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Evaluation of commercial rice grains present in the Amman market

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ABSTRACT

Rice is a staple food that contributes to significant energy intake. Jordan relies on importing to provide the market with the required quantities of rice. Different varieties from different sources with various qualities are available in the market. This study aimed to evaluate the quality of rice available in the markets in Amman city-Jordan. Twenty-five brands (three samples from each brand) were collected. Samples were evaluated regarding chemical composition, dimensions before and after cooking, percentage of different defects, pasting profile (pasting temperature, peak viscosity, peak time, trough, and final viscosity), whiteness, transparency, and milling degree. All rice samples tested comply with the Jordanian standard except for chalky kernels (four brands), heat-damaged kernels (one brand), and insect infestation (two brands). All samples that did not fulfil the Jordanian specifications were from the long-grain rice. Medium-grain rice has higher whiteness, transparency, milling degree, moisture, starch, peak viscosity, trough, and final viscosity than long-grain rice. On the other hand, long-grain rice has a higher protein, pasting temperature, and peak time. There were significant differences in pasting and chemical composition parameters within the two groups of grain sizes. The average elongation ratio for all samples was 1.57 ±0.14, with significant differences between different brands. Due to the higher pasting temperature and peak time, long-grain rice requires more energy during cooking than medium-grain rice.

Keywords: Commercial rice, Amman-Jordan, RVA pasting profile, dimensions, milling degree

INTRODUCTION

Rice is one of the main types of staple cereal food that contribute to about 40-80% of total energy intake **[1]**. Rice is not cultivated in Jordan, so to meet the needs of consumers, Jordan imports different types of rice from different countries, making quality evaluation a vital step. Cooking and eating quality are the main factors affecting consumer acceptability and, in turn, the economic value of rice **[1]**, **[2]**. Eating quality is related to different factors, including starch physicochemical properties, chemical composition, dimensions and elongation upon cooking, defects such as chalky rice content, broken rice, and milling degree (the extent of bran removal) **[1]**, **[3]**. Consumers need rice that conforms to the standards, which evaluate the rice in terms of dimensions and the impact of different factors encountered during harvesting, storage, processing, and distribution on the quality of rice. Cooking and eating quality are usually performed using sensory evaluation of cooked rice. However, this method has several limitations: the texture sensory attributes are not usually clearly defined and standardized **[4]**, the subjective nature of the test, the large sample number and size requirement, and the time-consuming **[2]**. Another approach to determining the rice-eating quality is studying starch, particularly amylose content, as the primary factor affecting quality. However, it is difficult to predict starch behaviour during cooking depending on amylose only **[5]**. Recently, the evaluation of rice eating quality by determining the Rapid Visco Analyzer (RVA) pasting properties has been increasingly adopted by researchers **[2]**, **[4]**, **[6]**, **[7]**, **[8]**, **[9]**. The principle of the RVA pasting profile relies on measuring rice flour suspension viscosity during heating, holding, and cooling cycles, from which valuable information is drawn, such as pasting temperature, peak viscosity, peak time, trough, setback, and final viscosity **[4]**; these parameters were found to be correlated with rice eating quality **[2]**.

To the best of our knowledge, the information on the quality of the commercial rice brands available in the Amman market is scarce. The research aimed to evaluate the available commercial polished rice brands in the Amman market regarding chemical composition, conformance to Jordanian standards, dimensions before and after cooking, and degree of cooking.

Scientific Hypothesis

Several rice brands with different grain lengths are available in Amman markets. There is an expectation of a variation in quality between and within rice brands with different grain lengths. We expect differences in chemical composition (mainly protein and starch), pasting properties, milling degree, and dimensions before and after cooking. We do not expect differences in terms of foreign materials' content.

MATERIAL AND METHODOLOGY

Samples

Twenty-five brands (Table 1) were randomly identified and collected from hypermarkets in Amman/Jordan. Six brands were medium-grain, and 19 were long-grain rice. Three samples (5 kg each) were collected from different batches from each brand. Each sample was divided into three parts: one composed of rice grain for chemical and cooking tests, the second part grounded (0.05 mm screen) intended for the RVA test, and the third part for measuring foreign materials and the degree of milling. Samples were filled in plastic bags and kept refrigerated until tested.

Table 1 Commercial brand names selected from the local market.

Number	Type	Brand name	Origin
1	medium	(M1-USA)	USA
2	medium	(M2-USA)	USA
3	medium	(M3-USA)	USA
4	medium	(M4-USA)	USA
5	medium	(M5-USA)	USA
6	medium	(M6-USA)	USA
7	long	(L1-India)	India
8	long	(L2-Thailand)	Thailand
9	long	(L3-India)	India
10	long	(L4-India)	India
11	long	(L5-India)	India
12	long	(L6-India)	India
13	long	(L7-India)	India
14	long	(L8-India)	India
15	long	(L9-India)	India
16	long	(L10-India)	India
17	long	(L11-India)	India
18	long	(L12-India)	India
19	long	(L13-India)	India
20	long	(L14-India)	India
21	long	(L15-USA)	USA
22	long	(L16-India)	India
23	long	(L17-India)	India
24	long	(L18-India)	India
25	long	(L19-India)	India

Instruments

Near-Infrared Analyzer (NIR, model DA 7250, Perten, Sweden), Rapid Visco Analyzer (RVA model 4500, Perten, Australia), analytical balance (Bel engineering, model M314Ai, Italy), grinding machine equipped with 0.05 mm screen (MF 10 basic, IKA-Werke, Germany), electric rice cooker (Proctor Silex, China), and rice milling meter (Satake, Australia) were used in the study.

Laboratory Methods

Chemical analysis: The moisture, protein, and starch percentage were determined using a Near-Infrared Analyzer using the manufacturer's recommendations.

Foreign materials and defects: One kilogram from each sample was tested manually by visual inspection for broken grains, chalky kernels, damaged kernels, heat-damaged kernels, paddy kernels, rice-based foreign materials, other classes of rice, non-rice-based foreign materials, red kernels, red-streaked kernels, immature kernels, odour, and infestation according to Jordanian standard **[10]**.

Pasting properties: determined using AACC method no. 61-02 **[11]**.

Dimensions before and after cooking: The length (L), width (W), and (T) thickness of ten rice kernels were determined from each sample before and after cooking, and the average was recorded. The following ratios were calculated for each sample:

- Length-thickness ratio (before cooking) = L (before cooking)/T (before cooking)
- Length-width ratio (before cooking) = L (before cooking)/W (before cooking)
- Length-thickness ratio (after cooking) = L (After cooking)/T (After cooking)
- Length-width ratio (after cooking) = L (After cooking)/W (After cooking)
- Elongation ratio = L (cooked) / L (uncooked)

Whiteness, transparency, and degree of milling: milling meter was used to determine whiteness, transparency, and degree of milling using manufacturer recommendations.

