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Evaluation of impact of polishing on Physico-chemical Characteristics and nutraceutical components of Selected Rice Varieties

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Abstract
Rice, a staple food since prehistoric times, continues to be a primary dietary component for over 2 billion people across Asia, especially in India. The rice milling process, essential for making rice consumable, includes a critical step known as polishing. While polishing improves the appearance and texture of rice, it significantly reduces its nutritional quality. This study investigates the impact of polishing on the physico-chemical properties and nutraceutical characteristics of various rice varieties. Multiple rice samples were analyzed before and after different degrees of polishing. Parameters such as moisture content, measured along with antioxidant activity and phenolic content. Results revealed a consistent decline in essential nutrients and bioactive compounds post-polishing. The findings emphasize the nutritional trade-offs of rice processing and highlight the need for consumer awareness and balanced milling practices. This research contributes to optimizing rice processing methods to preserve its health benefits.

Keywords: Polishing, nutraceutical components, antioxidant activity, phenolic content

Introduction
Cereals represent some of the earliest domesticated crops, with their cultivation tracing back to prehistoric periods. They constitute a fundamental component of the human diet, providing the primary source of energy and essential nutrients for a substantial portion of the global population. Cereals have played a pivotal role in the development of human civilization, influencing agricultural practices, food security, and economic systems worldwide (Awika, 2011) [1]. Cereals account for over 50% of the daily carbohydrate intake, approximately one-third of protein requirements, and 50-60% of vitamin B needs (Wrigley, 2010) [2].
Among all cereal crops, rice (*Oryza sativa*) occupies a prominent position as one of the most important staple foods worldwide, serving as the principal source of nutrition for over half of the global population (Bagchi *et al.*, 2016) [3]. Rice is originated in Asia and has been cultivated for thousands of years, gradually spreading to various regions around the world due to its adaptability and significance as a staple crop. Today, it is cultivated in over 100 countries and plays a vital role in the livelihoods of more than 3.5 billion people. Its importance is especially pronounced in Asia, which accounts for approximately 90% of global rice production and consumption (FAO, 2021).
Rice is commonly eaten as whole cooked grains, but it can also be processed into forms like puffed rice, flour, and starch, which serve as ingredients for many different food products (Joshi *et al.*, 2014) [5, 15]. Acknowledging its immense contribution to global food security and poverty reduction, the United Nations declared 2004 as the International Year of Rice, emphasizing its role in addressing hunger, improving nutrition, and supporting sustainable development (Gnanamanickam & Gnanamanickam, 2009) [6].
Rice is primarily composed of carbohydrates, in which starch being the main constituent. Starch contains approximately 85-90% of the grain's dry matter, and plays a key role in determining its physicochemical and cooking properties. Starch is a high-molecular-weight polysaccharide consisting entirely of α-D-glucose residues. The majority of these glucose units are joined by α-(1→4)-glycosidic linkages, resulting in linear or helical structures

known as amylose. A smaller proportion of α-(1→6)-linkages introduces branching points, thereby forming the highly branched architecture of amylopectin (Pandey *et al*., 2012) [7]. In which Amylose is a major factor affecting the eating quality of rice, with varieties classified as waxy (0-2%), very low (3-12%), low (13-20%), intermediate (21-25%), and high (>26%) based on their amylose content, which varies according to the rice variety and type (Juliano, 1985) [11].

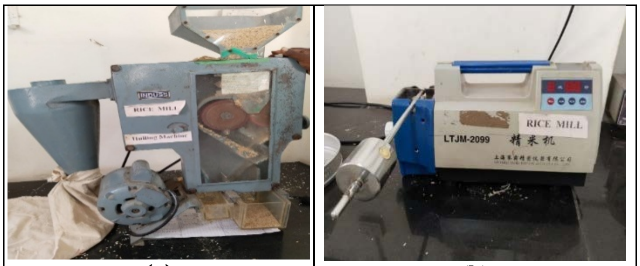
There are different types of rice, including white, brown, basmati and jasmine etc, each with distinct characteristics and nutritional profiles. Rice is available in over 5000 varieties, of which Basmati rice occupies a prime position on account of its extra-long superfine slender grains, pleasant, exquisite aroma, fine cooking quality, sweet taste, soft texture, length-wise elongation with least breadth-wise swelling on cooking and tenderness of cooked rice (Bhattacharjee *et al*., 2002) [9].

