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Physical, Physico-chemical and cooking qualities of major landraces of rice (*Oryza sativa* L.) found in western Nepal

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Abstract
To meet the growing demand of rice crops, most of the researchers are focused on producing high yielding varieties without considering the potential grain quality attributes of landraces. So, to excavate the knowledge on grain quality study was carried out with twenty landraces of rice (*Oryza sativa*) found in Tanahun, Lamjung and Kaski districts of Nepal for the assessment of physical, Physico-chemical and cooking traits on Complete Randomized Design at the research laboratory of Lamjung Campus. All the 20 varieties were examined for physical traits such as hulling, milling percentage, bulk density, 1000 kernel weight and grain dimensions, landraces were found to be significantly different at (P> 0.05). Ekle was found to have the highest bulk density and 1000 kernel weight of (0.90±0.009g/cm^3), (26.25±0.41g) respectively. Among the studied landraces 60% of the landraces were found to have high gelatinization and 40% of the landraces were found to have intermediate gelatinization temperature. The longest gel length and elongation ratio were recorded in Tude (85.67±2.33mm) and Tilki (1.55±0.02) respectively. Landraces such as Ekle, Tude, Kalogede are in the verge of being obsolete, yet they are found to be noble in terms of Physico-chemical and cooking traits so these landraces can also be used in modern rice breeding programs.

Keywords: Gelatinization temperature, gel consistency, alkali spreading test, grain qualities assessment

1. Introduction
With the increase in the world population, there is growing demand for food crops. Every nation in the world seeks for better food production program. The commercial and high input agriculture has ensured food security around the globe during the recent years. Technology assisted agriculture, introduction of hybrid varieties, gene selection for better productivity and adaptability has revolutionized the agricultural production of cereals. Among the cererals, Rice (*Oryza sativa*) has occupied the position as one of the leading food crops, around two-third of the world population depend wholly on rice for basic food consumption (Patil, 2014) [25]. To meet this demand of the rice crops, most of the research are focused on increasing productivity mostly by introducing the hybrid and high yielding varieties of rice, in other hand the rice landraces have been consumed since time immortal and have important role in livelihood and food security (Bhat & Riar, 2017) [2]. This trend of commercialization has overshadowed the nutritive and disease resistant traits of traditional varieties and landraces in the global context which has wiped out the traditional varieties posing serious threat for their conservation leading to the erosion of germplasm. More so, the high rate of influx of hybrid varieties and other new varieties to local farmers who abandon their cherished indigenous varieties without critical comparison is unacceptable (Oko *et al*., 2012) [23]. Indigenous rice varieties are renowned for their superior traits in term of disease resistant and wild characteristics. According to Pokhrel *et al*. (2020) [26], some of the indigenous rice varieties are found to be superior in term of physical, physiochemical and cooking traits, which are mostly preferred by consumer in their table. Grain quality of rice is one of the selection principles prioritized by farmers and consumers; thus farmers choose rice with superior traits that are needed for consumption as well as for production and sale (Horna *et al*., 2005) [14]. Rice qualities can be assessed with milling and physical characteristics which includes hulling percentage, head rice recovery, bulk density, Thousand Kernel Weight (TKW) and other chemical characteristics such as Gel Consistency (GC), amylose content, alkali spreading value, aroma, Gelatinization Temperature (GT) and

cooking characteristics such as optimum cooking time, Water Uptake Ratio (WUR) and Elongation Ratio (ER) (Bhattacharya, 2013) [3]. To explore the superior commercial cooking qualities of landraces and rice as a staple cereal crop, evaluating the physiochemical, nutritional and cooking qualities of rice has been given highest priority (Anjum & Hossain, 2019) [1]. Therefore, there is need to access the quality of the indigenous and traditional rice varieties which may be better than newly introduced varieties in overall merit. The overall objective of the study was to determine the level of diversity based on physical, physicochemical and cooking qualities that will provide significant information for further rice breeding program. Moreover evaluation of such physical, Physico-chemical and cooking traits has utmost importance in rice production, processing and commercialization. The specific objectives of the work is, therefore to evaluate the grain quality characteristics such as physical qualities, Physico-chemical qualities and cooking Qualities of landraces found in Tanahun, Lamjung and Kaski Districts of Nepal.