Description of the Experiment

Sample preparation: No special sample preparation was performed for testing chemical composition, foreign materials and defects, and whiteness, transparency, and degree of milling. The rice grain was ground with a grinder with a 0.05 mm screen to test the pasting properties. Rice pasting properties were determined using Rapid Visco Analyzer. In a canister, 25 ml of water was added, and after that, 3 g of the milled rice (weight was corrected to 12% moisture content), a paddle was placed in the canister, and the blade was jogged in the sample up and down ten times. The canister with the paddle inserted was placed in the instrument. From the software (TCW), the rice pasting profile test (AACC no. 61-02) **[11]** was selected (Table 2), and the test was begun. Dimensions after cooking were determined by boiling 20g of rice in 500 mL of water using a rice cooker. A pre-experiment was conducted to determine the appropriate cooking time in which rice grains were drawn every 30 sec. and pressed between two small glass plates. Rice grains were considered cooked after the disappearance of the white colour from the centre of the grains.

Table 2: RVA rice pasting profile test

Time	Type	Value
00:00:00	Temp	50 °C
00:00:00	Speed	960 rpm
00:00:10	Speed	160 rpm
00:01:00	Temp	50 °C
00:04:48	Temp	95 °C
00:07:18	Temp	95 °C
00:11:06	Temp	50 °C

Idle temperature: 50 ±1 °C
End of test: 12 min, 30 sec.
The time between readings: 4 sec

Number of samples analyzed: 75 samples were analyzed.

Number of repeated analyses: Measurements were made in duplicate.

Number of experiment replication: Number of replicates was three.

Design of the experiment: Twenty-five different rice brands were randomly collected from hypermarkets in Amman city. From each brand, three different batches were selected. The size of each sample was 5 kg. From each sample, 1 kg was assigned for defects, foreign materials test, and milling degree, 1 kg for rice dimensions tests and RVA-pasting profile analysis, and 1 kg for measuring chemical compositions.

Statistical Analysis

Statistical analysis software: Minitab 19 software (Minitab Inc., State College, PA, USA). Statistical tests performed: A completely randomized design was used to analyze the results using Minitab 19 software (Minitab Inc., State College, PA, USA). Tukey's test was used for means separation based on $p \leq 0.05$. Principal component analysis (PCA) was performed for all data to reduce its dimensionality and visualize different rice sample groups sharing the same characteristics. PCA results were presented as a biplot.

RESULTS AND DISCUSSION

Chemical Analysis

There were significant differences in chemical composition between rice samples (Table 3). The average moisture value was 12.01% ±0.44 for medium-grain rice and 10.19% ±0.60 for long-grain rice. All moisture values conform to the upper limit (15%) specified by the Jordanian standard **[10]**. The average protein value was 7.02% ±0.45 for medium-grain and 8.87% ±0.48 for long-grain rice. The lowest protein values were recorded for medium-grain rice samples (in addition to two samples of long-grain indicated by numbers 8 and 9). The lower protein content was recorded for medium-grain rice, which could be attributed to its higher milling degrees than long-grain rice (Table 7). The protein, fiber, and lipids were located in the outer bran layer, and milling significantly reduced their contents **[3]**. The protein content varies within and among rice **[12]** and is affected by the degree of exposure to solar radiation and fertilization by nitrogen **[13]**. Finally, the average starch value was 91.45% ± 1.60 for medium-grain rice and 90.18% 1.12 for long-grain rice. Medium-grain rice had significantly ($p \leq 0.05$) higher moisture and starch content than long-grain rice; however, long-grain rice had significantly ($p \leq 0.05$) higher protein content than medium-grain rice. It has been reported that the percentage of starch varies from 87 to 91% **[14]**, **[15]**.

Foreign Materials and Defects

Results showed significant differences ($p \leq 0.05$) between rice samples in broken grains, chalky kernels, damaged kernels, heat-damaged kernels, red-streaked grains, and immature kernels (Table 4). There were no significant differences in extraneous organic materials, other rice classes, and red kernels. The Jordanian standards for rice **[10]** stated the upper limits for different defects as follows: 6% for broken grains; 5% for chalky kernels; 3% for black damaged kernels; 2% for heat-damaged kernels; 0.3% for paddy kernels; 0.5% for extraneous organic materials; 1% for other classes of rice; 0.5% for non-organic extraneous materials; 12% for red and red-streaked kernels; and 2% immature kernels. The specifications also stated that rice should be free of visible insects. All rice samples tested comply with the Jordanian standard except for chalky kernels (brand numbers 9, 12, 16, and 17 exceeded specifications), heat-damaged kernels (brand number 21 exceeded specifications), and insect infestation (brand number 7 and 24 exceeded specifications). It was interesting to note that all samples that exceeded specifications were from the long-grain rice. Chalkiness is due to the white colour in the endosperm area, which is undesirable and weakens the rice kernel leading to breaking during rice handling, which reduces head rice recovery **[6]**. It is worth to be mentioned that the foreign materials and defects in rice grains in this research were determined using manual inspection by a trained operator; some researchers suggested using a better method using image processing to avoid the possible errors linked with the first method related to human fatigue while testing a large number of samples **[16]**, **[17]**.

Pasting Properties

Pasting properties in this research were determined using RVA, which has several advantages over other empirical methods represented in well-defined parameters, small sample size, short testing time **[18]**, and correlated with cooked rice sensory properties **[19]**. **[20]** reported that cooked rice acceptability was correlated with high peak viscosity, breakdown viscosity, final viscosity, and hold viscosity. Table (5 A) shows the pasting properties of the different rice samples. Pasting temperature is the temperature at the onset of this rise in viscosity **[1]** when the starch and protein absorb water **[5]**. Pasting temperature is considered an overestimation of gelatinization temperature **[21]**. In this research, the pasting temperature averaged 93.19 ±2.73 °C. Medium-grain rice samples had a lower average pasting temperature (88.58 ±1.43 °C) compared with long-grain rice (94.64 ±0.38 °C). All long-grain rice samples were significantly higher ($p \leq 0.05$) than the medium-grain rice. The pasting temperature indicates the minimum temperature required to cook a sample, directly impacting energy costs. Based on this, and due to its lower values of pasting temperature, medium-sized rice grains are expected to require less energy to be cooked than long-grain rice **[1]**.

Table 3 Percentages[1] of moisture, starch, and protein of rice samples.