Rice analysis is essential for maintaining its quality, nutritional value, and overall suitability for both consumers and the food industry. Among the various parameters, moisture content is a key factor that influences rice storage, processing, and shelf life (Kennedy, 2003) [10]. While amylose content in rice was determined using a direct method as described by Juliano, (1971) [11]. Because of the different limitations, many researchers are now adopting faster and more efficient indirect methods for analysis of moisture and amylose (Mittal *et al.*, 2019) [12].

Method and Materials

A total of twenty-six rice varieties (Gurjari, GR 11, Jaya, Mahsuri, GR 7, GR 3, IR 28, GR 103, Dandi, GR 21 (Vatrak), GAR 3, GAR 22 (Swagat), Mahisagar, GAR 201 (Anand Ashkhat), GAR 13, GR 101, GR 4, Narmada, GR 5, GAR 1, GR 6, NWGR-13031 GAR 14, GNR 3, NAUR 1, and GNR 8) were obtained from the Main Rice Research Centre, Navagam, Gujarat.

The dried paddy grains were manually cleaned to remove foreign materials such as dust, straw, stones, and other impurities. The cleaned grains were then dehusked using a rice sheller to obtain brown rice and subsequently, the brown rice samples were polished using a rice polisher to obtain well-milled white rice (Plate 3.1). The white rice samples after polishing were analyzed for their physical and physicochemical properties, with a primary focus on phenolic content and anti-oxidant content.



(a) (b)

Plate 2.1: Instruments used for milling of rice (a) Rice sheller; (b) Rice polisher

The moisture content was measured using the gravimetric method according to AOAC (2012). The total phenolic content was determined by the method described by Camargo *et al.* (2016) [14]. The antioxidant activity of the samples was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay as described by Joshi *et al.* (2014) [5, 15].

Results

Physical properties

The physical properties of various rice varieties were evaluated to determine their primary physical characteristics. These properties are critical as they significantly influence the rice's behaviour during post-harvest handling, storage, packaging, transportation, and processing operations. Physical properties such as kernel length, width, thickness, equivalent diameter, aspect ratio, sphericity, true density, bulk density, and porosity were measured and analysed.

Table 1: Dimensional Properties of Different Unpolished Rice Varieties

Sr no	Variety	Length	Width	Thickness	AMD	GMD	ED	AR
1	Mhasuri	5.54±0.18	2.06±0.07	1.52±0.07	3.04±0.05	2.59±0.04	2.61±0.04	0.37±0.02
2	GAR 3	7.00±0.19	1.84±0.04	1.66±0.04	3.50±0.08	2.78±0.05	2.78±0.05	0.26±0.01
3	GAR 13	5.75±0.11	1.92±0.07	1.69±0.04	3.12±0.04	2.65±0.04	2.66±0.04	0.33±0.01
4	Jaya	6.82±0.10	2.59±0.09	1.86±0.10	3.76±0.05	3.20±0.07	3.23±0.06	0.38±0.02
5	GAR 22	8.46±0.28	1.75±0.05	1.66±0.04	3.96±0.08	2.91±0.04	2.91±0.04	0.21±0.01
6	Dandi	6.18±0.14	2.49±0.08	1.71±0.09	3.46±0.08	2.97±0.08	3.01±0.07	0.40±0.01
7	IR28	6.97±0.07	2.10±0.09	1.71±0.06	3.59±0.03	2.92±0.03	2.93±0.03	0.30±0.01
8	GAR 14	7.16±0.20	2.17±0.08	1.71±0.05	3.68±0.07	2.98±0.05	2.99±0.05	0.30±0.02
9	GAR 201	6.75±0.18	2.56±0.08	1.91±0.07	3.74±0.08	3.21±0.06	3.23±0.06	0.38±0.02
10	GR11	5.50±0.12	1.78±0.07	1.57±0.05	2.95±0.07	2.49±0.06	2.49±0.06	0.32±0.01
11	GR 4	5.31±0.13	1.83±0.05	1.51±0.06	2.88±0.04	2.44±0.05	2.45±0.05	0.34±0.02
12	GAR 1	6.66±0.16	1.95±0.14	1.63±0.06	3.42±0.05	2.77±0.08	2.77±0.08	0.29±0.03
13	GR 21	5.69±0.19	1.80±0.03	1.55±0.07	3.01±0.08	2.51±0.06	2.52±0.06	0.32±0.01
14	Gurjari	7.03±0.12	2.62±0.12	1.91±0.04	3.85±0.05	3.27±0.05	3.30±0.06	0.37±0.02
15	GR7	6.93±0.19	2.04±0.06	1.61±0.04	3.52±0.07	2.83±0.05	2.84±0.05	0.29±0.01
16	Mahisagar	6.09±0.12	1.85±0.04	1.55±0.05	3.16±0.04	2.59±0.03	2.60±0.03	0.30±0.01
17	Narmada	6.33±0.14	1.73±0.06	1.50±0.05	3.19±0.04	2.54±0.03	2.55±0.03	0.27±0.01
18	GR-101	6.33±0.23	1.79±0.04	1.58±0.06	3.23±0.10	2.61±0.07	2.62±0.06	0.28±0.01
19	GR-103	5.11±0.12	1.93±0.11	1.46±0.06	2.83±0.07	2.43±0.06	2.45±0.06	0.38±0.02
20	NWGR-13031	6.84±0.19	2.52±0.11	1.94±0.29	3.77±0.08	3.21±0.14	3.24±0.13	0.37±0.02
21	NAUR-1	6.76±0.21	2.55±0.08	1.90±0.07	3.74±0.08	3.20±0.07	3.22±0.07	0.38±0.02
22	GNR-8	6.73±0.18	2.54±0.07	1.86±0.05	3.71±0.06	3.17±0.03	3.20±0.03	0.38±0.01
23	GNR-3	6.67±0.25	2.56±0.04	1.84±0.04	3.69±0.09	3.15±.06	3.18±0.06	0.38±0.01
24	GR-6	7.14±0.24	1.80±0.09	1.61±0.10	3.52±0.13	2.74±0.11	2.75±0.11	0.25±0.01
25	GR-5	6.39±0.22	2.42±0.14	1.77±0.04	3.53±0.09	3.01±0.07	3.04±0.08	0.38±0.02
26	GR-3	6.12±0.26	2.11±0.15	1.59±0.04	3.27±0.08	2.74±0.06	2.76±0.07	0.34±0.02