2. Material and methods

The study was carried out in the research laboratory of Lamjung campus, during the period of January 2019 to March 2020. The landraces were collected from the seed bank and farmers' group of Tanahun, Lamjung and Kaski districts. All the collected landraces were planted in First week of July with standardized agronomic practices and later harvested in the first week of October. After harvesting rice samples were cleaned and later taken to Food Research Department, NARC for Milling.

2.1 Milling Qualities

Before milling, the rice grains were adjusted to the moisture of 14% measured by wet weight basis of Wile-55 portable moisture meter. The milling was done with Ostake Rice mill. After milling recovery percentage was calculated by using equation

Milling Recovery = Wt. of milled Rice/Wt. of sample * 100%. (Juliano *et al*., 2002; Meas *et al*., 2011; Xangsayasane *et al*., 2018) [16, 20, 32]

2.2 Physical Analysis

2.2.1 Grain Dimension, L/W ratio, TKW, Bulk Density

Grain dimension comprises of average length, width, and thickness of milled rice which was measured in triplicates by using digital Vernier's caliber with precision of 0.01mm. The value of Length to Width (L/W) was recorded by dividing length by width (Thomas & Bhat, 2013) [29]. Based on the length to width ratio (L/W), the shape of the milled rice was determined (IRRI, 2004), rice cultivars can be classified as; Slender (>3.0), Medium (2.1-3.0), Bold (1.1-2.0) and Round (<1.1) grain types (Bhattacharya, 2013) [3].

TKW was calculated by counting of 1000 kernels of landraces and later weighing them with digital balance with lowest measuring scales of 0.01 gm accuracy (P *et al*., 2021; Sidhu *et al*., 2002) [24, 27]. The bulk density (g/cm^3) of milled rice was calculated according to the equation given by (Young, 1987) [33] where rice samples were poured in the vessel of 100 ml and the grain from the vessels were weighted using a digital balance.

Bulk Density = weight of kernels/volume displaced

2.3 Chemical Analysis

2.3.1 Gelatinization Temperature (GT)

Alkali digestion was determined using methodology described by (Bocevska *et al*., 2009) [7]. Disintegration by the alkali was determined by placing 7 rice grains in triplicates, in a Petri plate containing 20 ml of freshly prepared 1.7% (w/v) KOH solution; (1.7g in 100ml of distilled water) and Seeds were arranged with the provision of space between the grains for spreading. The Petri plates were then covered and placed in a 30 ^{0}C incubator for 23 hours. The degree of disintegration of each of the grains was rated visually according to standard evaluation system for rice by (IRRI, 1979) [15].

Table 1: Standard evaluation system for rice by IRRI

Score	Spreading Pattern	Alkali Digestion	Gelatinization Temperature
1	Kernel not affected	Low	High (>74 ^{0}C)
2	Swollen Kernel		
3	Swollen Kernel, Incomplete Collar and narrow		
4	Swollen Kernel, Complete Collar and wide	Intermediate	Intermediate (70-74 ^{0}C)
5	Split or segregated Kernel, collar complete and wide		
6	Dispersed Kernel, merging with collar	High	Low (<70 ^{0}C)
7	Completely Dispersed Kernel and intermingled		

Source: (Chemutai *et al*., 2016) [10], Physio-chemical Characteristics of Selected Rice (*Oryza sativa* L.) Genotypes based on Gel Consistency and Alkali Digestion, Biochemistry and Analytical Chemistry 2015 Vol.5.

2.3.2 Gel Consistency (GC)

The gel consistency was determined by the methods given by (Cagampang *et al*., 1973; Maniñgat & Juliano, 1978; Waters *et al*., 2006; Yu & Shin, 2015) [8, 19, 31, 34]. 100 mg (0.1g) of fine rice powder was weighted in triplicates and placed in the test tubes and wetted with 0.2ml 95% ethanol containing 0.025% thymol blue. The test tube was shaken and immediately 2ml of 0.2N KOH was added. The mixture obtained was dispersed using vortex mixture and placed in boiling water bath for 8 minutes. After removing from the water bath test tube were set at room temperature for 5 min, and then cooled in ice bath for 15 min. The test tubes were then horizontally laid on the table surface over a graph paper and after 1 hour the length of gel was measured from the bottom of the test tube to the gel front. This was done in replication and average gel length was computed. Furthermore standard was used for the categorization of Gel Consistency based on gel length.

