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Comparative study of physical and nutritional characteristics of rice and barnyard millet: Assessing barnyard millet as an alternative to rice

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Abstract
The objective of the present research is to investigate the viability of replacing rice with barnyard millet in traditional recipes by evaluating the physical, nutritional, and sensory characteristics of rice and barnyard millet. The physical research indicated that rice seeds had a much greater weight and size in comparison to barnyard millet, resulting in differences in their water absorption and cooking durations. From a nutritional standpoint, barnyard millet surpasses rice by having greater protein content (7.58% compared to 7.01%), lipid content (2.70% compared to 0.68%), fiber content (4.16% compared to 0.90%), and ash content (3.55% compared to 0.65%). Furthermore, it possesses a reduced amount of carbohydrates and readily available carbohydrates, which could potentially lead to a decreased glycemic index, therefore particularly advantageous for persons diagnosed with type 2 diabetes. Comparative sensory assessments of conventional jaula recipes made with rice and barnyard millet revealed no notable variations in terms of visual appeal, hue, taste, mouthfeel, consistency, general acceptance, and lingering taste. Both varieties of jaula were similarly deemed satisfactory by taste testers. The results indicate that barnyard millet, due to its better nutritional composition and comparable sensory qualities, is a feasible substitute for rice in conventional cuisine, perhaps providing health advantages and improving food security.

Keywords: Rice, barnyard millet, climate resilient crop, nutritional properties, physical properties

Introduction
The green revolution (1960–2000) was a huge success, increasing global food production significantly and nearly tripling the yield of staple crops. More than half of the world's population relies on rice (*Oryza sativa*) as their primary source of nutrition. More than 100 nations cultivate rice, with Asia contributing 90 percent of the global output and 40 percent of daily calories. (Fukagawa and Ziska, 2019) [7] Rigorous knowledge of crop water needs is crucial for rice cultivation. Rice is the primary agricultural product and is cultivated mostly during the rainy season, basically because of its substantial water demands. On average, rice yields are rather good, ranging from 4 to 5 tons per hectare, but they vary significantly among farmers. In addition, salt-stress, water shortage, and inadequate fertilizer management further exacerbate this delicate scenario. (Djaman *et al.* 2016) [4] Global change in climate trends indicates escalating temperatures, modified precipitation patterns, and a growing frequency of extreme events, all of which have an adverse impact on water resources worldwide. (Etukudoh *et al.* 2024) [5]

Along with rice being a crop with high water requirements falls under high Glycemic index (GI) food. The glycemic index (GI) categorizes the sources of carbohydrates (CHOs) based on the effect they have on postprandial blood sugar levels (Nayar and Madhu 2020) [12]. High-glycemic index (high-GI) foods, referred to as fast carbohydrates, have been shown to promote fat accumulation and raise the probability of obesity, thereby contributing to the development of diabetes and heart problems (Gaesser *et al.* 2021) [8]. Hence, there exists a need for an alternative to rice.

Barnyard millet, scientifically known as Echinochloa species, is a long-standing millet crop planted in warm and temperate locations worldwide. Asia, specifically India, China, Japan, and Korea, is the primary farming region for this crop.

It ranks as the fourth-most-produced minor millet, ensuring food security for numerous impoverished individuals worldwide. The classification of Echinochloa consists of two primary species, *Echinochloa esculenta* and *Echinochloa frumentacea*, largely produced for human consumption and cattle feed. Within the wide variety of cultivated and wild barnyard millet species, *Echinochloa frumentacea* (Indian barnyard millet) and *Echinochloa esculenta* (Japanese barnyard millet) stand out as two particular preferences. Contrary to rice, which is commonly cultivated on fertile soils, crops such as barnyard millet are grown in impoverished marginal areas with little attention given to their cultivation. Chronic climatic variations and adverse environmental conditions hinder the successful reproduction and survival of plants. Therefore, plants that can adapt to these obstacles might play a crucial role in ensuring food security. The Echinochloa species often exhibits inherent tolerance to a wide range of biotic and abiotic stressors (Padulosi *et al.* 2015) [13]

Although barnyard millet has proven to be highly nutritious and economically valuable, its limited recognition has resulted in its being regarded as a neglected and underutilized crop. Compared to other minor millets, research on the characteristics of barnyard millet in recent decades has been somewhat limited (Murukarthick *et al.* 2019) [11]. Regular use of barnyard millet meal is associated with a reduced glycemic index (GI) in population with type 2 diabetes. Available data indicated that the protein level (11.2–12.7%) in barnyard millet was comparatively greater than that of other prominent grains and millets.