(Data are expressed as mean ± SD, *n* = 10)

(ED-equivalent diameter, GMD-geometric mean diameter, AMD-arithmetic mean diameter)

Table 2: Physical Characteristics of Different Unpolished Rice Varieties

S No	Unpolish	Sphericity	Bulk Density	Tapped Density	True Density	Porosity (%)	1000 Kernal Wight(gm)
1	Mhasuri	0.47±0.01	0.80±0.01	0.87±0.01	1.43±0.01	43.83±0.33	12.46±0.05
2	GAR 3	0.40±0.01	0.79±0.02	0.88±0.02	1.38±0.02	42.76±0.62	17.84±0.03
3	GAR 13	0.46±0.01	0.81±0.01	0.88±0.03	1.42±0.03	42.95±0.80	12.90±0.03
4	Jaya	0.47±0.02	0.83±0.03	0.88±0.04	1.36±0.02	39.00±2.33	23.29±0.03
5	GAR 22	0.34±0.01	0.78±0.01	0.84±0.02	1.30±0.02	39.99±0.62	21.88±0.04
6	Dandi	0.48±0.01	0.79±0.03	0.86±0.02	1.32±0.03	40.23±5.46	16.13±0.03
7	IR28	0.42±0.01	0.82±0.02	0.89±0.02	1.37±0.02	40.15±0.44	17.23±0.03
8	GAR 14	0.42±0.01	0.81±0.03	0.87±0.03	1.46±0.03	44.54±1.60	17.48±0.03
9	GAR 201	0.48±0.01	0.83±0.02	0.87±0.02	1.36±0.02	38.98±0.41	22.35±0.04
10	GR11	0.45±0.01	0.82±0.01	0.88±0.02	1.36±0.02	39.67±1.48	11.41±0.03
11	GR 4	0.46±0.01	0.82±0.02	0.88±0.03	1.40±0.03	41.43±0.05	11.17±0.04
12	GAR 1	0.42±0.02	0.79±0.02	0.86±0.02	1.31±0.02	39.69±0.01	14.55±0.04
13	GR 21	0.44±0.01	0.84±0.01	0.87±0.02	1.40±0.02	39.95±1.86	12.10±0.03
14	Gurjari	0.47±0.01	0.83±0.03	0.89±0.03	1.31±0.03	36.66±0.43	25.21±0.05
15	GR7	0.41±0.01	0.82±0.01	0.88±0.02	1.32±0.02	37.76±3.31	16.01±1.19
16	Mahisagar	0.43±0.01	0.79±0.01	0.86±0.03	1.40±0.03	43.48±2.52	16.48±0.03
17	Narmada	0.40±0.01	0.78±0.02	0.84±0.02	1.42±0.02	45.01±1.38	15.99±0.05
18	GR-101	0.41±0.01	0.82±0.03	0.85±0.02	1.39±0.02	40.94±1.37	16.28±0.02
19	GR-103	0.48±0.01	0.80±0.01	0.84±0.01	1.33±0.01	39.66±3.50	11.09±0.02
20	NWGR-13031	0.47±0.03	0.79±0.01	0.88±0.02	1.36±0.02	41.65±4.43	22.43±0.03
21	NAUR-1	0.47±0.01	0.81±0.02	0.89±0.03	1.36±0.03	40.36±1.30	23.36±0.03
22	GNR-8	0.47±0.01	0.81±0.01	0.86±0.02	1.35±0.02	39.62±5.55	17.96±0.02
23	GNR-3	0.47±0.01	0.77±0.03	0.86±0.01	1.36±0.01	43.14±3.03	22.64±0.02
24	GR-6	0.38±0.01	0.79±0.02	0.82±0.03	1.43±0.03	44.44±4.45	19.75±0.02
25	GR-5	0.47±0.01	0.81±0.02	0.87±0.02	1.31±0.02	37.86±3.80	18.26±0.02
26	GR-3	0.45±0.02	0.81±0.01	0.87±0.01	1.36±0.01	39.87±6.55	19.69±0.02
	C.D.	0.027	0.035	0.022	0.024	4.751	0.385
	SE(m)	0.015	0.012	0.017	0.053	1.669	0.135
	SE(d)	0.016	0.017	0.024	0.076	2.361	0.191
	C.V.	1.029	2.609	3.386	6.762	7.069	1.337