Brand	Grain type[2]	Moisture (%)[3]	Protein (%)[4]	Starch (%)[4]
1	M	12.26 ±0.01ab	6.56 ±0.15g	93.55 ±0.18a
2	M	11.57 ±0.28abc	7.19 ±0.02defg	90.14 ±0.51abcd
3	M	12.17 ±0.17ab	7.05 ±0.07efg	89.18 ±0.26cd
4	M	12.1 ±0.42ab	6.92 ±0.34fg	92.65 ±0.69abc
5	M	12.38 ±0.04a	6.84 ±0.19fg	91.29 ±0.24abcd
6	M	11.56 ±0.78abc	7.89 ±0.16cde	91.87 ±0.04abcd
7	L	9.74 ±0.07gh	8.57 ±0.05abc	90.34 ±0.48abcd
8	L	11.28 ±0.03bcd	7.5 ±0.42def	92.69 ±0.04ab
9	L	10.33 ±0.04defg	8 ±0.14bcd	90.07 ±1.32abcd
10	L	9.75 ±0.18fgh	8.85 ±0.13ab	89.74 ±0.52bcd
11	L	10.36 ±0.02defg	9 ±0.14a	89.1 ±0.99d
12	L	10.82 ±0.06cdef	8.78 ±0.10ab	90.4 ±2.83abcd
13	L	10.64 ±0.15cdef	9.15 ±0.07a	90.09 ±1.04abcd
14	L	10.15 ±0.01efgh	8.56 ±0.07abc	89.6 ±1.27bcd
15	L	9.17 ±0.09h	9.11 ±0.01a	88.59 ±0.45d
16	L	10.32 ±0.02defg	9.17 ±0.09a	88.85 ±0.86d
17	L	10.99 ±0.27cde	8.84 ±0.01ab	89.5 ±0.06bcd
18	L	10.05 ±0.50efgh	8.85 ±0.50ab	90 ±0.25abcd
19	L	9.48 ±0.39gh	9.35 ±0.21a	90.095 ±0.36abcd
20	L	10.1 ±0.42efgh	9.23 ±0.39a	90.59 ±1.36abcd
21	L	10.6 ±0.28cdef	8.82 ±0.11ab	90.3 ±0.57abcd
22	L	10.65 ±0.07cdef	9.38 ±0.11a	90.23 ±0.10abcd
23	L	9.31 ±0.15gh	9.28 ±0.03a	90.71 ±0.41abcd
24	L	10.33 ±0.10defg	9.07 ±0.24a	90.93 ±0.11abcd
25	L	9.79 ±0.22fgh	9.04 ±0.43a	90.84 ±0.03abcd
All samples		10.62 ±0.96	8.44 ±0.91	90.48 ±1.39
M-grain		12.01 ±0.44	7.02 ±0.45	91.45 ±1.60
L-grain		10.19 ±0.60	8.87 ±0.48	90.18 ±1.12

Note: [1]Values are expressed as Means ± Standard deviation. According to the Tukey test, the means that do not share the same letter in each column are not significantly different (p >0.05); [2] M: medium-grain rice; L: Long-grain rice; [3] Wet matter bases; [4] Dry matter bases.

There were no significant differences in pasting temperature for samples from long-grain rice; however, there were significant differences ($p \leq 0.05$) in medium-grain rice, and the lowest significant pasting temperature was for samples number 1, 2, 4, and 5. Pasting temperature differences could be related to differences in rice chemical composition. This study founds a strong positive correlation ($R^2 = 0.76$) between rice protein content and pasting temperature (Figure 1). **[5]** attributed the increase in pasting temperature for some types of rice to the resistance of starch granules against swelling, which could be related to the type of starch present. **[22]** reported that amylose content is correlated with high pasting temperature. High amylose content is correlated with the hardness of cooked rice grains, while low amylose content is correlated with stickiness **[23]**, **[24]**.

The highest viscosity during the heating cycle is known as peak viscosity **[25]**, associated with water-holding capacity. The average value of peak viscosity (Table 5 A) was 1093 ±864 cp. Medium-grain rice had significantly higher ($p \leq 0.05$) values (2518 ±443 cp) than long-grain rice (642.4 ±251.2 cp). Sample 6 from medium-grain rice had a significantly lower peak viscosity (1696.5 ±226.980) than the other samples from medium-grain rice. There were significant differences ($p \leq 0.05$) in samples from long-grain. The swelling power and disruption rate are responsible for the variations in peak viscosity **[26]**. It had been reported that rice with high amylose had low peak viscosity, while rice low in amylose had high peak viscosity **[27]**, **[28]**, which suggests that, in our study, long-grain rice had higher amylose content than medium-grain rice. Peak viscosity was reported to be negatively correlated with rice hardness **[29]**. **[19]** reported that consumers preferred rice with high peak viscosity.

Table 4 A Rice foreign materials and defects[1].

Brand number	Broken grains (%)	Chalky kernels (%)	Damaged kernels (black) (%)	Heat-damaged kernels (%)	Paddy kernels (%)	Organic extraneous materials (%)
1	2.8 ±0.64	3.6 ±0.42	0.1 ±0.02	0.1 ±0.02	0	0
2	2.8 ±0.67	1.5 ±0.58	0.1 ±0.09	0.2 ±0.09	0	0
3	3.5 ±0.67	2.5 ±0.91	0.2 ±0.24	0.1 ±0.11	0	0
4	2.2 ±0.08	4.9 ±0.28	0.1 ±0.06	0 ±0.05	0	0
5	3.4 ±0.81	2.8 ±1.02	0.1 ±0.05	0.1 ±0.08	0	0
6	4.3 ±1.02	4 ±0.59	0.9 ±0.11	0.1 ±0.02	0 ±0.05	0
7	0 ±0.03	0	0.3 ±0.1	0.2 ±0.07	0	0
8	1.3 ±0.04	0	0.1 ±0.04	0.6 ±0.22	0	0
9	0	15.4 ±8.81	0.5 ±0.28	0.2 ±0.22	0	0
10	0.4 ±0.05	0.1 ±0.01	0.2 ±0.12	0.2 ±0.00	0	0
11	0.2 ±0.22	0.1 ±0.09	0.1 ±0.14	0.3 ±0.07	0	0
12	0.4 ±0.09	17.8 ±4.05	0.3 ±0.16	0	0	0
13	0.1 ±0.14	0 ±0.06	0.2 ±0.03	0.2 ±0.14	0	0
14	0	0	0 ±0.04	0.2 ±0.05	0	0
15	0.3 ±0.02	0	0.8 ±0.18	0.5 ±0.45	0	0
16	0.9 ±0.66	16.7 ±1.10	0.2 ±0.28	0.3 ±0.01	0	0
17	0.1 ±0.06	13.1 ±2.74	0.1 ±0.18	0.1 ±0.00	0	0
18	0.2 ±0.27	0	0.4 ±0.27	0.1 ±0.03	0	0
19	0.1 ±0.04	0.1 ±0.02	0.5 ±0.15	0	0	0
20	0.1 ±0.03	0.1 ±0.10	0.3 ±0.13	0.1 ±0.08	0	0
21	5.3 ±1.30	0	0.1 ±0.08	2.1 ±0.55	0	0
22	0.1 ±0.19	0	0.1 ±0.08	0.1 ±0.18	0	0
23	0.1 ±0.14	0	0.2 ±0.11	0.1 ±0.12	0	0
24	0.1 ±0.03	0.1 ±0.10	0.3 ±0.15	0 ±0.03	0	0
25	0.5 ±0.47	0	0.3 ±0.05	0.9 ±1.10	0	0

Note: [1]Values are expressed as Means ± Standard deviation.