The objective of this study is to collect comparable information on the physical and nutritional characteristics of rice and barnyard millet and to verify the suitability of substituting barnyard millet for rice in a conventional recipe.

2. Materials and Methods

The arrangement of apparatus for handling, harvesting, processing, and conserving the grain is influenced by the chemical and physical characteristics of millet, as well as those of other grains and seeds. The cooling and heating of food products, as well as the properties of solid items transported by air or water, are all influenced by these factors.

2.1 Physical properties

1000 kernel weight, 1000 kernel volume, Soaking capacity, Soaking index, Hydration capacity, and Hydration index were determined by following the method given by Williams *et al*., 1983 [18]. For estimation of the cooking time method as described by Batcher *et al*., 1956 [19] was utilized.

2.2 Proximate composition

Proximate composition consisting of moisture percent, crude fat, crude fiber, crude protein, and ash content was estimated using the standard method as given by AOAC, 2000 [3]. The total carbohydrate content was determined by subtracting 100 from the combined dry matter-based estimates of total ash, crude protein, crude fiber, and crude fats. The resulting value was then expressed as grams per 100 grams of the sample. The available carbohydrates were determined using the FAO 2003 [6] method, which involves subtracting the sum of total crude fat, crude protein, ash, and total dietary fiber from 100. The sample's physiological calorific value (Kcal/100 g) was determined by multiplying the percentages of protein, fat, and available carbohydrates by 4, 9, and 4, respectively followed by their addition (Mudambi and Rao, 1989) [10].

2.3 Formulation of traditional Bhatt ka *Jaula*

The method of preparation of the traditional *jaula* recipe was used as given by Agnihotri *et al.*, 2021 [20] with modification. Where the addition of millets was excluded from the original preparation. Two products one in tradational manner and another where rice was completely replaced with barnyard millet was used.

2.4 Sensory evaluation

Both the *jaula* were evaluated for sensory characteristics using sensory score card method (Amerine *et al*., 1965) [2]. Sensory evaluation was done by 30 semi-trained panel members.

2.5 Statistical evaluation

The data reported in the tables are averages with standard deviation of triplicate observations. The data were subjected to statistical analysis using WASP 2.0 software developed by ICAR-CCARI.

3. Result and Discussion

Physical properties of rice and barnyard millet

There are notable variations in the physical and functional properties of barnyard millet and rice when different metrics are compared.

Rice has a 1000 seed weight of 27.17 grams. On the other hand, the 1000 seed weight of barnyard millet is significantly lower at 4.60 grams, suggesting that the seeds from rice are significantly heavier than those of barnyard millet. Barnyard millet seeds have a significantly lesser volume of 4.00 ml, while rice seeds take up 21.00 ml in terms of volume. This implies that compared to barnyard millet seeds, rice seeds are bigger and take up more space. The weight of the rice increases to 41.80 grams after it has been soaked, showing that it absorbs a significant amount of water. In contrast, after being soaked, barnyard millet weighed 5.49 grams ± 0.17 grams, indicating a lesser weight increase and maybe less water absorption than rice. There is a difference in the soaking volume of barnyard millet (5.87 ml) and rice (22.16 ml). This provides more evidence for the finding that rice expands and absorbs more water than barnyard millet. Rice has a slightly higher seed density (1.25 g/ml) than barnyard millet (1.15 g/ml). This suggests that the denser rice seeds are compared to those of barnyard millet. In terms of swelling capacity, rice exhibits a capacity of 1.15 grams, whereas the capacity of barnyard millet is greater at 1.87 grams. This indicates that when moistened, barnyard millet expands more than rice does. There is a noticeable difference in the swelling index between the two grains. While barnyard millet shows a far higher swelling index of 46.83, indicating a lot bigger expansion following hydration, rice shows a modest swelling value of 5.47. Rice has a hydration capacity of 15.63 ml, which indicates that it can absorb water. In contrast, the hydration capacity of barnyard millet is much lower at 0.89 ml, indicating a significant reduction in water absorption. Rice has a hydration value of 59.72, which is significantly greater than barnyard millet's hydration index of 19.32. This shows that rice can absorb and hold onto water better than barnyard millet. Rice takes less time to cook than barnyard millet—it takes 14.28 minutes ± 0.29 minutes—after heating for 12.41 minutes ± 0.27 minutes. This suggests that rice cooks more quickly than millet from a barnyard. Raghuvanshi *et al.* 2017 [14] and Reddy *et al.* 2019 [15] showed similar findings in their research.

