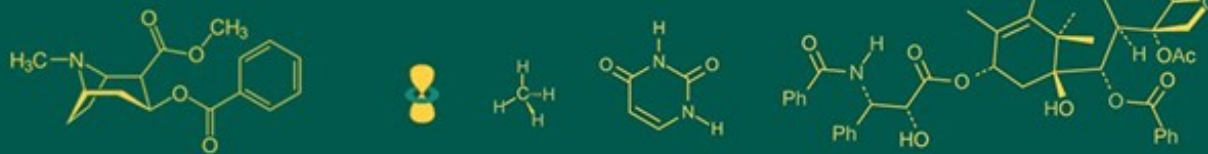


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Effect of pretreatment on the physical and chemical properties of rice, sorghum, green gram and ragi

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ABSTRACT

The present study evaluated the effect of pretreatment on the physical and chemical composition of two rice varieties (IRRI 125 and Kshatriya), green gram, sorghum and ragi, selected for their complementary functional properties and nutritional composition as gluten-free source of carbohydrates, protein, dietary fibre and minerals. Multigrain products can provide a balanced nutritional profile. Rice, sorghum and ragi were subjected to soaking, steaming and drying, while green gram was soaked, sprouted and dried to improve their cooking, rehydration and processing characteristics and their suitability for use in the development of value-added instant or ready to cook gluten-free food products. Porosity of the grains increased from $32.83 \pm 2.04\%$ (jowar) - $39.56 \pm 0.16\%$ (Kshatriya) to $40.47 \pm 0.44\%$ (jowar) - $58.27 \pm 2.62\%$ (IRRI 125) whereas length, breadth, thousand-kernel weight and volume, bulk density and true density decreased as a result of pretreatment. Protein and crude fibre increased in some pretreated samples, with protein increased from $7.24 \pm 0.11\%$ (Kshatriya) - $22.7 \pm 1.30\%$ (green gram) to $7.55 \pm 0.10\%$ (kshatriya) - $25.34 \pm 1.73\%$ (green gram) and crude fibre from $0.26 \pm 0.01\%$ (kshatriya) - $4.12 \pm 0.01\%$ (green gram) to $0.24 \pm 0.01\%$ (kshatriya) - $4.21 \pm 0.14\%$ (green gram). Among the taken samples the highest ash, protein and crude fiber content was found in green gram before and after the pretreatment ranging from $3.73 \pm 0.01\%$ - $3.50 \pm 0.12\%$, $22.7 \pm 1.30\%$ - $25.34 \pm 1.73\%$ and $4.12 \pm 0.01\%$ - $4.21 \pm 0.14\%$ respectively. Obtained results showed that rice variety kshatriya had the highest carbohydrate content among the selected samples both before ($83.06 \pm 0.17\%$) and after ($85.75 \pm 0.35\%$) pre-treatment. These changes improve cooking, grinding, water absorption and rehydration characteristics, thereby enhancing the suitability of the grains for development of nutritious, gluten-free and convenient food products.

Keywords: Rice varieties (IRRI 125 and Kshatriya), Green gram, Sorghum, Ragi, Pre-treatment, Physical properties, Chemical composition

1. Introduction

Cereals, pulses and millets are important sources of energy, protein, dietary fibre, vitamins and minerals, making them valuable ingredients for the development of nutritious food products. Rice (*Oryza sativa* L.), sorghum (*Sorghum bicolor* L.), green gram (*Vigna radiata* L.) and finger millet or ragi (*Eleusine coracana* L.) were selected for their complementary nutritional properties. Rice, a staple gluten-free carbohydrate, provides ~21% of global energy (Kennedy *et al.*, 2003) [1], Jowar (*Sorghum bicolor*) contains about 75% carbohydrates, 10% protein and is a good source of fiber, iron, zinc and phenolic compounds, providing approximately 356 kcal per 100 g (Gopalan *et al.*, 1996) [2], Green gram (*Vigna radiata*) or mung bean, is a nutrient-dense legume rich in digestible protein (20 – 24%), fiber, vitamins, minerals and antioxidants (Gujral *et al.*, 2013) [3] and finger millet contains higher levels of dietary fibre, minerals, vitamins and calcium (344 mg/100 g) than most cereals (Verma *et al.*, 2013) [4].