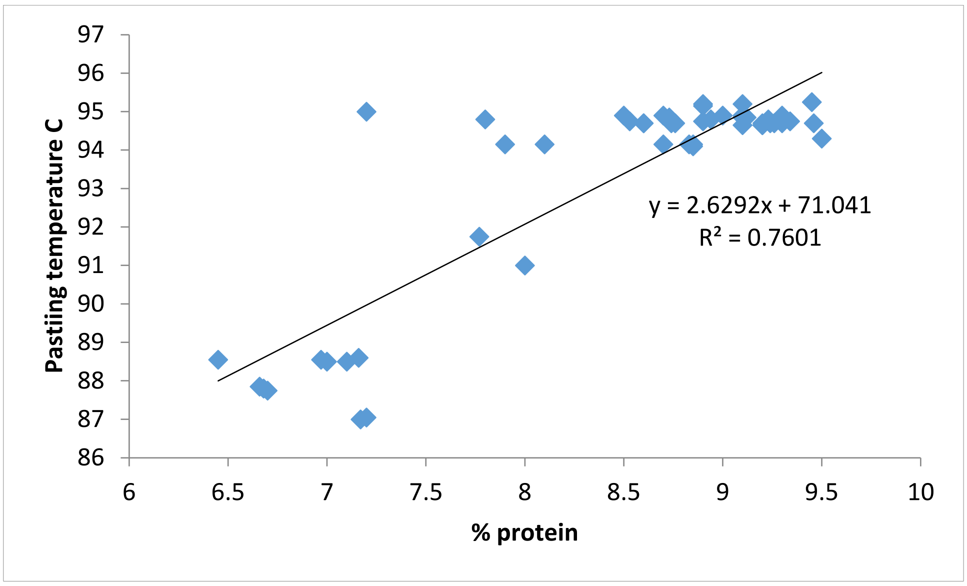

Figure 1 Correlation between % protein in rice samples and the corresponding pasting temperature.

Table 4 B Rice foreign materials and defects[1].

Brand number	Other classes of rice (%)	Inorganic extraneous materials (%)	Red kernels (%)	Red streaked kernels (%)	Immature kernels (%)	Odour[2]	Infestation		
							Free	Infested	Type[3]
1	0	0	0	0	0.5 ±0.12	N	X		
2	0	0	0	0	0.6 ±0.08	N	X		
3	0.1 ±0.17	0	0	0	0.7 ±0.01	N	X		
4	0 ±0.05	0	0	0	1.1 ±0.04	N	X		
5	0 ±0.05	0	0	0	0.8 ±0.36	N	X		
6	0.3 ±0.06	0 ±0.03	0	0.3 ±0.02	0.2 ±0.15	N	X		
7	0	0	0	0.1 ±0.01	0.4 ±0.27	N		X	STW
8	0	0	0	0	0.90 ±0.21	N	X		
9	0	0	0	0.1 ±0.05	1.6 ±0.71	N	X		
10	0	0	0	0.2 ±0.05	0.6 ±0.16	N	X		
11	0	0	0	0.2 ±0.15	1 ±0.35	N	X		
12	0	0	0	0.3 ±0.24	0.8 ±0.39	N	X		
13	0	0	0	0.2 ±0.11	0.7 ±0.15	N	X		
14	0	0	0	0.2 ±0.19	1.2 ±0.37	N	X		
15	0	0	0	0	0.4 ±0.45	N	X		
16	0	0	0	0.3 ±0.20	1 ±0.51	N	X		
17	0	0	0	0.2 ±0.03	0.2 ±0.08	N	X		
18	0	0	0	2.2 ±0.02	0.8 ±0.39	N	X		
19	0	0	0	0.7 ±0.36	0.6 ±0.13	N	X		
20	0	0	0	0.4 ±0.19	0.5 ±0.14	N	X		
21	0	0	0	0.1 ±0.01	1.6 ±0.17	N	X		
22	0	0	0	0.2 ±0.15	1.4 ±0.86	N	X		
23	0	0	0	0.4 ±0.12	0.4 ±0.01	N	X		
24	0	0	0	0.3 ±0.26	0.5 ±0.05	N		X	FB
25	0	0	0.1±0.08	0.4 ±0.05	0.5 ±0.08	N	X		

Note: [1]Values are expressed as Means ± Standard deviation. According to the Tukey test, the means that do not share the same letter in each column are not significantly different (p >0.05); [2] N: normal odour; [3] STW: Sawtoothed grain beetles; FB: Flour beetles.

The time corresponding to peak viscosity is known as peak time and is associated with the time required for rice cooking **[25]**. From Table 5 A, the medium-grain rice had significantly lower values (5.65 ±1.7 min) than long-grain rice (6.99 ±0.1 min). There were no significant differences in peak viscosity time between samples from the same type: medium or long rice grains. The degree of milling is one factor responsible for variation in peak time **[30]**. For energy consumption, rice with a low peak time is preferred **[1]**. It has been reported that the peak time for polished rice ranged between 5.4 to 7 min **[25]**.

There were wide variations in the trough viscosity values (Table 5 B), with the lowest viscosity in the temperature-holding stage **[4]**. The average trough viscosity for all samples was (830.4 ±370 cp). The average value for medium-grain rice was (1348.9 ±194.7 cp), which is higher than the average for long-grain rice (666.6 ±235.8 cp).

Table 5 (A) Rice samples RVA pasting parameters[1] (pasting temperature, peak viscosity, and peak time).

