliant on seasonal wages. A substantial proportion of households (41.7%) earned a monthly income below Rs 5,000 and 45.0 per cent earned between Rs 5,000 and 10,000. Nuclear family

Table 1. Socioeconomic and demographic distribution of participants

Characteristic	Respondents (N = 120)			p-value
	Experimental group (CR Dhan 310) (n = 60)	Control group (MTU 1010) (n = 60)	Total (N = 120)	
Age (years) (Mean ± SD)	33.4 ± 5.2	34.1 ± 4.8	33.8 ± 5.0	0.450
Age (years)				0.781
20-30	22 (36.7%)	20 (33.3%)	42 (35.0%)	
31-40	26 (43.3%)	28 (46.7%)	54 (45.0%)	
41-45	12 (20.0%)	12 (20.0%)	24 (20.0%)	
Education level				0.895
Illiterate	14 (23.3%)	16 (26.7%)	30 (25.0%)	
Primary	28 (46.7%)	26 (43.3%)	54 (45.0%)	
Middle/high school	18 (30.0%)	18 (30.0%)	36 (30.0%)	
Landholding				0.690
Landless agricultural labour	18 (30.0%)	20 (33.3%)	38 (31.7%)	
Marginal (<1.0 ha)	32 (53.3%)	30 (50.0%)	62 (51.7%)	
Small (1.0-2.0 ha)	10 (16.7%)	10 (16.7%)	20 (16.7%)	
Monthly household income (Rs)				0.522
<5,000	24 (40.0%)	26 (43.3%)	50 (41.7%)	
5,000-10,000	28 (46.7%)	26 (43.3%)	54 (45.0%)	
>10,000	8 (13.3%)	8 (13.3%)	16 (13.3%)	
Family type				0.852
Nuclear	38 (63.3%)	36 (60.0%)	74 (61.7%)	
Joint	22 (36.7%)	24 (40.0%)	46 (38.3%)	
Baseline dietary habit				1.000
Daily rice intake (350 g/day)	60 (100.0%)	60 (100.0%)	120 (100.0%)	

p-values calculated using independent student's t-test for continuous variables (age) and chi-square test for categorical variables; All p-values >0.05 indicate that baseline differences between the two groups are not statistically significant, ensuring ideal conditions for a randomized controlled trial; Daily rice intake fixed as per inclusion criteria and regional dietary averages

structures predominated (61.7%) over joint families (38.3%).

Crucially, statistical analysis revealed no significant differences ($p > 0.05$) between the experimental and control groups across any evaluated demographic, educational or economic parameters. This absolute homogeneity at baseline demonstrates successful randomization, establishing an ideal foundation to isolate the nutritional impacts of the dietary intervention.

Dietary nutrient intake

The effects of six months of consumption of the biofortified rice variety CR Dhan 310 on nutrient intake and anthropometric characteristics are presented in Table 2. Baseline values for both the experimental and control groups were comparable, allowing a direct assessment of changes following the dietary intervention.

The experimental group showed a significant improvement in dietary protein intake after six months. Mean protein intake increased from 23.80 ± 0.23 at baseline to 36.05 ± 0.27 g per day, resulting in a net increase of 12.25 g per day ($p < 0.01$). In contrast, no change in protein intake was observed in the control group consuming MTU 1010 rice.

Similarly, calcium intake increased significantly in the experimental group from 35.00 ± 0.41 to 45.50 ± 0.50 mg per day, representing a mean increase of 10.50 mg/day ($p < 0.01$). No significant change was recorded in the control group. Daily energy intake remained almost unchanged in both groups. Although the experimental group showed a small increase of 7 kcal

Table 2. Nutrient intake and anthropometric measurements of respondents (initial and after six months of intervention)