Pretreatment methods such as soaking, steaming, germination and drying are commonly employed to modify the physical and chemical composition of food grains before further processing. Soaking and germination can activate endogenous enzymes, reduce antinutritional factors and influence nutrient availability, whereas steaming may cause starch gelatinisation and changes in protein structure. Drying reduces moisture content and helps prepare grains for subsequent milling and product development. The extent of these changes depends on the type of grain and the processing conditions applied (Mandge *et al.*, 2014) [5].

The efficient and proper design of various separating, handling and drying equipment requires an understanding of physical characteristics such as size, shape, mass, volume, thousand grain weight, bulk density, true density and porosity (Pandiselvam *et al.*, 2015) [6]. This gives the information about the grain behaviour during handling, processing and size reduction operations that are involved in the development of value-added food products. The present study was undertaken to evaluate the effect of pretreatment on the physical

properties and chemical composition of rice, sorghum, green gram and finger millet, providing information useful for selecting and processing ingredients for the development of value-added food products.

2. Materials and Methods

2.1 Materials

Rice varieties (IRRI 125 and Kshatriya) were procured from JNKVV, Jabalpur. jowar, green gram and ragi were purchased from the local market of Jabalpur, Madhya Pradesh. Chemicals of analytical grade and glassware used during study was available in the Department of Food Science and Technology at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, utilized three replicates for each sample analysis, following detailed methods outlined in the subsequent sections.

2.2 Methods

2.2.1 Pre treatment

The cleaned rice, sorghum, ragi and green gram were soaked in water at a 1:2 (w/v) grain-to-water ratio. Rice was soaked for 30 min, while sorghum, ragi and green gram were soaked overnight (for 12 h) at $25 \pm 1^\circ\text{C}$. The soaked rice and sorghum were steamed for 20 min at $100 \pm 1^\circ\text{C}$, whereas green gram was sprouted for 24 h. Then the samples were spread in steel trays ($80 \times 40 \times 3$ cm) in about 2.5 cm bed thickness and dried at 70°C for about 3 hours to approximately 5-6% moisture content and stored in airtight containers until further analysis.

Grains were analysed for length, breadth, 1000-kernel weight, 1000 kernel volume, bulk density, true density, porosity and chemical components (protein, fat, ash, moisture, crude fibre) were determined using AOAC 2012 [7] methods. Every calculation was made in triplicate, and the average value was used to present the findings.

2.2.2 Physical properties

2.2.2.1 Length and breadth

Three randomly chosen grains from each sample were measured for length and width in this study using a vernier calliper for accuracy.

2.2.2.2 1000 kernel weight

1000 randomly chosen grains were counted and weighed on an electronic weighing balance with a 0.001 g precision to determine the thousand kernel weight.

2.2.2.3 1000 kernel volume: A Volume will be calculated by measuring cylinder and the amount of kerosene displayed by 1000 kernels (Dutta *et al.*, 1988) [8].

2.2.2.4 Bulk density: The grain sample was placed in a 50 ml beaker, gently levelled without applying compression and adjusted to a uniform height of 20 cm in order to determine its value. After weighing the sample with the beaker, the beaker was filled to the same level

with an equal volume of water. Bulk density was calculated using the method described by Fan *et al.*, 1998 [9].