Brand number	Pasting temperature (°C)	Peak viscosity (cp)	Peak time (min)
1	88.2 ±0.95cd	2723 ±144.25a	5.5 ±0.0b
2	87.00 ±1.2d	2992 ±410.12a	5.6 ±0.05b
3	88.5 ±0.0c	2543 ±43.84a	5.7 ±0.04b
4	88.2 ±0.57cd	2589.5 ±60.10a	5.7 ±0.06b
5	88.2 ±0.57cd	2566 ±132.94a	5.7 ±0.04b
6	91 ±0.53b	1696.5 ±226.98b	5.7 ±0.14b
7	94.7 ±0.04a	580.5 ±14.85cde	7 ±0.0a
8	94.9 ±0.34a	192 ±16.97e	7 ±0.0a
9	94.2 ±0.0a	1006.5 ±19.09cd	7 ±0.0a
10	94.8 ±0.07a	696 ±7.07cde	7 ±0.0a
11	95.2 ±0.0a	421.5 ±470.22de	7 ±0.0a
12	94 ±0.0a	1046 ±25.46bcd	7 ±0.0a
13	94.7 ±0.0a	610 ±4.24cde	7 ±0.0a
14	94.8 ±0.14a	718 ±42.43cde	7 ±0.0a
15	94.9 ±0.04a	672 ±.3460cde	7 ±0.0a
16	94.8 ±0.04a	658.5±2.12cde	7 ±0.05a
17	94.1 ±0.08a	1081.5 ±119.50bc	7 ±0.0a
18	94.8 ±0.18a	686.5 ±159.1cde	7 ±0.0a
19	94.7 ±0.0a	583 ±144.25cde	7 ±0.0a
20	95.08 ±0.32a	450 ±14.14cde	7 ±0.0a
21	94.93 ±0.53a	241.5 ±50.21e	7 ±0.0a
22	94.7 ±0.0a	727.5 ±13.44cde	7 ±0.0a
23	94.8 ±0.14a	673 ±57.98cde	7 ±0.0a
24	94.8 ±0.0a	577 ±189.51cde	7 ±0.0a
25	94.9 ±0.0a	584 ±241.83cde	7 ±0.0a
All samples	93.19 ±2.73	1093 ±864	6.68 ±0.58
M-grain	88.58 ±1.43	2518 ±443	5.65 ±1.7
L-grain	94.64 ±0.38	642.4 ±251.2	6.99 ±0.01

Note: [1]Values are expressed as Means ± Standard deviation. According to the Tukey test, the means that do not share the same letter in each column are not significantly different (*p* >0.05).

A significant difference (*p* ≤0.05) between medium and long-grain rice was observed in terms of breakdown viscosity (Table 5 B). The breakdown viscosity is the difference between peak viscosity and trough viscosity, 1169 ±450 cp for medium rice grain and -3.16 ±11.87 cp for long rice grain. High breakdown viscosity is correlated with improved cooked rice palatability **[25]**.

The final viscosity is the viscosity reached at the end of the cooling stage **[5]**. All rice samples' average final viscosity value was 1840 ±847cp (Table 5 B). Medium-grain rice had significantly higher (*p* ≤0.05) final viscosity values (2887 ±365 cp) than long-grain rice (1510 ±666 cp). The setback viscosity is the difference between peak and final viscosity **[4]**. The average setback value for all rice samples was 732.4 ±552 cp. Medium-grain rice had significantly lower (*p* ≤0.05) values (371 ±712 cp) than long-grain rice (846.6 ±443.7 cp). The setback viscosity indicates starch's ability to retrograde **[31]**, whereas a lower setback viscosity indicates a lower tendency of starch to retrograde **[4]**.

Table 5 (B) Rice samples RVA pasting parameters[1](trough viscosity, final viscosity and set back).

Brand number	Trough viscosity (cp)	Breakdown viscosity (cp)	Final viscosity (cp)	Set back (cp)
1	1447.5 ±154.86ab	1275.5 ±10.6a	3104 ±8.49ab	381 ±135.79ghijk
2	1545 ±370.52a	1447.0 ±39.6a	2835 ±282.54abc	-147 ±141.42k
3	1267 ±76.37ab	1276.0 ±32.5a	2731 ±98.99abc	188 ±55.15hijk
4	1158 ±28.28abcd	1431.5 ±31.8a	2547 ±48.08bcd	-42.5 ±108.19jk
5	1210.5 ±9.19abc	1355.5 ±123.7a	2591 ±.6930bc	25 ±63.64ijk
6	1465.5 ±27.58ab	231.0 ±199b	3516 ±151.32a	1819.5 ±378.30a
7	587 ±14.14fghi	-6.5 ±0.71c	1122 ±.6930ghi	541.5 ±54.45efghi
8	194.5 ±17.68i	-2.5 ±0.71c	284 ±32.53j	92 ±15.56ijk
9	1007 ±.198bcdef	-0.50 ±0.71c	2829 ±1.41abc	1840.5 ±45.96a
10	703 ±8.49defgh	-7.0 ±1.41c	1433 ±57.98fgh	737 ±50.911efgh
11	791 ±45.26cdefg	31.0 ±50.9bc	2128.5 ±45.97cdef	1342 ±0abcd
12	1054 ±24.04bcdef	-8.0 ±1.41c	2411 ±70.71bcde	1365 ±45.26abc
13	615 ±2.83efghi	-5.0 ±1.41c	1094 ±24.04ghi	484 ±28.28fghij
14	723.5± 41.72defg	-5.5 ±0.71c	1630.5 ±71.42efgh	701.5 ±14.85cdefg
15	676 ±.3960efgh	-4.0 ±0.0c	1373.5 ±54.45fgh	701.5 ±14.85efgh
16	664 ±1.41efghi	-5.5 ±0.71c	1638.5 ±75.66iefgh	980 ±73.54bcdef
17	108 9±117.38abcde	-7.5 ±2.12c	2594 ±.28150bc	1489.5 ±194.45ab
18	690 ±159.81defgh	-3.5 ±0.71c	1610 ±373.35fgh	901 ±246.07cdefg
19	590 ±144.25fghi	-7.0 ±0.0c	1401 ±367.67fgh	818 ±223.45cdefg
20	454.5 ±12.02ghi	-4.5 ±2.12c	947.5 ±12.02hij	497.5 ±26.16efghij
21	244 ±50.91hi	-2.5 ±0.71	404.5 ±82.73ij	163 ±32.53hijk
22	734 ±13.43defg	-7.0 ±0.0c	1792 ±36.77defg	1064 ±23.33bcde
23	678.5 ±57.28efgh	-5.5 ±0.71c	1492 ±114.55fgh	819 ±56.57cdefg
24	582 ±189.51fghi	-5.0 ±0.0c	1360 ±.47730fgh	783.5 ±287.79cdefg
25	588 ±243.25fghi	-4.0 ±1.41	1139 ±439.82ghi	554 ±199.40efghi
All	830.4 ±370	278.3 ±549.0	1840 ±847	732.4 ±552
M-grain	1348.9 ±194.7	1169 ±450	2887 ±365	371 ±712
L-grain	666.6 ±235.8	-3.16 ±11.87	1510 ±666	846.6 ±443.7

Note: [1]Values are expressed as Means ± Standard deviation. According to the Tukey test, the means that do not share the same letter in each column are not significantly different ($p > 0.05$).

