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Quality characterization of a pigmented indigenous rice variety in contrast to a modern variety: Importance in consumer frame of reference

Vidya D'cruz, C Monisha, Narendra Pangi, Ashish Rawson, N Venkatachalapathy and KA Athmaselvi

Abstract
The grain quality of a traditional variety, Karuppu kavuni or black rice was evaluated and compared with a modern variety, BPT 5204. Physical, physicochemical, milling, cooking, and pasting property characterization was done for both varieties. The physical parameters include size, shape, color, and hardness and physicochemical parameters include amylose and gel consistency. The final research findings of most of these parameters indicated a significant difference ($p<0.05$) between them. The traditional variety showed higher amylose content (20.08 ± 0.16), soft gel consistency, greater grain volume (13.47 ± 1.74) and surface area (3.81 ± 0.11), soft and flaky cooked rice texture, and high pasting temperature (79.59^{o}C). The softness of cooked karuppu kavuni rice makes it suitable for the preparation of many dishes including culinary dishes and desserts. The modern variety exhibited good size and shape (L:B ratio - 2.66 ± 0.13), hardness (5.04 ± 0.41), milling yield (71.09 ± 0.63), and a whiter appearance. The outcomes of this research provided insights into the importance of traditional rice varieties in terms of various quality parameters from the viewpoint of consumers.

Keywords: Rice, traditional variety, modern variety, physical characteristics, pasting properties

1. Introduction
Rice is an essential staple food that is produced and consumed in most of the regions across the globe. World rice production in 2021-22 is approximated to be 714.2 million metric tonnes (MMT) and the milled rice equivalent is 522.5 MMT, ranking second among food crops (FAO, 2022) [4]. It is the principal energy source in the diet of most countries in Asia, Africa, and North and South America continents (FAO, 2004) [4].
Numerous paddy varieties are found all over the world which includes traditional or indigenous varieties consumed by humans from ancient times as well as modern varieties. Extensive research on rice has been done to improve the quality of rice production with better stress resistance and milling yield in view of enhancing the productivity of rice to satisfy the demands of the increasing population. This expedited the release of many modern varieties. While comparing traditional and modern varieties, the former has a less cost of production (Loida *et al.*, 2010) [8] but is produced and consumed less due to more demand for the latter. Traditional varieties were consumed for their numerous health benefits and the introduction of modern varieties restricted these benefits from reaching the human population.
Comparative studies on the health benefits of traditional varieties, when compared to modern varieties, have been conducted by few researchers (Ashokkumar *et al.*, 2020; Katara *et al.*, 2008; Malini *et al.*, 2018) [16, 24, 27]. Karuppu Kavuni is a pigmented traditional rice variety of Tamil Nadu and it has been reported to have nutritional and health benefits including anti-oxidant, anti-diabetic and anti-arthritic activities (Malini *et al.*, 2018) [27]. However, a lack of research knowledge exists between their quality characterisation in terms of physical, cooking and pasting properties. This study will bring insights into the comparison of different quality attributes of both varieties and help the consumers to choose the suitable product according to their needs. This might help in improving their popularity.
Hence, this study was carried out to evaluate the quality variation between an Indian traditional variety, Karuppu kavuni and a modern variety, BPT with regard to their physical, physicochemical, milling, cooking and pasting characteristics.

2. Materials and Methodology

2.1 Sample preparation

Two paddy varieties, Karuppu kavuni (KK), a traditional variety of Tamil Nadu, and BPT, a ruling variety were selected for the study. KK was procured from local farmers of Thanjavur district, TN and BPT from the local market. They were dried under shade to a moisture of 12-14% for safe storage. Paddy was cleaned by manual winnowing to remove any impurities, chaff, or dust and stored at room temperature.

2.2 Milling conditions

Initially, 300 grams of paddy was shelled to remove the husk by a laboratory sheller to yield brown rice and then the bran portion was removed by polishing using a laboratory polisher (Satake Corporation, Japan) to yield final milled rice. The degree of milling was 8 ± 0.5%. Time taken for obtaining this degree was noted. The milling process was such that the shelling loss was less than 1.5 g.