(Data are expressed as mean ± SD, *n* = 10)

Table 3: Dimensional Properties of Different Polished Rice Varieties

Sr no.	Variety	Length	Width	Thickness	AMD	GMD	ED	Aspect ratio
1	Mhasuri	5.39±0.10	1.97±0.08	1.48±0.07	2.95±0.06	2.50±0.06	2.52±0.06	0.37±0.02
2	GAR 3	6.52±0.21	1.75±0.10	1.60±0.06	3.29±0.09	2.63±0.08	2.63±0.08	0.27±0.02
3	GAR 13	5.68±0.12	1.90±0.08	1.61±0.04	3.06±0.07	2.59±0.06	2.59±0.06	0.33±0.01
4	Jaya	6.66±0.14	2.55±0.07	1.84±0.07	3.68±0.06	3.15±0.06	3.18±0.06	0.38±0.02
5	GAR 22	8.15±0.31	1.71±0.02	1.62±0.04	3.83±0.10	2.83±0.04	2.83±0.04	0.21±0.01
6	Dandi	5.85±0.11	2.29±0.08	1.53±0.09	3.22±0.05	2.73±0.07	2.77±0.07	0.39±0.02
7	IR28	6.76±0.20	1.89±0.07	1.59±0.04	3.42±0.07	2.73±0.04	2.74±0.05	0.28±0.02
8	GAR 14	6.48±0.28	1.79±0.04	1.55±0.04	3.27±0.09	2.62±0.04	2.62±0.04	0.28±0.02
9	GAR 201	6.74±0.21	2.54±0.10	1.85±0.06	3.71±0.09	3.16±0.07	3.19±0.08	0.38±0.02
10	GR11	5.29±0.18	1.76±0.05	1.43±0.05	2.83±0.06	2.37±0.04	2.38±0.04	0.33±0.01
11	GR 4	5.13±0.12	1.77±0.04	1.46±0.06	2.79±0.05	2.37±0.04	2.38±0.04	0.35±0.01
12	GAR 1	6.63±0.19	1.83±0.07	1.55±0.04	3.34±0.08	2.66±0.06	2.67±0.06	0.28±0.01
13	GR 21	5.66±0.15	1.89±0.04	1.46±0.04	3.00±0.05	2.50±0.03	2.51±0.03	0.33±0.01
14	Gurjari	6.61±0.15	2.41±0.10	1.92±0.05	3.65±0.07	3.13±0.07	3.14±0.07	0.37±0.02
15	GR7	6.74±0.26	1.88±0.05	1.63±0.06	3.42±0.11	2.74±0.07	2.75±0.07	0.28±0.01
16	Mahisagar	6.20±0.19	1.80±0.05	1.51±0.04	3.17±0.06	2.56±0.04	2.57±0.04	0.29±0.01
17	Narmada	6.50±0.18	1.78±0.04	1.48±0.03	3.25±0.07	2.58±0.04	2.58±0.04	0.27±0.01
18	GR-101	6.10±0.12	1.73±0.06	1.52±0.04	3.12±0.05	2.52±0.04	2.53±0.04	0.28±0.01
19	GR-103	5.10±0.15	1.86±0.08	1.39±0.04	2.78±0.06	2.36±0.05	2.38±0.05	0.37±0.02
20	NWGR-13031	6.58±0.20	2.44±0.09	1.77±0.08	3.60±0.08	3.05±0.08	3.08±0.08	0.37±0.02
21	NAUR-1	6.41±0.15	2.60±0.04	1.88±0.06	3.63±0.05	3.15±0.04	3.18±0.04	0.41±0.01
22	GNR-8	6.21±0.17	2.36±0.14	1.84±0.05	3.47±0.09	3.00±0.08	3.02±0.09	0.38±0.02
23	GNR-3	6.65±0.12	2.51±0.10	1.75±0.07	3.64±0.04	3.08±0.05	3.11±0.05	0.38±0.02
24	GR-6	6.88±0.29	1.76±0.09	1.49±0.04	3.38±0.12	2.62±0.08	2.63±0.08	0.26±0.01
25	GR-5	6.30±0.19	2.34±0.09	1.69±0.08	3.44±0.09	2.92±0.07	2.95±0.07	0.37±0.02
26	GR-3	6.21±0.13	2.19±0.07	1.71±0.06	3.37±0.06	2.85±0.05	2.87±0.06	0.35±0.02