Dimensions Before and After Cooking

The length values of uncooked medium-rice grains (5.58 ±0.08 mm) with no significant differences between them (Table 6 A). However, the length values of uncooked long-rice samples (8.01 ±0.51 mm) varied considerably with significant differences. The average width value of uncooked medium-grain rice samples was 2.56±0.09 mm, significantly higher than long-grain rice (1.86 ±0.12 mm). There were significant differences in uncooked grain width within medium and long-grain rice groups. It has been reported that cooking quality is correlated with rice gain width **[31]**. The average thickness value of the medium-grain rice samples was 1.83 ± 0.03 mm, significantly higher than long-grain rice (1.56 ±0.07 mm). There were no significant differences in thickness values within medium and long-grain rice samples.

After cooking, the average length value of medium-rice grains was 8.95 ±0.34mm, significantly lower than long-grain rice (12.63 ±1.41mm). There were no significant differences within medium-grain rice samples; however, there were significant differences within long-grain samples. The average width value of cooked medium-grain rice was 3.39 ±0.23, significantly higher than long-grain rice (2.5 ±0.17). There were no significant differences between medium-grain rice samples and significant differences between long-grain samples.

The uncooked medium-grain rice L/T ratio (Table 6 B) was 3.05 ±0.06, significantly lower than long-grain rice (5.14 ±0.07). There were no significant differences in the L/T ratio between medium-grain rice and significant differences between long-grain samples. Uncooked medium-grain rice had an average L/W ratio of 2.21 ±0.12, significantly lower than long-grain rice (4.33 ±0.37). Similarly, there were no significant differences in the L/W ratio between uncooked medium-grain rice and significant differences between uncooked long-grain samples. The cooked medium-grain L/T ratio was 3.42 ±0.49, significantly lower than long-grain rice (6.73 ±.00). For cooked rice L/W ratio, medium-grain rice had an average value of 2.72 ±0.23, significantly lower than long-grain rice. For both cooked rice ratios (L/T and L/W), there were no significant differences between medium-grain rice and significant differences between long-grain rice. The L/W ratio determines the shape of rice grain: ratios >3 are considered slender shaped, while ratios ≤3 are considered bold, according to the International Rice Research Institute **[32]**.

One of the most important ratios is the elongation ratio **[33]**, which indicates rice cooking quality. The average value of the elongation ratio for all rice samples was 1.57 ±0.14. There were significant differences between rice samples. Elongation in one direction (length) is preferred to elongation in both length and width **[1]**. It was reported that storage conditions (time and temperature) affected the physicochemical properties of rice grains **[34]**.

Table 6 (A) Dimensions[1] of rice grains before and after cooking.

Sample number	Dimensions of rice grain					
	Before cooking			After cooking		
	L [2] (mm)	W (mm)	T (mm)	L (mm)	W (mm)	T (mm)
1	5.6 ±0.02	2.6 ±0.08	1.8 ±0.04	8.7 ±0.02	3.2 ±0.11	2.4 ±0.18
2	5.6 ±0.0	2.5 ±0.04	1.8 ±0.04	8.7 ±0.46	3.3 ±0.10	2.5 ±0.14
3	5.6 ±0.03	2.6 ±0.02	1.9 ±0.02	8.8 ±0.28	3.4 ±0.28	3.5 ±1.36
4	5.6 ±0.15	2.7 ±0.01	1.9 ±0.01	9 ±0.07	3.4 ±0.32	2.5 ±0.16
5	5.6 ±0.03	2.5 ±0.10	1.8 ±0.01	9 ±0.16	3.5 ±0.05	2.5 ±0.10
6	5.4 ±0.04	2.4 ±0.05	1.8 ±0.01	9.5 ±0.01	3.6 ±0.36	2.7 ±0.03
7	8 ±0.18	1.8 ±0.01	1.6 ±0.05	12.4 ±0.71	2.5 ±0.12	1.9 ±0.06
8	7.6 ±0.09	2.1 ±0.08	1.8 ±0.01	10.4 ±0.11	2.8 ±0.03	2.1 ±0.10
9	8.3 ±0.01	2 ±0.01	1.6 ±0.01	15.7 ±0.92	2.6 ±0.16	1.8 ±0.33
10	7.8 ±0.23	1.7 ±0.0	1.6 ±0.04	11.4 ±0.42	2.3 ±0.08	1.9 ±0.06
11	8.4 ±0.13	1.9 ±0.01	1.5 ±0.05	12.3 ±0.05	2.4 ±0.09	1.8 ±0.01
12	7.4 ±0.49	1.8 ±0.28	1.5 ±0.04	13.2 ±0.62	2.5 ±0.07	1.8 ±0.0
13	7.4 ±0.20	1.7 ±0.04	1.5 ±0.03	11.6 ±0.69	2.4 ±0.13	1.8 ±0.16
14	8 ±0.01	1.9 ±0.01	1.6 ±0.03	13.1 ±0.42	2.4 ±0.05	1.8 ±0.03
15	7.8 ±0.16	1.8 ±0.06	1.6 ±0.01	11.8 ±0.29	2.4 ±0.05	1.9 ±0.09
16	8.5 ±0.27	2 ±0.01	1.6 ±0.06	14.6 ±0.19	2.5 ±0.14	1.9 ±0.01
17	7.7 ±0.05	1.8 ±0.01	1.5 ±0.04	13 ±0.7	2.5 ±0.02	1.9 ±0.04
18	8.6 ±0.09	1.8 ±0.0	1.6 ±0.04	13.5 ±0.31	2.7 ±0.05	2 ±0.04
19	8.5 ±0.0	1.8 ±0.12	1.6 ±0.07	13.1 ±0.20	2.6 ±0.0	1.9 ±0.11
20	8.6 ±0.14	1.8 ±0.0	1.5 ±0.01	13 ±0.07	2.5 ±0.13	2 ±0.05
21	7 ±0.19	2 ±0.01	1.6 ±0.06	9.6 ±0.26	2.9 ±0.08	2.2 ±0.22
22	8.5 ±0.08	1.8 ±0.04	1.5 ±0.03	13 ±0.24	2.6 ±0.07	1.9 ±0.09
23	8.4 ±0.18	1.8 ±0.06	1.5 ±0.05	13 ±0.03	2.3 ±0.18	1.9 ±0.04
24	8.4 ±0.17	1.9 ±0.06	1.6 ±0.03	13.7 ±0.13	2.4 ±0.03	2 ±0.07
25	7.6 ±0.35	1.8 ±0.04	1.6 ±0.01	11.6 ±0.03	2.3 ±0.15	1.9 ±0.04
All samples	7.34 ±1.14	2.02 ±0.32	1.63 ±0.13	11.75 ±2.01	2.71 ±0.42	2.09 ±0.44
M-grain	5.58 ±0.08	2.56 ±0.09	1.83 ±0.03	8.95 ±0.34	3.39 ±0.23	2.68 ±0.56
L-grain	8.01 ±0.51	1.86 ±0.12	1.56 ±0.07	12.63 ±1.41	2.5 ±0.17	1.90 ±0.13