2.2.1 Milling characteristics

The quantity of paddy taken for milling and the quantity of husk, brown rice, bran, and polished rice obtained were noted and the following parameters were calculated from them according to Bao (2018) [17] and Gujral *et al*. (2007) [22] with slight modifications.

$$\text{Husk (\%)} = \frac{\text{weight of husk collected}}{\text{total weight of paddy taken}} \times 100 \quad (1)$$

$$\text{Brown rice (\%)} = \frac{\text{mass of brown rice after shelling}}{\text{mass of paddy taken for shelling}} \times 100 \quad (2)$$

$$\text{Bran (\%)} = \frac{\text{Mass of bran removed}}{\text{Mass of brown rice taken}} \times 100 \quad (3)$$

$$\text{Nooks (\%)} = \frac{\text{Mass of nooks obtained}}{\text{Mass of brown rice taken}} \times 100 \quad (4)$$

$$\text{Milled Rice Yield (\%)} = \frac{\text{Mass of total milled rice obtained}}{\text{The total mass of paddy taken}} \times 100 \quad (5)$$

2.3 Physical properties

2.3.1 Size, shape and weight

A rice grain's size and shape can be described using its length (L), breadth or width (W), diameter or thickness (T). The equivalent diameter, sphericity, grain volume, surface area, and aspect ratio were further evaluated using the following equations (Mohsenin, 1986; Jain and Bal, 1997; Maduako and Faborode, 1990) [10, 5, 9].

$$\text{Equivalent diameter}, D_p(\text{mm}) = \left(L \frac{(W+T)^2}{4}\right)^{\frac{1}{3}} \quad (6)$$

$$\text{Sphericity}, \varphi = \frac{(\text{LWT})^{\frac{1}{3}}}{\text{L}} \quad (7)$$

$$\text{Grain volume, V (mm}^3) = 0.25\left[\left(\frac{\pi}{6}\right)\text{L}(\text{W}+\text{T})^2\right] \quad (8)$$

$$\text{Surface area, S (mm}^2) = \frac{\pi \text{BL}}{(2\text{L}-\text{B})}^2, \text{where B} = \sqrt{\text{WT}} \quad (9)$$

$$\text{Aspect ratio}, \text{R}_\text{a} = \frac{\text{W}}{\text{L}} \quad (10)$$

By measuring the weight of a known volume of paddy with a graduated measuring cylinder and applying the mass-to-volume relationship, the bulk density was found (Fraser *et al*., 1978) [2]. 1000 head of rice were physically counted and weighed to determine the weight of 1000 grains.

2.3.2 Colour

Colour measurement was done according to the CIE colour model by using a HunterLab colorimeter. Using black and white tiles provided by HunterLab, the equipment was calibrated. Following that, the sample of rice grains was put in the sample holder and covered with the lid. Reading was taken as L*, a* and b* values. The measurement was done for each sample in triplicates. (Purohit & Rao, 2017) [33].

2.3.3 Hardness

Hardness was measured by placing one rice grain under the probe of the hardness tester (Kiya Seisakusho) and measuring the force required for rupturing the grain (Kongseree *et al*., 1972) [25].

2.4 Physicochemical properties

2.4.1 Amylose

Amylose was determined according to a simplified procedure by Juliano (1971) [6]. 100 mg finely ground rice flour (100 mesh size) was weighed into 50ml test tubes. It was placed in water bath at 100ºC after addition of 1 ml ethanol and 9 ml 1N NaOH, for 10 minutes. It was brought to room temperature and with several cycles of washings from test tubes, it was put to a 100 ml standard flask. It was mixed well and then pipetted 5 ml from this solution to a separate 100 ml standard flask. 2 ml Iodine solution (0.2 g iodine and 2 g KI2 in 100 ml distilled water) and 1N acetic acid (1 ml) were added and the volume was brought to the 100 ml level using distilled water. The contents were shaken and kept aside for 20 minutes. Absorbance was read by a Shimadzu UV-1800 spectrophotometer at 620 nm. The following equation was then used to determine the amylose content.

$$\text{Amylose (\%)} = \frac{\text{OD}\times 20}{0.284} \quad (12)$$

Where OD is the optical density value at 620 nm, 20 is the dilution factor and 0.286 is the conversion factor.