(Data are expressed as mean ± SD, *n* = 10) (ED-equivalent diameter, GMD-geometric mean diameter, AMD-arithmetic mean diameter)

Table 4: Physical Characteristics of Different Polished Rice Varieties

S No	Polish	Sphericity	Bulk Density(g/cm^3)	Tapped Density(g/cm^3)	True Density(g/cm^3)	Porosity (%)	1000 Kernal Wight (gm)
1	Mhasuri	0.46±0.01	0.82±0.01	0.87±0.01	1.39±0.03	40.99±1.09	12.10±0.02
2	GAR 3	0.40±0.01	0.82±0.02	0.87±0.03	1.34±0.02	38.78±1.33	17.02±0.05
3	GAR 13	0.46±0.01	0.83±0.01	0.90±0.01	1.32±0.01	37.11±0.83	11.62±0.03
4	Jaya	0.47±0.01	0.82±0.01	0.87±0.03	1.32±0.03	37.87±0.65	22.45±0.06
5	GAR 22	0.35±0.01	0.83±0.01	0.89±0.03	1.31±0.03	36.58±2.29	20.19±0.08
6	Dandi	0.47±0.02	0.83±0.02	0.87±0.01	1.31±0.02	36.65±1.16	15.67±0.05
7	IR28	0.40±0.01	0.83±0.02	0.90±0.01	1.31±0.01	36.63±1.81	15.96±0.04
8	GAR 14	0.40±0.01	0.82±0.02	0.89±0.02	1.33±0.03	38.33±1.20	16.22±0.05
9	GAR 201	0.47±0.01	0.80±0.01	0.88±0.02	1.29±0.04	37.91±2.33	22.06±0.09
10	GR11	0.45±0.01	0.83±0.02	0.89±0.02	1.35±0.03	38.48±1.44	10.88±0.12
11	GR 4	0.46±0.01	0.82±0.01	0.88±0.01	1.32±0.05	37.83±1.75	10.68±0.05
12	GAR 1	0.40±0.01	0.85±0.03	0.89±0.03	1.32±0.02	35.63±2.93	14.62±1.71
13	GR 21	0.44±0.01	0.82±0.02	0.89±0.03	1.32±0.02	37.88±0.54	11.57±0.05
14	Gurjari	0.47±0.01	0.86±0.03	0.90±0.02	1.33±0.04	35.36±0.94	24.15±0.03
15	GR7	0.41±0.01	0.86±0.02	0.91±0.02	1.31±0.02	34.36±1.13	14.17±0.05
16	Mahisagar	0.41±0.01	0.81±0.01	0.86±0.01	1.38±0.04	41.20±2.86	15.70±0.03
17	Narmada	0.40±0.01	0.78±0.01	0.84±0.02	1.34±0.02	41.76±1.54	15.27±0.05
18	GR-101	0.41±0.01	0.84±0.03	0.85±0.02	1.42±0.02	40.86±0.63	15.20±0.03
19	GR-103	0.46±0.01	0.81±0.02	0.84±0.01	1.30±0.03	37.67±0.86	10.83±0.03
20	NWGR-13031	0.46±0.01	0.83±0.02	0.88±0.02	1.42±0.02	41.55±0.53	20.98±0.05
21	NAUR-1	0.49±0.01	0.81±0.02	0.86±0.01	1.32±0.02	38.64±0.53	22.45±0.04
22	GNR-8	0.48±0.01	0.87±0.02	0.88±0.02	1.39±0.02	37.42±1.47	17.29±0.05
23	GNR-3	0.46±0.01	0.83±0.01	0.88±0.01	1.34±0.03	38.04±0.95	21.48±0.05
24	GR-6	0.38±0.01	0.77±0.01	0.83±0.01	1.31±0.02	41.22±0.99	19.16±0.08
25	GR-5	0.46±0.01	0.85±0.02	0.86±0.01	1.29±0.01	34.12±1.62	17.95±0.04
26	GR-3	0.46±0.01	0.80±0.01	0.86±0.01	1.33±0.02	39.82±1.43	18.95±0.07
	C.D.	0.029	0.038	0.039	0.046	2.454	0.557
	SE(m)	0.016	0.013	0.014	0.016	0.862	0.196
	SE(d)	0.018	0.019	0.019	0.023	1.219	0.277
	C.V.	1.231	2.824	2.691	2.077	3.911	2.029