Table 1: Physical properties of rice (milled) and barnyard millet (milled)

S. No	Parameter	Rice	Barnyard Millet
1	1000 Seed weight (g)	27.17 ± 0.17	4.60 ± 0.20
2	Volume (ml)	21.00 ± 0.01	4.00 ± 0.01
3	Soaked weight (g)	41.80 ± 0.26	5.49 ± 0.17
4	Soaked volume (ml)	22.16 ± 0.04	5.87 ± 0.06
5	Seed Density (g/ml)	1.25 ± 0.05	1.15 ± 0.05
6	Swelling Capacity (g)	1.15 ± 0.04	1.87 ± 0.06
7	Swelling Index	5.47 ± 0.45	46.83 ± 1.46
8	Hydration capacity (ml)	15.63 ± 0.48	0.89 ± 0.06
9	Hydration Index	59.72 ± 2.45	19.32 ± 0.06
10	Cooking time (min)	12.41 ± 0.27	14.28 ± 0.29

Values are means of three replications ± SD

Nutritional properties of rice and barnyard millet

The moisture content of rice is 11.78%, suggesting that a substantial proportion of rice's weight is attributed to water. In contrast, the moisture content of barnyard millet is 10.27%. The somewhat reduced moisture content indicates that barnyard millet is drier than rice, potentially impacting its storage and processing properties. The crude protein composition of rice is precisely 7.01%. This protein amount is somewhat below the mean crude protein content of barnyard millet, which is 7.58%. The greater protein content in barnyard millet renders it a more protein-dense alternative in comparison to rice, hence potentially advantageous for dietary requirements centered on protein consumption. The crude fat percentage of rice is 0.68%, but barnyard millet presents a crude fat content of 2.70%. The elevated fat content of barnyard millet suggests a greater presence of oil and fat in comparison to rice. This may give rise to a larger caloric density, therefore influencing its nutritional composition and culinary characteristics. With a crude fiber content of 0.90%, rice is comparatively low. By contrast, barnyard millet has a far greater crude fiber content of 4.16%. The aforementioned observation suggests that barnyard millet has a higher content of dietary fiber, facilitating digestion and promoting general gastrointestinal well-being. Higher fiber intake is correlated with increased satiety and may be advantageous for weight control. Total Ash: The overall ash content, which indicates the mineral content remaining after combustion, is 0.65% for rice and notably higher at 3.55% for barnyard millet. The elevated ash level in barnyard millet indicates a higher concentration of minerals, which may enhance its overall nutritional value by potentially supplying more vital elements such as calcium, iron, and magnesium.

Carbohydrate Analysis: Rice has a relative total carbohydrate content of 91.66%, suggesting that a significant proportion of rice's mass consists of carbs. Based on its reduced carbohydrate content of 86.17%, barnyard millet has a somewhat distinct carbohydrate profile that may impact its glycemic index and energy release. The accessible carbohydrate content of rice is 88.87%, indicating the proportion of carbs that can be metabolized and utilized by the body. Barnyard millet has a reduced available carbohydrate content of 77.08%, indicating that a smaller proportion of its carbohydrate content is easily accessible for energy intake. This could affect the relative glycemic effect and energy production of barnyard millet in comparison to rice. In terms of physiological energy, both rice and barnyard millet offer quite comparable quantities. The caloric content of rice is 401 kcal per 100 grams, whereas barnyard millet contains 399 kcal per 100 grams. The slight variation in energy content implies that both grains provide similar quantities of energy, so qualifying either as a viable source of calories in a well-rounded diet. Values for proximate composition were found similar to that reported by Verma and Srivastav (2017) [17] and Lohani *et al.* (2014) [9].