Table 2: *Standard Gel Consistency type given by IRRI*

Scale	Gel Length	Gel Consistency Type
1	81-100 mm	Soft
2	61-80 mm	Soft
3	41-60 mm	Intermediate
4	36-40 mm	Hard
5	<36 mm	Hard

Source: (Chemutai *et al*., 2016) [10], Physio-chemical Characteristics of Selected Rice (*Oryza sativa* L.) Genotypes based on Gel Consistency and Alkali Digestion, Biochemistry and Analytical Chemistry 2015 Vol.5.

2.3.3 Aroma
Aroma test was done as per the procedure described by (Bhonsle & Sellappan, 2010) [6]. 200 mg (0.2g) of whole milled rice kernel was weighted and placed in culture tube. 0.5ml of 0.1N KOH was pipetted into culture tube and closed with the lid. After 15 min, the lid was open and smelled. Three person were used as judge and mean score was taken. In case of any doubt the lid was again closed and smelled after 15 min.

2.4 Cooking Traits Analysis
2.4.1 Optimum Cooking Time (OCT)
Optimum cooking time was determined by (Ohtsubo & Nakamura, 2017) [22], where milled Rice samples of 2g were placed in 100 ml beaker and cooking in boiling hot water bath at 95ºC in 20 ml of water. The optimum cooking time was determined by pressing the cooked rice samples between two glass slides at regular intervals of 10 minutes till no white starch core was left (Dahdouh *et al*., 2021; Mané *et al*., 2021; Véronique Vidal *et al*., 2006) [11, 18, 30].

2.4.2 Water Uptake Ratio (WUR)
Rice samples of 2g in 20 ml of water were cooked in the boiling water at 95ºC for optimum cooking time. The water left was drained and the water from the cooked rice was soaked in the filter paper. The cooked samples of rice were weighted accurately to calculate WUR. (Bhattacharya K.R., 1987) [5].
Water Uptake ratio = weight of the kernel after cooking/weight of the kernel after cooking

2.4.3 Elongation Ratio (ER)
The rice samples were cooked till the optimum cooking time. Randomly selected cooked rice varieties were measured for length and divided by the length of uncooked rice
Elongation Ratio: Average Length of Cooked Rice/Average Length of Uncooked Rice

2.5 Statistical Analysis
The experiment was conducted in the laboratory condition with three replications. The data was subjected to descriptive statistics and expressed as mean ± SEM. One-Way Analysis of Variance (ANOVA) followed by Duncan's Post hoc test was done for pair-wise separation and comparison of mean. Statistical significance was set at 95% confidence interval. SPSS V26.0 package was used for statistical analysis and graph were made using MS Excel 2007.

3. Result
3.1. Physical Properties
3.1.1 Bulk Density
The bulk density of rice landraces ranged from 0.90 g/cm^3 to 0.73 g/cm^3. Significant differences among the landraces were found at ($P < 0.05$) with the CV of 5.42%. Highest bulk density was recorded in Ekle (0.90±0.00g/cm^3) which is followed by Manamuri (0.89±0.00g/cm^3) and Biranful Prabat (0.87±0.00g/cm^3). Whereas lowest bulk density were recorded in Bayerni (0.73±0.00g/cm^3) followed by Mansara (0.76±0.01g/cm^3).

3.1.2. Milling Recovery
The highest Milling recovery percentage was observed in Kalo Gede (84.42%) followed by Bayerni (84.15%) and Rate (83.78%) and the least milling recovery percentage was observed in Dude Anadi (75.24%) followed by Sawa Mansuli (76.54%). All the landraces were found to be significantly difference with the CV of 5.44%.