(Data are expressed as mean ± SD, *n* = 10)

Unpolished rice varieties exhibited significant variation in dimensional parameters such as length, width, and thickness. GAR 22 recorded the highest length (8.46 mm), while GR-103 had the lowest (5.11 mm). The geometric mean diameter (GMD) ranged from 2.44 mm to 3.27 mm, indicating varietal differences. Aspect ratio varied from 0.21 to 0.40, showing differences in shape characteristics. Overall, these variations reflect genetic and regional diversity in rice morphology.

Sphericity among unpolished rice ranged from 0.34 to 0.48, indicating differences in roundness. Bulk density and true density varied with highest porosity observed in Narmada (45.01%) and lowest in Gurjari (36.66%). Kernel weight ranged between 10.68 g (GR 4) to 25.21 g (Gurjari), showing substantial weight differences. Most varieties had bulk densities between 0.78-0.84 g/cm³. These results are useful for post-harvest processing and equipment design.

Polishing slightly reduced the size of rice kernels in most varieties, especially in width and thickness. GAR 22 remained the longest even after polishing (8.15 mm), while GR-103 had the smallest kernels. The aspect ratio remained relatively stable, indicating shape consistency. GMD and AMD values slightly decreased due to polishing. The dimensional uniformity post-polishing is crucial for packaging and cooking quality.

Polished rice showed a slight reduction in kernel weight and porosity compared to unpolished varieties. Sphericity remained consistent, though polishing had minor effects on roundness. Gurjari had the highest 1000-kernel weight (24.15 g), while GR11 had the lowest (10.88 g). Bulk and tapped densities were generally higher post-polishing, improving flow properties. These findings support polishing's impact on physical traits relevant to consumer and industrial preferences.

The study reveals significant variations in dimensional and physical properties among different unpolished and polished rice varieties. Polishing slightly reduced kernel dimensions and altered physical characteristics like density, porosity, and kernel weight. Varieties like Gurjari and GAR 22 showed superior traits in terms of size and weight. These findings are valuable for varietal selection, processing optimization, and equipment design in the rice industry.

Moisture content

Moisture content is a critical parameter influencing the post-harvest quality, storage stability, and processing characteristics of rice grains. It also affects mechanical properties and shelf life, playing a vital role in maintaining grain integrity during handling and storage.

The observed variation in moisture content between unpolished and polished rice is primarily due to the removal of the bran layer during polishing, which exposes the hygroscopic endosperm. This exposed layer tends to absorb ambient moisture more easily, leading to an increase in moisture content in some varieties. However, the effect is not consistent across all genotypes, highlighting the role of genetic differences. GAR 201 showed the highest moisture increase (+1.23%) after polishing, while Dandi showed the largest decrease (−0.81%). Grain-specific traits like kernel hardness and bran composition likely influence these trends. Varieties such as GAR 3 and GR 7 maintained consistently low moisture levels, making them suitable for storage. The statistical thresholds (C.D. and SEM) confirm that some moisture differences among varieties are significant and reliable.