Table 2: Proximate composition and carbohydrate profile of rice (milled) and barnyard millet (milled)

S. No	Components	Rice	Barnyard Millet
1	Moisture (%)	11.78 ± 0.09	10.27 ± 0.18
2	Crude protein (%)	7.01 ± 0.22	7.58 ± 0.26
3	Crude fat (%)	0.68 ± 0.04	2.70 ± 0.28
4	Crude fiber (%)	0.90 ± 0.01	4.16 ± 0.15
5	Total ash (%)	0.65 ± 0.06	3.55 ± 0.25
6	Carbohydrate profile		
	Total CHO by difference (%)	91.66 ± 0.13	86.17 ± 0.20
	Available carbohydrate (%)	88.87 ± 0.32	77.08 ± 0.52
	Physiological energy (Kcal)	401 ± 0	399 ± 2

Values are means of three replications ± SD on a dry weight basis
N:P conversion factor - 5.95 for rice, 5.71 for black soybean, and 6.25 for barnyard millet

Sensory evaluation of rice and barnyard millet incorporated *jaula*

Table 3 presents a full comparison of sensory qualities between rice jaula and barnyard millet jaula. The sensory parameters assessed include appearance, color, flavor, taste, texture, overall acceptability, and aftertaste.

An analysis of the sensory qualities of rice *jaula* and barnyard millet *jaula* reveals that *jaula* from both grains exhibit statistical similarity in all evaluated aspects. The ratings for visual features and color were similar, with no notable disparities noted, suggesting that their visual appeal is similarly satisfactory. No significant variations were seen in the flavor and taste profiles of the two grains, indicating that both products are similarly agreeable in terms of taste. Furthermore, the texture ratings for both rice *jaula* and barnyard millet *jaula* were identical, suggesting that the mouthfeel is considered to be similar for both types of grains. Both *jaula* had the same overall acceptability ratings, indicating that neither grain was favoured above the other in terms of overall acceptance. Furthermore, the aftertaste was evaluated equally for both *jaula*, without any notable preference observed for one variety over the other. These findings indicate that the lingering flavor after eating does not show preference for either product.

In summary, the thorough examination indicates that rice *jaula* and barnyard millet *jaula* exhibit similarities in terms of their visual attractiveness, color, taste, texture, general acceptability, and aftertaste. At a significance level of 5%, the data indicate no statistically significant differences. Accordingly, both *jaula* are equally acceptable considering these sensory characteristics, emphasizing their same quality across the assessed aspects.

Table 3: Mean scores (score ranging from 1 -Dislike extremely to 10 -Like extremely) of sensory attributes for rice and barnyard millet *jaula*

Parameters	Rice *jaula*	Barnyard millet *jaula*	Significance at 5%
Appearance	7.83 ±1.06	7.92 ±0.89	NS
Color	7.85 ±0.99	7.85 ±0.98	NS
Flavour	7.83 ±0.99	7.53 ±0.98	NS
Taste	7.92 ±1.11	7.65 ±0.91	NS
Texture	8.05 ±1.07	7.90 ±1.16	NS
Overall Acceptability	8.20 ±1.08	7.90 ±0.94	NS
After Taste	9.50 ±0.68	9.50 ±0.57	NS

Values are mean ± SD of thirty replications
Mean values with different alphabetical superscripts within the same row differ significantly ($p<0.05$).

4. Conclusion
The present work aims to evaluate the possible interchangeability of rice and barnyard millet by comparing their physical, nutritional, and sensory criteria. Physically, rice has a much greater weight, volume, and soaking capacity per 1000 seeds than barnyard millet. Consequently, rice has a higher water absorption capacity and cooks at a faster rate (12.41 minutes) compared to barnyard millet (14.28 minutes), Therefore impacting its culinary attributes.

Barnyard millet has higher nutritional value than rice, particularly in terms of protein, fat, and fiber content. It has 7.58% protein, 2.70% fat, and 4.16% fiber, compared to rice's 7.01%, 0.68%, and 0.90%, respectively. Barnyard millet's higher nutritional density contributes to its potential benefits for promoting satiety and managing weight. The lower carbohydrate and accessible carbohydrate content of this food indicates a lower glycemic index, which could contribute to improved regulation of blood sugar levels.

Comparative sensory assessments reveal that rice and barnyard millet, which are used in traditional jaula recipes, exhibit similar characteristics in terms of appearance, color, flavor, taste, texture, general acceptability, and aftertaste. Empirical investigation reveals no statistically significant disparities, suggesting comparable sensory acceptance.

Therefore, although barnyard millet has significant nutritional benefits and comparable sensory characteristics to rice, it provides a feasible and nutritious substitute. The present study emphasizes the potential of barnyard millet as a sustainable alternative to rice in many gastronomic settings.

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