3.1.3. Thousand Kernel Weight
The weight of 1000 whole kernel of the rice landraces ranged from 13.21g to 26.93g. Landraces were highly significant at (P value < 0.05) with the CV of 14.86%. Maximum 1000 kernel weight was observed in Ekle (26.25±0.41g) followed by Sano Madesi (21.49 ±0.59g) and Lahare Gurdi (21.46±0.38g) whereas minimum 1000 kernel weight was observed in Staniya Biranful (14.01±0.46g) followed by Basmati (14.60±0.26g) and Ramani (14.99±0.46g).

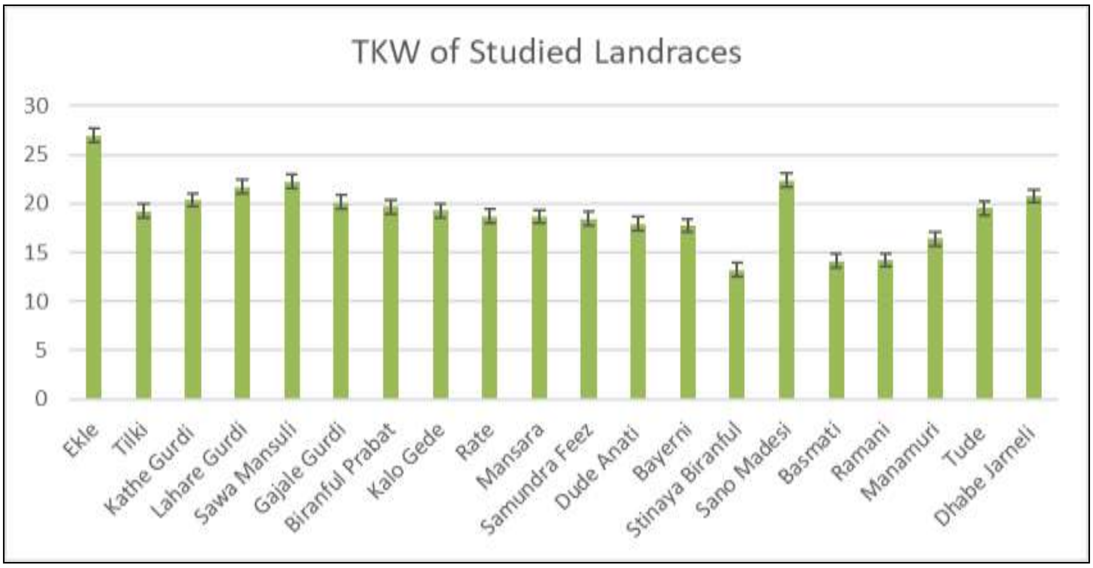

Fig 1: Thousand Kernel Weight of Rice Landraces

3.1.4 Length
Both length and breadth of the grains were highly significant among the landraces (p value <0.05). The maximum length was observed in Samundra Feez (6.98±0.05mm) followed by Ramani (6±0.10mm) and Dhabe Jarneli (5.94±0.03mm). Likewise Shortest length was measured in Ekle (4.72±0.02mm) followed by Sawa Mansuli (4.74±0.06mm) and Tilki (4.77±0.03mm).

3.1.5 Length to Breadth Ratio
The shape of the rice grain is determined on the basis of length to breadth ratio of a grain. Significant difference of ($P < 0.05$) was observed in the length to breath ratio of the landraces. All

the landraces were grouped into two types as medium and bold shapes based on the length –breadth ratio of the grains, among which 9 landraces were of medium type and 11 landraces were of bold type grains. The length to breadth ratio was highest in Kathe Gurdi (2.91±0.00) followed by Lahare Gurdi (2.61±0.00) Ekle (2.57±0.00).Likewise lowest L/W ratio was calculated in Mansara (1.51±0.01) followed by Bayerni(1.54±0.06) and Dhabe Jarneli (1.58±0.01).

3.2. Physico-chemical Properties

3.2.1 Gelatinization Temperature

Among the landraces 40% of the landraces were found to have intermediate gelatinization temperature i.e. of 70-74 ^{0}C and 60% of the landraces were found to have high gelatinization temperature i.e. > 74 ^{0}C. However no any landraces were found to have low gelatinization temperature < 70 ^{0}C. The intermediate gelatinization temperature was found in Sawa Mansuni, Biranful Prabat, Mansara, Samundra Feez, Dude Andai etc. Likewise high gelatinitization temperature was recorded in Ekle, Tiliki, Kathe Gurdhi, Lahare Gurdi etc.