Table 5: Moisture Content of Different Polished and Unpolished Rice Varieties

S No	Variety	Unpolished (%)	Polished (%)
1	Dandi	12.62±0.25	11.81±0.15
2	GAR 13	11.56±0.38	11.40±0.28
3	GAR 14	12.57±0.33	12.30±0.47
4	GAR 22	11.54±0.23	11.58±0.23
5	GNR 3	12.44±0.42	11.35±0.70
6	GNR 8	11.34±0.18	11.51±0.39
7	GAR 1	11.35±0.38	11.41±0.53
8	GR 3	12.47±0.27	11.54±0.38
9	GR 4	12.42±0.41	11.35±0.50
10	GR 5	11.46±0.32	11.87±0.07
11	GR 6	11.69±0.29	12.67±0.41
12	GR 11	11.56±0.28	12.37±0.45
13	GR 21	11.48±0.22	12.45±0.43
14	GR 101	12.49±0.31	12.29±0.29
15	GR 103	12.40±0.30	12.65±0.17
16	GAR 201	11.33±0.38	12.56±0.33
17	Gurjari	11.56±0.14	11.49±0.23
18	IR 28	11.60±0.37	11.48±0.35
19	JAYA	12.57±0.33	11.55±0.37
20	Mahisagar	11.38±0.27	12.39±0.69
21	Mahsuri	11.52±0.41	11.34±0.15
22	Narmada	12.26±0.34	12.33±0.57
23	NAUR 1	11.45±0.32	11.55±0.27
24	NWGR 13031	12.45±0.40	12.37±0.43
25	GAR 3	9.44±0.26	9.83±0.30
26	GR 7	10.02±0.27	9.95±0.18
	C.D.	0.53	0.65
	SE(m)	0.18	0.23

(Data are expressed as mean ± SD, *n* = 3)

3.3 Total Phenols Contents and Antioxidant of Different Polished and Unpolished Rice

Pigmented rice varieties typically exhibit greater total phenolic content and antioxidant activity than non-pigmented (white) rice,

Table 6: Total Phenols Contents and Antioxidant of Different Polished and Unpolished Rice

S No	Variety	Total Phenol Contents in Unpolished Rice (mg GAE/g)	Total Phenol Content in polished Rice (mg GAE/g)	Antioxidant Activity in Unpolished Rice (%)	Antioxidant Activity in polished Rice (%)
1	Mhasuri	56.96±1.53	35.45±0.62	4.85±0.03	4.44±0.03
2	GAR 3	57.45±2.04	38.06±0.36	1.74±0.05	1.57±0.01
3	GAR 13	47.48± 1.55	40.60±0.48	6.16±0.09	5.79±0.03
4	Jaya	59.52±1.45	54.60±0.63	4.06±0.08	3.87±0.04
5	GAR 22	58.67±1.09	46.95±0.37	2.11±0.04	2.02±0.06
6	Dandi	64.61±1.15	44.74±0.31	3.20±0.05	0.42±0.02
7	IR28	56.38±1.29	49.65±0.24	5.69±0.07	5.53±0.03
8	GAR 14	52.58±1.48	43.63±0.39	4.41±0.07	0.36±0.04
9	GAR 201	58.77±1.84	40.65±0.33	4.80±0.04	4.13±0.05
10	GR11	54.64±1.69	58.49±0.63	7.77±0.09	3.95±0.04
11	GR 4	61.21±0.84	45.63±0.68	11.75±0.08	8.24±0.07
12	GAR 1	69.77±1.58	55.34±0.16	3.96±0.10	3.05±0.06
13	GR 21	41.85±0.67	36.55±0.24	11.92±0.06	4.17±0.10
14	Gurjari	43.32±0.87	41.96±0.25	3.22±0.06	1.73±0.09
15	GR7	66.41±1.10	42.43±0.24	8.81±0.05	4.55±0.06
16	Mahisagar	61.51±1.63	56.68±0.43	8.01±0.06	4.26±0.05
17	Narmada	61.19±1.06	55.35±0.24	8.38±0.08	5.40±0.05
18	GR-101	46.28±1.75	40.47±0.30	5.59±0.09	2.03±0.04
19	GR-103	57.28±0.98	51.54±0.49	6.26±0.06	4.21±0.06
20	NWGR-13031	54.00±1.03	48.79±074	6.69±0.09	4.70±0.09
21	NAUR-1	50.21±1.12	42.78±0.75	5.45±004	3.53±0.07
22	GNR-8	41.62±1.32	38.28±0.03	5.09±0.08	4.75±0.06
23	GNR-3	58.03±1.16	52.20±0.10	6.38±0.04	3.18±0.04
24	GR-6	43.40±1.60	36.09±0.43	4.09±0.07	1.43±0.02
25	GR-5	43.23±1.48	40.11±0.49	5.45±0.08	2.35±0.03
26	GR-3	62.99±1.48	57.79±0.39	7.67±0.09	3.90±0.06
	C.D.	2.265	0.722	0.113	0.087
	SE(m)	0.796	0.254	0.04	0.031
	SE(d)	1.126	0.359	0.056	0.043
	C.V.	2.508	0.956	1.163	1.478