2.4.2 Gel consistency

According to Cagampang *et al*., a gel consistency test was conducted (1973). In a test tube, 100mg of pulverized rice powder was taken and 0.025% solution of thymol blue in 95% ethanol (0.2 ml) was added. The contents were shaken for suspending the starch. 2 ml 0.2N KOH was added and vortexed for dispersing the contents It was brought to room temperature, refluxed in boiling water for 8 minutes, and then submerged in ice water for 15 minutes. The tubes were then placed horizontally over a scaled paper, and after 60 minutes, the distance travelled by the gel was measured.

2.5 Cooking quality

2.5.1 Optimum time for cooking

The Ranghino method was used to determine the optimum time for cooking the grains (Mohapatra & Bal, 2006) [6]. 2 grams of polished head rice along with 10 ml deionised water was taken in a cooking tube and placed in a boiling water bath. It was allowed to cook for 20 minutes after which some kernels were taken from the cooked sample. It was pressed between two microscopic slides and observed for any white core. The time taken until no opaque core is visible was noted as the optimum cooking time.

2.5.2 Cooked rice volume
10g polished rice along with 25 ml distilled water was taken in cooking tubes and is cooked for 45 minutes by placing in boiling water bath. During cooking the tubes were enclosed with glass balls to avoid evaporation. After cooking, it was cooled and the final volume was observed. The results were expressed in ml/100g of rice (Sowbhagya, 1996) [15].

2.6 Cooked rice quality
2.6.1 Colour
The same procedure for milled rice colour measurement was followed.

2.6.2 Texture
Textural attributes of cooked rice were analyzed by a TA HD plus Texture Analyser using a two-cycle compression programme with a P/35 cylinder probe. Three cooked grains were placed under the probe on a base plate. The speed settings were set at 0.5, 0.5 and 2 mm/s for pre-test, test and post-test speeds respectively. A 75% strain was given to the kernels. The different textural attributes were then computed by Exponent Stable Micro Systems software (Tao *et al*., 2020) [35].

2.7 Pasting properties
With the use of a Rapid Visco Analyzer, the rheology of the rice flour was evaluated. (Anton-Paar Rheometer, Austria) according to Nawaz *et al*. (2016) [31]. Initially, 2g rice flour was weighed along with 25ml distilled water was vortexed in a centrifuge tube and positioned in the sample canister of the rheometer. The spindle rotation was set at 160 rpm. A starch gelification temperature ramp-up programme was run (50 to 95 ºC, holding at 95 ºC and cooling to 50 ºC). The peak, breakdown, setback and final viscosity were computed by Rheoplus software.

2.8 Statistical Analysis
Results of this experiment were analysed using IBM SPSS Statistics 28.0.0.0 using Tukey's test for grouping at a level of significance of 5%.

3. Results and Discussion
3.1 Milling characteristics
Various milling parameters were computed and shown in Table 1. Time taken for obtaining an 8% degree of bran removal by the abrasive polisher took 30 seconds for KK whereas BPT needed 3 minutes and 30 seconds for the same. This may be due to the higher hardness value of BPT (discussed in the physical characteristics section). Hard grains require more time and energy for polishing (Puri *et al*., 2014). Nooks represent the broken particles and immature grains that get separated along with the bran due to their small size. It hasn't shown any significant difference among the varieties. Milled rice yield (MRY) was significantly higher for BPT mainly due to the presence of a remarkably lesser percent of husk. The same reason can be accounted for the higher percentage of brown rice in BPT. This means it requires less mass of paddy to yield a given amount of brown rice than KK. MRY should be at least more than 50% to be considered economical and hence both varieties have a desired economy. MRY is usually affected by moisture content, variety, environmental factors and milling machinery (Bao, 2018; Nasirahmadi *et al*., 2014) [17]. Overall, better milling characteristics were shown by the modern variety.

Table 1: Milling characteristics of Karuppu Kavuni (KK) and BPT varieties

Parameter	KK	BPT
Husk (%)	26.91 ± 1.7^a	20.8 ± 0.79^b
Brown rice (%)	73.03 ± 2.02^b	77.82 ± 1.01^a
Bran (%)	8.03 ± 0.34^a	8.52 ± 0.52^a
Nooks (%)	1.37 ± 1.15^a	0.84 ± 0.21^a
Milled Rice yield (%)	65.73 ± 2.74^b	71.09 ± 0.63^a

Notes: Means within rows with similar superscripts represent insignificantly different (p<0.05)

Fig 1: Various milling fractions of Karuppu kavuni (top row) and BPT (bottom row)

3.2 Physical characteristics
The appearance of a kernel depends on its size and shape. The size of a rice variety is defined by its length and shape is defined by its L:B ratio. According to the scale given by Singh (2000), the size of KK and BPT is medium and short respectively whereas both have a medium shape. Any significant differences were not found in their length, thickness and sphericity whereas the width, grain volume, surface area, 1000 grain weight and aspect ratio were significantly higher for KK. Also, BPT has a higher bulk density. Hence, it is evident that BPT is comparatively smaller and denser rice. Also, it has a higher hardness value which gives it a compact structure and thus yields better milling characteristics.