Note: [1]Values are expressed as Means ± Standard deviation; [2]L: The length, W: width, and T: thickness.

Table 6 (B) Dimensions[1] of rice grains (ratio) before and after cooking.

Sample number	Dimensions of rice grain				
	Ratios				Elongation
	Uncooked		Cooked		
	L[2]/T	L/W	L/T	L/W	
1	3.1 ±0.06	2.1 ±0.06	3.6 ±0.26	2.8 ±0.09	1.5 ±0.0
2	3.1 ±0.11	2.2 ±0.04	3.4 ±0.37	2.6 ±0.06	1.3 ±0.24
3	3 ±0.05	2.3 ±0.25	2.8 ±1.17	3.1 ±0.37	1.6 ±0.04
4	3 ±0.06	2.1 ±0.00	3.6 ±0.19	2.7 ±0.23	1.6 ±0.04
5	3.1 ±0.04	2.2 ±0.10	3.6 ±0.08	2.6 ±0.08	1.6 ±0.04
6	3 ±0.04	2.2 ±0.06	3.5 ±0.04	2.7 ±0.28	1.7 ±0.01
7	5.2 ±0.04	4.5 ±0.07	6.4 ±0.58	4.9 ±0.52	1.5 ±0.57
8	4.2 ±0.16	3.6 ±0.17	5 ±0.28	3.7 ±0.0	1.4 ±0.04
9	5.2 ±0.04	4.2 ±0.02	8.9 ±1.14	6.1 ±0.01	1.9 ±0.11
10	5 ±0.01	4.2 ±0.13	6 ±0.41	4.9 ±0.34	1.5 ±0.10
11	5.7 ±0.11	4.5 ±0.05	7 ±0.19	5.3 ±0.31	1.5 ±0.05
12	4.8 ±0.42	4.2 ±0.35	7.3 ±0.35	5.4 ±0.10	1.8 ±0.21
13	4.8 ±0.04	4.3 ±0.21	7.3 ±0.02	4.9 ±0.56	1.6 ±0.05
14	5.1 ±0.11	4.2 ±0.05	7.4 ±0.12	5.4 ±0.28	1.6 ±0.06
15	5 ±0.06	4.3 ±0.05	6.3 ±0.18	4.9 ±0.01	1.5 ±0.06
16	5.5 ±0.37	4.3 ±0.16	7.9 ±0.04	5.9 ±0.42	1.7 ±0.04
17	5 ±0.11	4.3 ±0.01	6.8 ±0.95	5.2 ±0.32	1.7 ±0.08
18	5.5 ±0.18	4.7 ±0.05	6.9 ±0.28	5 ±0.02	1.6 ±0.06
19	5.5 ±0.25	4.6 ±0.30	6.9 ±0.49	5.1 ±0.08	1.5 ±0.03
20	5.7 ±0.12	4.9 ±0.08	6.7 ±0.21	5.2 ±0.29	1.5 ±0.02
21	4.4 ±0.04	3.4 ±0.09	4.4 ±0.33	3.3 ±0.19	1.4 ±0.0
22	5.5 ±0.18	4.6 ±0.13	7 ±0.21	5.1 ±0.04	1.5 ±0.01
23	5.4 ±0.06	4.6 ±0.05	7 ±0.14	5.6 ±0.43	1.6 ±0.03
24	5.4 ±0.01	4.4 ±0.23	7 ±0.18	5.7 ±0.01	1.6 ±0.05
25	4.8 ±0.18	4.2 ±0.27	6 ±0.12	4.9 ±0.30	1.5 ±0.07
All samples	4.64 ±0.98	3.82 ±0.92	5.94 ±1.69	4.51 ±1.18	1.57 ±0.14
M-grain	3.05 ±0.06	2.21 ±0.12	3.42 ±0.49	2.72 ±0.23	1.56 ±0.15
L-grain	5.14 ±0.07	4.33 ±0.37	6.73 ±1.00	5.08 ±0.68	1.57 ±0.14

Note: [1]Values are expressed as Means ± Standard deviation; [2]L: The length, W: width, and T: thickness.

Whiteness, Transparency, and Degree of Milling

Rice is usually consumed in the milled form **[33]**, where the bran layers are removed. Because proteins and lipids are located in the bran, milling increases starch content and decreases lipids and protein content **[36]**. Therefore, the composition and pasting properties are changed, making reporting the degree of milling essential when evaluating pasting properties **[3]**. Satake degree of milling (SDM) is the commonly used method to determine the degree of milling **[3]**. Measurement is based on measuring whiteness and transparency and calculating SDM using a special algorithm. SDM express results in a value between 0 to 199, where 0 represents brown rice, and 199 represents white wholly milled rice **[35]**. Table (7) shows the whiteness, transparency, and degree of milling for different rice samples. The average whiteness value of medium-grain rice was 40.84 ±1.62, significantly higher ($p \leq 0.05$) than long-grain rice (32.09 ±4.28). There were no significant differences between medium-grain rice samples, while there was a significant difference between long-grain rice samples. Medium-grain rice samples' transparency average was 3.03 ±0.44, significantly higher ($p \leq 0.05$) than long-grain rice (2.49 ±0.41). There were significant differences ($p \leq 0.05$) between and within medium and long-grain rice samples. The average milling degree for medium grain was 100.83 ±6.39, significantly higher than long grain rice, 57.92 ±19.1. There were no significant differences between medium-grain rice, but there are between long-grain rice.

Table 7 Whiteness, transparency, and milling degrees[1] of rice samples.