(Data are expressed as mean ± SD, *n* = 3)

The total phenolic content in unpolished rice ranged from 41.62 to 69.77 mg GAE/100 g, with GAR 1 showing the highest value. Polishing significantly reduced these levels, ranging from 35.45 to 58.49 mg GAE/100 g, indicating that phenolics are mainly concentrated in the bran layer. This trend was consistent across all varieties studied. Previous studies by Shen *et al*. (2009) [16], Sripum *et al*. (2017) [17], and Shao *et al*. reported similar ranges, supporting these findings. Overall, polishing results in a substantial loss of phenolic compounds in rice.

The antioxidant activity in unpolished rice ranged from 1.74% to 11.92%, while in polished rice it dropped to between 0.36% and 8.24%, as shown in Table 4.8. This reduction after polishing confirms that the bran layer is the main source of antioxidant compounds. The observed values align with reported DPPH inhibition ranges of 3-46% depending on variety and processing (Shen *et al*., 2009; Sripum *et al*., 2017) [16, 17]. Polishing not only alters the rice's appearance but also lowers its nutraceutical potential (Tamura *et al*. Prior studies also support that rice bran is rich in phenolics and antioxidants (Shobana *et al*., 2011; Zhang *et al*., 2010) [18, 19]. Therefore, retaining the bran layer helps enhance the health benefits of rice (Zhou *et al*., 2004) [20].

Conclusion

The physical properties of various rice varieties, both polished and unpolished, showed considerable variation across multiple parameters, reflecting genetic diversity and potential suitability for different post-harvest applications. Among unpolished varieties, kernel length ranged from 5.11 mm (GR-103) to 8.46 mm (GAR 22), with geometric mean diameter (GMD) varying between 2.44 mm and 3.27 mm. Aspect ratio values ranged from 0.21 to 0.40, indicating significant differences in grain shape. Sphericity, a measure of grain roundness, varied between 0.34 and 0.48, while bulk densities ranged from 0.77 to 0.84 g/cm³, and true density values ranged from 1.29 to 1.46 g/cm³. Porosity, which affects airflow and drying efficiency, was highest in Narmada (45.01%) and lowest in Gurjari (36.66%). The 1000-kernel weight varied significantly, from 10.68 g in GR 4 to 25.21 g in Gurjari, highlighting differences in grain mass.

Polishing generally reduced kernel size slightly, particularly in width and thickness, though GAR 22 remained the longest even after polishing (8.15 mm). GMD and AMD also decreased marginally post-polishing, but the aspect ratio remained relatively stable, indicating shape consistency. Kernel weights and porosity values decreased slightly after polishing, while bulk and tapped densities often increased, improving flow properties. Sphericity remained consistent, though some minor changes were noted. In terms of moisture content, unpolished rice varieties ranged from 11.33% to 12.62%, while polished rice ranged from 11.35% to 12.67%, with a general trend of slightly lower moisture content after polishing, although some varieties showed an increase. These variations in dimensional, physical, and moisture characteristics are crucial for optimizing rice processing, packaging, storage, and equipment design, and also provide insight into varietal performance and consumer preferences.

Polishing significantly reduces the phenolic content and antioxidant activity of rice, as these compounds are concentrated in the bran layer. This nutritional loss affects the rice's health-promoting properties. Retaining the bran enhances nutraceutical value and supports dietary benefits. The findings align with previous research, emphasizing the importance of minimally processed rice.

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