Table 2: Physical characteristics of Karuppu kavuni (KK) and BPT

Parameter	KK	BPT
Length (mm)	5.83 ± 0.5[a]	5.07 ± 0.06[a]
Width (mm)	2.57 ± 0.21[a]	1.91 ± 0.07[b]
L:B ratio	2.27 ± 0.07[b]	2.66 ± 0.13[a]
Thickness or Diameter (mm)	1.58 ± 0.12[a]	1.35 ± 0.09[a]
Equivalent Diameter	2.93 ± 0.12[a]	2.38 ± 0.07[b]
Sphericity	0.49 ± 0.03[a]	0.46 ± 0.02[a]
Grain Volume (mm^3)	13.47 ± 1.7 4[a]	7.19 ± 0.62[b]
Surface Area (mm^2)	3.81 ± 0.11[a]	2.99 ± 0.18[b]
Aspect Ratio	0.44 ± 0.01[a]	0.38 ± 0.02[b]
Hardness (kg)	3.81 ± 0.61[b]	5.04 ± 0.41[a]
Bulk density (g/cm3)	0.77 ± 0.01[b]	0.80 ± 0.01[a]
One grain weight (g)	0.02 ± 0.00[a]	0.01 ± 0.00[b]
1000 grain weight (g)	19.26 ± 1.34[a]	10.4 ± 0.12[b]

Notes: Means within row with similar superscripts represent insignificantly different (p<0.05)

3.3 Physico-chemical characteristics

Table 3: Physico-chemical characteristics of Karuppu kavuni (KK) and BPT

Parameter	KK	Category	BPT	Category
Amylose (%)	20.08 ± 0.16[a]	Intermediate	17.46 ± 0.11[b]	low
Gel consistency (cm)	4.7 ± 1.15[a]	Medium	2.4 ± 0.1[b]	hard

Notes: Means within rows with similar superscripts represent insignificantly different (p<0.05).

According to Kumar and Khush (1986), KK fall in intermediate (20-25%) and BPT in the low amylose category (10-19%). Amylose is an essential parameter which directly impacts the rice eating quality. Generally, intermediate amylose content rice is more ideal for consumers since it produces soft, palatable and flaky rice (Cuevas *et al*., 2018) [1]. The gel consistency test evaluates the cooked rice flour's cold paste viscosity. Graham (2002) [3] categorised them into soft, medium and hard gel consistency having gel lengths>60 mm, 41-60 mm and <40 mm respectively. Results indicated that KK gel is softer than BPT and hence gives more tender cooked grains, which is preferred by consumers (Pokharel *et al*., 2020).

3.4 Cooking characteristics

Table 4: Cooking quality parameters of Karuppu kavuni (KK) and BPT

Parameter	KK	BPT
Cooking Time (minutes)	22.67 ± 1.53[b]	16.33 ± 0.58[b]
Cooked rice volume (ml/100g)	403.3 ± 1.53[b]	436.7 ± 0.58[a]

Notes: Means within rows with similar superscripts represent insignificantly different (p<0.05)

Amylose% has an inverse relation and hardness has a direct correlation to cooking time. In contrast to the previous studies, the less hard and lesser amylose-containing variety (BPT) took less time to cook. This variation may be due to the less degree of removal of bran from the KK grain surface (Table 1). This leads to complex formation between starch in endosperm and proteins and lipids in the bran portion, resulting in longer cooking time (Meullenet *et al*., 2000) [28]. From the cooked rice volume values, KK can be graded as good and BPT as a very good cooking quality rice according to the categories given by Sowbhagya *et al*., (1996) [15]. During cooking, rice absorbs water and expands in volume. A higher volume of BPT indicates the requirement for more water for its cooking.