Parameter	Respondents (n = 60)	Baseline (initial) (Mean ± SEM)	After six months (Mean ± SEM)	Net mean change	95% confidence interval (CI)	Intra-group paired t-test
Dietary Protein (g/capita/ day)	Control (MTU 1010)	23.80 ± 0.23	23.80 ± 0.23	0.00	0.00, 0.00	t = 0.000, p >0.05 (NS)
	Experimental (CR Dhan 310)	23.80 ± 0.23	36.05 ± 0.27	+12.25	11.72, 12.78	t = 45.361, p <0.01 (HS)
Dietary calcium (mg/capita/ day)	Control (MTU 1010)	35.00 ± 0.41	35.00 ± 0.41	0.00	0.00, 0.00	t = 0.000, p >0.05 (NS)
	Experimental (CR Dhan 310)	35.00 ± 0.41	45.50 ± 0.50	+10.50	9.52, 11.48	t = 21.002, p <0.01 (HS)
Gross calories (kcal/capita /day)	Control (MTU 1010)	1218.00 ± 5.81	1218.00 ± 5.81	0.00	0.00, 0.00	t = 0.000, p >0.05 (NS)
	Experimental (CR Dhan 310)	1218.00 ± 5.81	1225.00 ± 5.16	+7.00	–7.21, 21.21	t = 0.985, p >0.05 (NS)

Values are presented as Mean ± SEM, NS = Not significant (p >0.05), S = Significant (p >0.05), HS = Highly significant (p >0.01), Dietary nutrient values calculated based on a daily rice intake of 350 g per participant

per day, the difference was not statistically significant (p >0.05).

In the present study, both farm women groups consumed the same quantity of rice (350 g/day), allowing the nutritional effects of the two rice varieties to be compared without differences in food intake.

Daily energy intake remained almost unchanged between the two groups, indicating that the observed improvements in nutritional status were not due to higher calorie consumption but to the improved nutritional composition of biofortified rice.

The experimental group showed a significant increase in dietary protein intake (+12.25 g/day; p <0.01) after consuming CR Dhan 310 for six months. This improvement can be attributed to the higher grain protein content of CR Dhan 310 compared with the conventional variety MTU 1010. Previous studies have also reported that CR Dhan 310 retains higher protein content after milling than many commonly cultivated rice varieties (Das et al 2023). In addition, the variety is rich in threonine and lysine (Anon 2015).

Calcium intake also increased significantly in the experimental group (+10.50 mg/day; p <0.01). Although rice is not a good source of calcium (Silva et al 2022), the increase suggests that the improved nutritional profile of CR Dhan 310 contributed to a higher intake of essential nutrients.

Anthropometric measurements

Both groups showed improvements in anthropometric measurements during the study period, however, the magnitude of improvement was greater in the experimental group (Tables 3, 4).

Body weight increased significantly in both the groups after six months. The control group showed an average increase of 1.10 kg, whereas, the experimental group recorded a significantly higher increase of 1.85 kg (p <0.01).

A small but statistically significant increase in height was observed in both the groups. The experimental group showed a mean increase of 0.98 cm compared with 0.85 cm in the control group (p <0.05).

Body mass index (BMI) also improved in both the groups. The increase was greater in the experimental group (0.65 kg/m^2) than in the control group (0.32 kg/m^2). The improvement in BMI among participants consuming CR Dhan 310 was highly significant (p <0.01).

Table 3. Anthropometric measurements of respondents (before and after six months of intervention)

Parameter	Respondents (n = 60)	Baseline (initial) (Mean ± SEM)	After six months (Mean ± SEM)	Net mean change	95% confidence interval (CI)	Intra-group paired t-test
Body weight (kg)	Control (MTU 1010)	48.20 ± 0.58	49.30 ± 0.56	+1.10	0.98, 1.22	t = 18.331, p <0.05 (S)
	Experimental (CR Dhan 310)	48.10 ± 0.59	49.95 ± 0.57	+1.85	1.71, 1.99	t = 27.205, p <0.01 (HS)
Body height (cm)	Control (MTU 1010)	158.40 ± 0.80	159.25 ± 0.79	+0.85	0.77, 0.93	t = 21.941, p <0.05 (S)
	Experimental (CR Dhan 310)	158.50 ± 0.79	159.48 ± 0.78	+0.98	0.89, 1.07	t = 21.674, p <0.05 (S)
Body mass index (kg/m^2)	Control (MTU 1010)	19.21 ± 0.15	19.53 ± 0.14	+0.32	0.29, 0.35	t = 20.652, p <0.05 (S)
	Experimental (CR Dhan 310)	19.17 ± 0.15	19.82 ± 0.14	+0.65	0.60, 0.70	t = 27.951, p <0.01 (HS)