Brand number	Whiteness	Transparency	Milling degree
1	42.30 ± .28a	3.04 ±0.09abcd	107.5± 0.71a
2	38.75 ±0.48ab	3.44 ±0.04a	94.5 ±6.36ab
3	39.90 ±2.55a	3.16 ±0.34ab	97.5 ±9.19ab
4	41.95 ±0.07a	3.13 ±0.07abc	106.5 ±0.71a
5	40.75 ±1.48a	3.22 ±0.08ab	101.5 ±6.36ab
6	41.40 ±0.14a	2.18 ±0.21fghij	97.5 ±2.12ab
7	30.55 ±0.5de	2.87 ±0.01abcdef	52.5 ±2.12de
8	33 ±0.71de	2.96 ±0.01abcde	65 ±2.83cde
9	38 ±1.56abc	1.81 ±0.08ij	82 ±7.07bc
10	30.10 ±0.14e	2.64 ±0.08bcdefg	49.5 ±0.71de
11	31.15 ±0.5de	2.79 ±0.26abcdef	55.5 ±4.95de
12	38.15 ±0.07abc	1.96 ±0.13ghij	81.5 ±0.71bc
13	32.3 ±0.14de	2.80 ±0.02abcdef	60.5 ±0.71cde
14	33.90 ±0.42cde	2.82 ±0.04abcdef	68.5 ±2.12cd
15	29.55 ±0.5e	2.46 ±0.04cdefghi	46.5 ±2.12de
16	35.10 ±0.71bcd	1.58 ±0.08j	67.5 ±3.54cde
17	41.35 ±0.07a	2.42 ±0.08defghi	98.5 ±0.71ab
18	31.55 ±0.35de	2.73 ±0.28bcdef	56.5 ±3.54de
19	31.20 ±0.85de	2.71 ±0.26 bcdef	55 ±5.66de
20	30.20 ±0.28e	2.69 ±0.14bcdef	50.5 ±0.71de
21	20.95 ±0.92f	1.91 ±0.00hij	4.5 ±3.54f
22	31.15 ±0.64de	2.85 ±0.01abcdef	56 ±2.83de
23	30.05 ±0.07e	2.85 ±0.18bcdefgh	49 ±1.41de
24	31.70 ±3.82de	2.6 ±0.3bcdefgh	56 ±19.1de
25	29.55 ±1.06e	2.33 ±0.38efghi	45 ±7.07e
All samples	34.19 ±5.35	2.62 ±0.47	68 ±25.05
M-grain	40.84 ±1.62	3.03 ±0.44	100.83 ±6.39
L-grain	32.09 ±4.28	2.49 ±0.41	57.92 ±19.1

Note: [1]Values are expressed as Means ± Standard deviation. According to the Tukey test, the means that do not share the same letter in each column are not significantly different ($p > 0.05$).

PCA biplot

Figure 2 shows the PCA biplot for different rice samples using the first two principal components responsible for 99.97% of the variation between samples. The first two principal components separated the rice sample into two distinct groups: one for medium-grain rice and the other for long-grain rice. Medium-grain rice samples are closer to each other than long-grain rice, indicating similar quality. Medium grain rice correlates with high milling degree values, peak viscosity, starch, trough, width, and thickness after cooking. On the other hand, long-grain rice is correlated with high values of pasting temperature, peak time, protein content, setback, uncooked and cooked L/T, and L/W ratios. A previous study reported correlations between pasting properties, cooking, and appearance quality **[37]**.

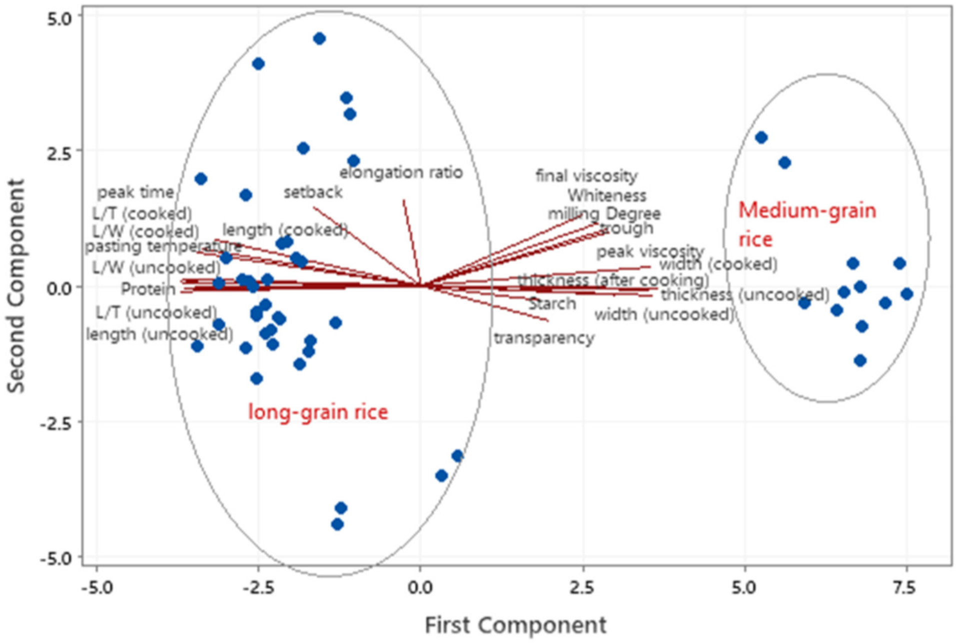

Figure 2 PCA biplot of different parameters tested.

CONCLUSION

All rice samples tested comply with the Jordanian standard except for chalky kernels (four brands), heat-damaged kernels (one brand), and insect infestation (two brands). All samples that exceeded specifications were from the long-grain rice. Medium-grain rice has higher whiteness (40.84), transparency (3.03), milling degree (100.83), moisture (12.01%), starch (91.45%), peak viscosity (2518 cp), trough (1348.9 cp), and final viscosity (2887 cp) than long-grain rice (32.09, 2.49, 57.92, 10.19%, 90.18%, 642.4 cp, 666.6 cp, and 1510 cp, respectively). On the other hand, long-grain rice has a higher protein (8.87%), pasting temperature (94.64 °C), and peak time (6.99 min) than medium-grain rice (7.02%, 88.58 °C, 5.69 min, respectively). There were significant differences in pasting and chemical composition parameters within the two groups of grain sizes. The average elongation ratio for all samples was 1.57 ±0.14, with significant differences between different brands. Due to the higher pasting temperature and peak time, long-grain rice requires more energy during cooking than medium-grain rice. The limitations of this research are not measuring the cooked rice by instrumental texture and sensory evaluation and not measuring the amylose content. Further studies are recommended to measure cooked rice by instrumental texture and sensory evaluation and to measure amylose content to correlate with what had been found in this study.

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This article does not contain any studies that would require an ethical statement.

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