3.5 Cooked rice texture and colour

The texture and colour of cooked grains is a crucial parameter which determines consumer acceptability. The different textural parameters were obtained from the texture analysis of cooked grains. Similar to the raw grains, cooked grains also showed a significantly greater hardness for BPT. It indicates the requirement of more force to disintegrate it while compressing between teeth. This might affect its palatability (Bello *et al*., 2006). The cooked KK grains were soft and sticky than BPT as indicated by its high adhesiveness value (12.4 ± 8.77 g.sec). However, the difference was insignificant. Resilience is the recovery of grains from being deformed and it showed no significant differences among them while springiness, cohesiveness, gumminess and chewiness were remarkably higher for BPT. This means it requires more energy to disintegrate and chew to a swallowing stage. The tenderness of KK rice makes it suitable for preparation of porridge, puddings and other desserts.

Table 5: Cooked rice textural attributes of Karuppu kavuni (KK) and BPT

Parameter	KK	BPT
Hardness (g)	807.9[a] ± 54.1	821.3[a] ± 61.7
Adhesiveness (g.sec)	12.4[a] ± 8.77	-0.47[a] ± 0.31
Springiness	0.5[b] ± 0.05	0.67[a] ± 0.04
Cohesiveness	0.21[b] ± 0.00	0.28[a] ± 0.02
Gumminess	197.8[a] ± 27.7	233.47[a] ± 14.91
Chewiness	100.3[b] ± 24.4	158.4[a] ± 17.9
Resilience	0.08[a] ± 0.01	0.1[a] ± 0.02

Notes: Means within rows with similar superscripts represent insignificantly different (p<0.05)

Table 6: Colour values of raw and cooked grains of Karuppu kavuni (KK) and BPT

Parameter		KK	BPT
Raw rice	L*	42.55 ± 0.04[b]	65.10 ± 0.14[a]
	a*	3.55 ± 0.04[a]	2.34 ± 0.08[b]
	b*	4.42 ± 0.04[b]	14.28 ± 0.03[a]
Cooked rice	L*	29.39 ± 0.1[b]	63.64 ± 0.04[a]
	a*	6.33 ± 0.05[a]	-0.9 ± 0.00[b]
	b*	3.67 ± 0.02[a]	3.28 ± 0.02[b]

Notes: Means within rows with similar superscripts represent insignificantly different (p<0.05)

Colour of rice is represented as L*, a* and b* values for uncooked and cooked grains and are shown in Table 6. L* is brightness measurement with values ranging from 0 (black) to 100. (white). Mostly, white-coloured rice is preferred by consumers due to its attractive appearance. BPT gave more whiteness (L*) than KK and hence might be more appealing. Lightness (L*) was observed to decrease during cooking and a large variation was seen in the case of KK. The initial presence of white core might have been more in KK than BPT, which completely disappeared on cooking. This might have caused such a variation. The cooked KK colour became more reddish (increase in a*) and bluish (decrease in b*) whereas cooked BPT became greener (decrease in a*) and bluish (decrease in b*) (Table 6). A decrease in b* may be due to the leaching of yellow colour into the cooking water (Bett-Garber *et al*., 2012). For rice with more degree of polishing, the water uptake will be more, resulting in the penetration of grain surface colours into deeper layers (Jung

Kwang Park *et al*., 2001) [23]. This gives less red and yellow on cooked rice surface as observed for BPT, which was having a more degree of polishing.

3.6 Pasting properties

Table 7: Pasting attributes of Karuppu kavuni (KK) and BPT paddy varieties

Parameter		KK	BPT
Viscosity (cP)	Peak	2014	618.2
	Trough	4369	3848
	Breakdown	1636	589.8
	Final	4747	3877
	Setback	2,733	3,258
Peak Viscosity Time (min)		8.33	8.33
Pasting Temperature (ºC)		50.65	74.48

The findings of the pasting property analysis are shown in Figure 3 and values are given in Table 7. The starch molecules in the flour are gelatinized due to the action of heat and moisture resulting in the formation of a viscous solution (Dias *et al*., 2011) [21]. All the viscosity values were found to be lower for BPT than KK except for setback viscosity (SV) but the time to reach peak viscosity was the same for both. Breakdown viscosity (BV) values indicate the extent of swollen grains breakdown or starch crystallinity (Singh *et al*., 2006). Here, KK showed high BV due to its greater starch crystallinity. Also, rice hardness is inversely related to BV (Thanompolkrung *et al*., 2017) [36]. The findings of this study agreed with this statement (Table 2). The propensity of molecules of starch to undergo retrogradation during cooling stage is explained by setback viscosity (SBV) and BPT was observed to have more tendency (Lee *et al*., 2012) [26]. The pasting temperature (PT) is the least temperature required for cooking the flour and rice giving more cooked volume (BPT) gives less PT due to more water uptake (Nawaz *et al*., 2016) [31].