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{Weight of the grains (g)}}{\text{Volume occupied by the grains (mL)}} \quad (1)$$

2.2.2.5 True density: Using the toluene displacement method outlined by Mohsenin 1970 [10], 10 g of the grains were added to 20 ml of toluene in a 100 ml graduated cylinder. After recording the final liquid volume, the true volume of the grains was calculated by deducting the initial volume from the final reading.

$$\text{True density (g/cm}^3\text{)} = \frac{\text{Weight of the grains (g)}}{\text{True volume (mL)}} \quad (2)$$

2.2.2.6 Porosity (ϵ)

The porosity (ϵ) of the bulk grain was defined as the fractions of the space in the bulk grain that is not occupied by the grain. The porosity, ϵ was calculated using formula (Wang *et al.*, 2007) [11]

$$\text{Porosity} = \frac{(\rho_t - \rho_b) \times 100}{\rho_t} \quad (3)$$

2.2.3 Chemical composition

The chemical composition of the grains, including moisture, protein, fat, ash, and crude fiber, was examined. The analysis was conducted using the methodology described in AOAC, 2012 [7]. Every determination was made in triplicate, and the average value was used to present the findings. Carbohydrate content was determined by difference method, deducting the total amount of moisture, total ash, protein, fiber and fat from 100.

All chemicals utilized in the present investigation were of Analytical Reagent (AR) or Laboratory Reagent (LR) grade. Standard stock solutions and reagents were freshly prepared using purified deionized water to maintain accuracy and reliability of the results. Glassware items were obtained from the departmental laboratory and cleaned thoroughly before use.

3. Result and Discussion

3.1 Physical properties

Data pertaining to various physical parameters including length, breadth, L/B ratio, 1000 kernel weight, 1000 kernel volume, bulk density, true density and porosity were researched and findings obtained are displayed in Table 1 (raw samples) and Table 2 (pre-treated samples). Among the raw ingredients, rice variety kshatriya showed the highest grain length (6.57 ± 0.95 mm), having true density ($1.39 \pm 0\text{g/cm}^3$) and porosity ($39.56 \pm 0.16\%$), whereas green gram exhibited comparatively higher breadth (3.98 ± 0.13 mm), 1000 kernel weight (36.73 ± 0.33 gm), 1000 kernel volume (28.66 ± 0.58 ml), bulk density (0.86 ± 0.01 g/cm³), the results were in agreement with the earlier findings of Pandiselvam *et al.*, 2017 [12] for green gram.

Table 1. Physical properties of raw rice varieties (IRRI 125 and kshatriya), green gram, sorghum and ragi

Samples	Length (mm)	Breadth (mm)	L/B ratio	1000 kernel weight (gm)	1000 kernel vol (ml)	Bulk density (g/cm ³)	True density (g/cm ³)	Porosity (%)
IRRI 125	6.11 ± 0.34	2.27 ± 0.13	2.70 ± 0.30	15.58 ± 0.82	12.33 ± 0.58	0.84 ± 0.01	1.37 ± 0.00	38.35 ± 0.69
Kshatriya	6.57 ± 0.95	2.11 ± 0.46	3.11 ± 0.68	15.59 ± 0.03	11.33 ± 0.58	0.84 ± 0.01	1.39 ± 0.00	39.56 ± 0.16
Green gram	4.65 ± 0.70	3.98 ± 0.13	1.17 ± 0.14	36.73 ± 0.33	28.66 ± 0.58	0.86 ± 0.01	1.34 ± 0.01	35.58 ± 0.84
Sorghum	4.16 ± 0.24	3.56 ± 0.22	1.17 ± 0.03	32.70 ± 1.58	25.66 ± 0.58	0.82 ± 0.01	1.23 ± 0.02	32.83 ± 2.04
Ragi	1.72 ± 0.04	1.68 ± 0.03	1.02 ± 0.02	2.81 ± 0.04	2.30 ± 0.10	0.81 ± 0.01	1.27 ± 0.01	35.68 ± 0.18

The values are presented as Mean $\pm$ SD where $n = 3$ (Each value represents the average of three determinations)

(continued on next page)

Table 2. Physical properties of pre-treated rice varieties (IRRI 125 and kshatriya), green gram, sorghum and ragi