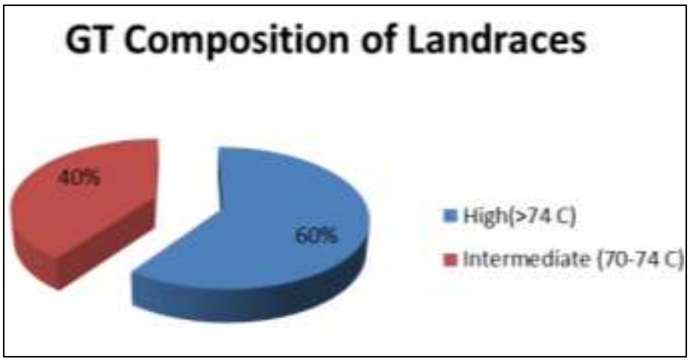

Fig 2: Gelatinization Temperature of Landraces

3.2.2 Aroma

Of the total landraces 15% of the landraces had strong aroma, 35% of the landraces had mild aroma and rest 50% of the landraces were recorded having no any aroma. The strong scented landraces were Basmati, Staniya Biranful and Tilki. Likewise varieties like Basmati and Tilki can be used for breeding so that their traits for strong aroma can be incorporated which is more preferred to consumers.

3.2.3 Gel Consistency

Gel Consistency measures the tendency of cooked rice starch to harden after cooking; varieties with soft gel consistency have higher degree of tenderness when cooked (Prakash, 2019). Tude, Rate and Dude Anadi were studied to have longest gel length of (86.67±2.33mm), (82.15±1.15mm) and (77.33±2.90mm) respectively. Kalo Gede and Kathe Gurdhi were reported to have low length of gel with the gel length of (21.33±0.02mm) and (31±3.78mm) respectively. Among the 20 studied landraces, 5 are found to have hard, 7 have intermediate gel consistency and 8 have soft gel consistency. So, The varieties like Tude, Rate and Dude Anadi remains soft even after cooking, which is most desirable trait preferred by the consumer.

3.3. Cooking Qualities

3.3.1 Optimum Cooking Time

The average cooking time of the landraces were found to be significantly different (P< 0.05). Cooking time was found to be maximum for Sano Madeshi (35.77±1.06min), which is followed by Ekle (34.19±0.94min) and Tilki (33.98±0.65min). Least cooking time was recorded in Dhabe Jarneli (22.40±0.71min) followed by Biranful Prabat (22.95±0.94min). Fig 3.4

3.3.2 Water Uptake Ratio

Significant differences were obtained among the landraces for Water Uptake Ratio (P< 0.05). The water uptake ratio ranged from (6.1 to 1.4). The highest water uptake ratio was recorded in Tude (6.11±0.15) followed by Dhabe Jarneli (5.21±0.45), Kathe Gurdi (4.56±0.02) whereas lowest water uptake ratio was observed in Mansara (1.14±0.02) followed by Ekle (1.23±0.02) and Bayerni (1.49±0.04).

3.3.3. Elongation Ratio

Elongation Ratio of studied landraces were found to be significant at (P< 0.05). Tude showed the highest elongation ratio of (1.55±0.02) followed by Tilki (1.53±0.00), Ekle (1.42±0.00) and lowest elongation ratio was recorded in Sawa mansuli (1.07±0.02) followed by Kathe Gurdi (1.08±0.01) and Bayerni (1.08±0.01).