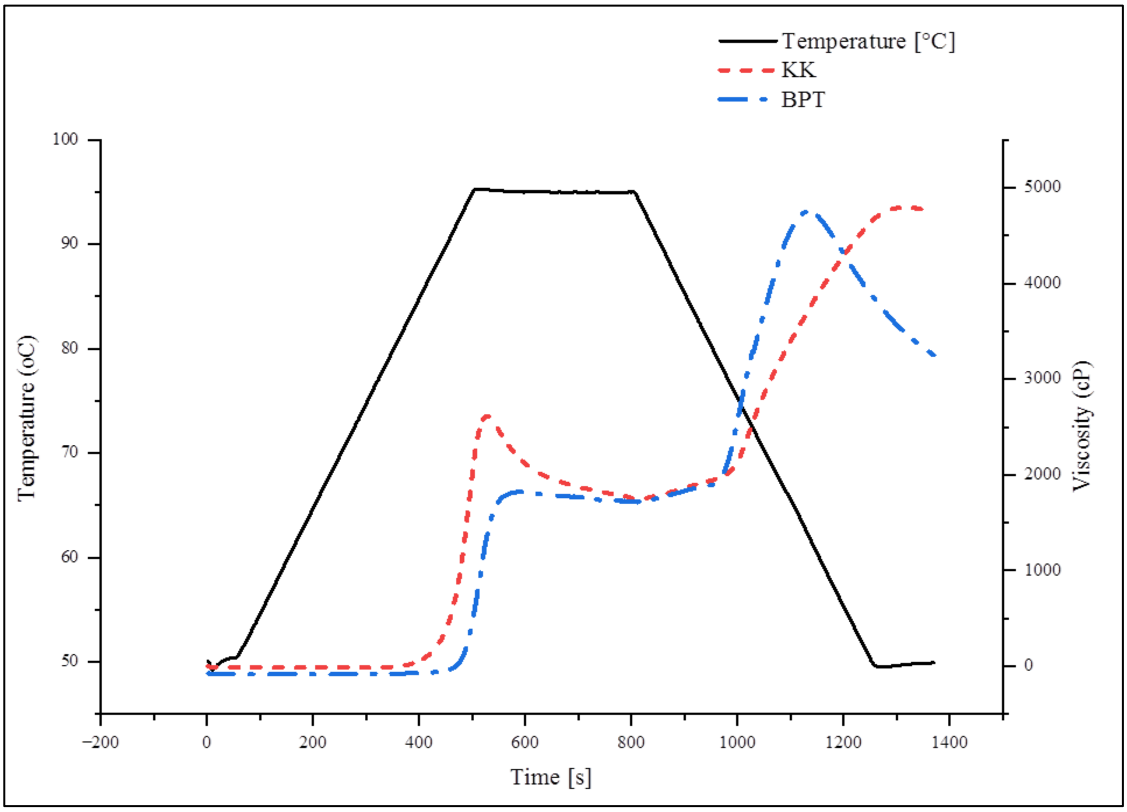

Fig 2: Rapid viscosity profiles of Karuppu kavuni (KK) and BPT paddy varieties

4. Conclusion

The physical, physicochemical, milling, cooking and pasting characteristics of the traditional variety, Karuppu kavuni and the modern variety, BPT were found to have optimistic differences. Better cooked rice properties and acceptable milling characteristics were exhibited by KK from the consumer point of view. However, better physical characteristics (size, colour, hardness) and milling quality were shown by BPT. This was not an astonishing fact because modern varieties are built to have better physical characteristics. Nevertheless, the traditional variety showed physicochemical parameters and pasting properties in the preferred range. Thus, it is important to consider the traditional varieties not only for their nutritional and health benefits but also for their other quality attributes mainly, eating quality.

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