Samples	Length (mm)	Breadth (mm)	L/B ratio	1000 kernel weight (gm)	1000 kernel vol (ml)	Bulk density (g/cm ³)	True density (g/cm ³)	Porosity (%)
IRRI 125	5.65 ± 0.20	1.78 ± 0.04	3.17 ± 0.04	13.08 ± 0.61	10 ± 0.00	0.53 ± 0.01	1.28 ± 0.05	58.27 ± 2.62
Kshatriya	6.92 ± 0.38	1.81 ± 0.06	3.82 ± 0.16	13.29 ± 0.31	8.66 ± 0.58	0.56 ± 0.01	1.28 ± 0.05	56.25 ± 2.68
Green gram	4.28 ± 0.16	2.95 ± 0.11	1.45 ± 0.02	26.27 ± 0.74	23.66 ± 0.58	0.65 ± 0.01	1.13 ± 0.04	42.38 ± 2.18
Sorghum	3.62 ± 0.17	3.01 ± 0.15	1.2 ± 0.01	24.91 ± 0.28	21.66 ± 0.58	0.66 ± 0.01	1.09 ± 0.03	40.47 ± 0.44
Ragi	1.43 ± 0.11	1.32 ± 0.08	1.08 ± 0.02	2.56 ± 0.01	2 ± 0.00	0.62 ± 0.02	1.07 ± 0.07	41.86 ± 1.67

The values are presented as Mean ± SD where $n = 3$ (Each value represents the average of three determinations)

Ragi had the smallest grain dimensions (length - 1.72 ± 0.04 mm, breadth - 1.68 ± 0.03 mm), lower 1000-kernel weight (2.81 ± 0.04 gm), 1000 kernel volume (2.3 ± 0.1 ml), bulk density (0.81 ± 0.01 g/cm³). Dharmaraj *et al.*, 2015 [13] and Goswami *et al.*, 2015 [14] reported more or less similar range values for ragi, while sorghum showed intermediate values. Results reported are in close agreement with the findings of Robles-Plata *et al.*, 2023 [15] for sorghum. Following pretreatment, a slight reduction in grain dimensions, 1000-kernel weight and volume was observed, whereas porosity increased in all the ingredients from $32.83 \pm 2.04\%$ (jowar) - $39.56 \pm 0.16\%$ (rice variety kshatriya) to $40.47 \pm 0.44\%$ (jowar) - $58.27 \pm 2.62\%$

(rice variety IRRI 125). The reduction in physical dimensions was associated with drying-induced shrinkage, while increased porosity result from structural changes and formation of inter-particle voids during soaking, steaming and drying. Reduction in grain size and bulk density, together with increased porosity, facilitate moisture penetration, improve hydration and promote rapid reconstitution of the developed instant/ ready to cook value-added product. Partial gelatinisation during steaming may further reduce cooking time and improve the functional characteristics of the any developed instant/ready to cook value added final product. The results are in close agreement with the findings of Dharmaraj *et al.*, 2015 [13].

**Figure 1.** Effect of pretreatment on porosity

3.2 Chemical composition

The chemical composition including moisture, ash, fat, protein, crude fiber, carbohydrate was shown in Table 3 (raw samples) and Table 4 (pre-treated samples).

In terms of chemical composition, green gram contained comparatively higher protein ($22.7 \pm 1.30\%$), ash content ($3.73 \pm 0.01\%$) and crude fiber ($4.12 \pm 0.01\%$). Gopalan *et al.*, 1989 [16] reported the sim-

ilar range of values for green gram, followed by ragi whose ash content was $2.57 \pm 0.02\%$ and crude fiber $3.72 \pm 0.10\%$. Gopalan *et al.*, 2009 [17]; Shobana *et al.*, 2013 [18] reported the similar range of values for ragi. Rice had the lowest chemical composition including ash, fat, protein, crude fiber among the selected samples, whereas sorghum showed intermediate values. Verma and Shukla 2011 [19] reported the similar range of values for rice. Onoja *et al.*, 2014 [20] and Kale *et al.*, 2019 [21] reported the similar range of values for sorghum.