Values presented as Mean ± SEM, NS = Not Significant (p >0.05), S = Significant (p >0.05), HS = Highly significant (p >0.01)

Table 4. Inter-group cross-sectional analysis of net growth (after six months of intervention)

Growth delta metric (after minus initial)	Control group (MTU 1010) (Mean Delta ± SEM)	Experimental group (CR Dhan 310) (Mean Delta ± SEM)	Net group difference	Independent t-value	Cross-cohort significance
Net structural weight gain (kg)	1.10 ± 0.06	1.85 ± 0.07	+0.75	8.441	p <0.01 (HS)
Net skeletal height extension (cm)	0.85 ± 0.04	0.98 ± 0.05	+0.13	2.183	p <0.05 (S)
Net body mass index shift (kg/m^2)	0.32 ± 0.02	0.65 ± 0.02	+0.33	11.752	p <0.01 (HS)

S = Significant (p >0.05), HS = Highly significant (p >0.01)

The improvement in nutrient intake was accompanied by favourable changes in anthropometric measurements. Participants consuming CR Dhan 310 gained an average of 1.85 kg in body weight, compared with 1.10 kg in the control group. The greater weight gain observed in the experimental group is likely associated with improved protein intake, which supports normal tissue growth and maintenance. Similar improvements in nutritional status following the consumption of protein-rich staple foods have been reported in previous studies (Bouis and Saltzman 2017).

Body mass index (BMI) also improved significantly in the experimental group, with a mean increase of 0.65 kg per m^2 compared with 0.32 kg per m^2 in the control group. This finding suggests that regular consumption of biofortified rice may contribute to improved nutritional status among rural women, particularly in populations where rice is the major staple food.

A small but statistically significant increase in height was observed in both groups. However, the difference between the experimental and control groups was relatively small (0.13 cm). Since changes in adult height occur slowly, particularly among women aged 20-45 years, the modest increase observed over six months was expected.

The results indicate that regular consumption of CR Dhan 310 for six months improved dietary protein and calcium intake and produced greater gains in body weight and BMI than consumption of the conventional rice variety MTU 1010. Overall, the findings of the

present study indicate that replacing conventional rice with the biofortified variety CR Dhan 310 improved dietary protein intake and was associated with better anthropometric outcomes. These results support earlier reports that biofortified staple crops can contribute to improved nutritional security and may help reduce protein-energy malnutrition in rice-dependent populations.

Nutritional implications

In addition to its higher protein content, CR Dhan 310 contains approximately 15 ppm zinc (Jaiswal 2017), an essential micronutrient involved in immune function, cell growth and tissue repair. Regular consumption of zinc-rich foods may help reduce micronutrient deficiencies that are common in rice-dependent populations. The combined availability of higher-quality protein and zinc in CR Dhan 310 may, therefore, contribute to improved nutritional status and overall health, although additional clinical studies are needed to evaluate its long-term effects on immune function.

Implications for agricultural extension

Agricultural extension can play an important role in promoting CR Dhan 310 through frontline demonstrations, timely availability of quality seed and nutrition education highlighting the benefits of biofortified rice and balanced diets.

Extension programmes should encourage farm women to retain part of the produce for household consumption and strengthen linkages among research institutions, seed agencies and village seed banks. Integration of biofortified rice into suitable government food and nutrition programmes could further support its wider adoption and contribute to improved household nutritional security.

CONCLUSION

The study demonstrates the nutritional potential of CR Dhan 310 as a high-protein biofortified rice variety for rural farm women. Regular consumption of CR Dhan 310 for six months resulted in a significant improvement in dietary protein and calcium intake and was accompanied by greater increases in body weight and BMI than consumption of MTU 1010. The improvement in protein intake is particularly important for rural women who depend heavily on rice as a staple food and may have limited access to diverse protein-rich foods.

The findings suggest that improving the nutritional quality of a commonly consumed staple can be a practical way of addressing nutritional insecurity without requiring major changes in eating habits. Wider promotion of CR Dhan 310, supported by agricultural extension, quality seed availability and nutrition education, could help strengthen household nutrition and contribute to reducing protein-energy malnutrition in rice-dependent communities. However, longer-term studies involving a wider range of nutritional and health indicators are needed to establish its sustained effects on nutritional status.

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