Table 3. Table 1 chemical composition of raw rice varieties (IRRI 125 and kshatriya), green gram, sorghum and ragi.

	Moisture %	Ash %	Fat %	Protein %	Crude fiber %	Carbohydrate %
IRRI 125	8.64 ± 0.18	0.64 ± 0.01	0.53 ± 0.02	7.42 ± 0.01	0.28 ± 0.04	82.49 ± 0.30
Kshatriya	8.26 ± 0.13	0.62 ± 0.01	0.54 ± 0.01	7.24 ± 0.11	0.26 ± 0.01	83.06 ± 0.17
Green gram	10.33 ± 0.11	3.73 ± 0.01	1.71 ± 0.02	22.7 ± 1.30	4.12 ± 0.01	57.80 ± 1.49
Sorghum	10.43 ± 0.14	1.22 ± 0.02	1.74 ± 0.02	9.40 ± 0.12	2.11 ± 0.06	75.10 ± 0.26
Ragi	12.56 ± 0.23	2.57 ± 0.02	1.24 ± 0.01	7.62 ± 0.18	3.72 ± 0.10	71.88 ± 0.46

The values are presented as Mean ± SD where $n = 3$ (Each value represents the average of three determinations)

(continued on next page)

Table 4. Chemical composition of pre-treated rice varieties (IRRI 125 and kshatriya), green gram, sorghum and ragi

	Moisture %	Ash %	Fat %	Protein %	Crude fiber %	Carbohydrate %
IRRI 125	5.36 ± 0.16	0.62 ± 0.01	0.54 ± 0.01	7.77 ± 0.06	0.30 ± 0.01	85.41 ± 0.07
Kshatriya	5.29 ± 0.25	0.62 ± 0.01	0.55 ± 0.01	7.55 ± 0.10	0.24 ± 0.01	85.75 ± 0.35
Green gram	5.52 ± 0.05	3.50 ± 0.12	1.47 ± 0.02	25.34 ± 1.73	4.21 ± 0.14	60.25 ± 2.01
Sorghum	5.57 ± 0.15	1.39 ± 0.03	1.68 ± 0.05	9.75 ± 0.09	2.38 ± 0.23	79.22 ± 0.10
Ragi	5.42 ± 0.02	3.14 ± 0.03	1.72 ± 0.14	8.00 ± 0.25	3.91 ± 0.09	77.19 ± 0.59

The values are presented as Mean ± SD where $n = 3$ (Each value represents the average of three determinations)

Pretreatment resulted in a slight decrease in moisture and fat in some samples, while protein and crude fibre increased on a dry-weight basis in green gram from $22.7 \pm 1.305\%$ to $25.34 \pm 1.73\%$ and $4.12 \pm 0.01\%$ to $4.21 \pm 0.14\%$ respectively. The results were in accordance with Tilekar *et al.*, 2019 [22]. Such changes were attributed to leaching of soluble components during soaking, redistribution of nutrients and concentration effects followed by drying. Sprouting of green gram additionally contribute to changes in protein and fibre fractions through enzymatic and metabolic activity.

4. Conclusion

Pretreatment was carried out to improve the suitability of rice, sorghum, green gram, and ragi for the development of food products through modifying their structural and compositional properties. Grain dimensions, 1000-kernel weight and volume, and bulk and true density decreased as a result of soaking, steaming, sprouting, and subsequent drying, but porosity increased, indicating structural modification and higher potential for moisture penetration. Additionally, pretreatment resulted in moderate variation among the ingredients and slight changes in proximate composition, especially in protein and crude fiber. From the perspective of food engineering, these modifications are significant as they can facilitate quicker hydration, better reconstitution, shorter cooking times, and better processing qualities. Overall, pretreatment enhanced the functional suitability of the selected grains for their incorporation into convenient, nutritionally improved and instant/ready to cook multigrain food products.

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