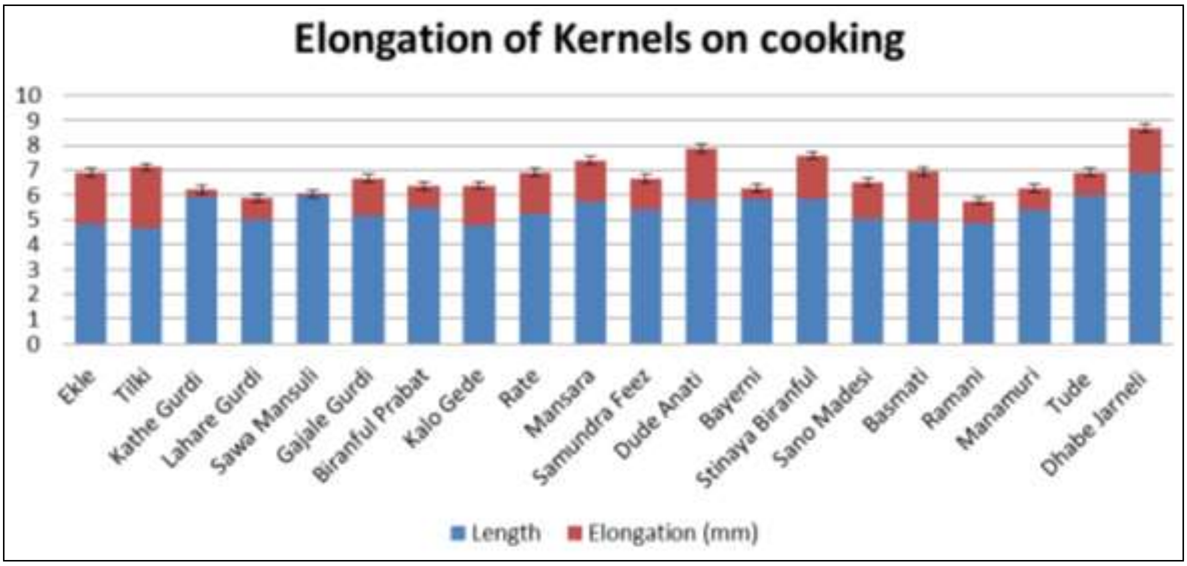

Fig 3: Elongation Ratio of Rice Landraces

4. Discussions

The rice quality is evaluated through the analysis of physical, Physico-chemical and cooking traits. The variation found in the traits is solely due to genetic and environmental causes.

The milling trait of the rice is important for the commercial industry as it influences the marketability of the rice varieties. In case of Asian countries milling by-products are used for feeding cattle, so farmers prefers rice with greater milling recovery. Likewise rice processing industry can be benefited if the knowledge on milling characteristics is traced out. Landraces which have higher milling recovery trait is mostly preferred by the rice processing industries. In our study we found that Kalogede and Bayerni have the highest milling percentage which suggests that they have also higher head recovery percentage. Besides the varietal difference, type of mill used for milling also affects the milling recovery percentage (Bhattacharya *et al*., 1978; Bhattacharya K.R., 1987; Kim *et al*., 2010; Noda *et al*., 2003) [4, 5, 17, 21].

The physical characteristics like grain dimension, bulk density and TKW are of vital interest for the rice processing and storage. According to the study of Hettiarachchy *et al*. (1997) [13], Bulk Density is inversely proportional to L/W ratio, round grains shows higher bulk density than the thin and slender samples. Similar finding was obtained in the experiment as Bayerni and Mansara having minimum bulk density and Kathe Gurdi having maximum bulk density .This knowledge of bulk density is useful during storage and further processing. Another important physical trait that determines the quality of rice is L/W ratio. According to Juliano *et al*. (2002) [16] and Subedi *et al*. (2016) [28], Bulk Density is inversely proportional to the L/W ratio but in the study we didn't found any relation of bulk density with the L/W ratio, which may be due to the lesser degree of milling, further study is need to examine the relationship between Bulk Density and L/W ratio.

The chemical characteristics of the grain determine the cooking behavior. In the study carried out by Juliano *et al*., (2002) [16], found that Gelatinization temperature as indicators of cooking time and shorter cooking time are of great importance as it saves the significant fuel amount. Geletanization temperature influences the cooking time, samples with high gelatinization temperature requires more time to cook compared to the samples with low GT. In the experiment it was found that landraces such as Biranful Prabat, Dude Anadi, Sawa Mansuli, Tude had intermediate gelatinization temperature, these are also found to have short cooking time. Shorter cooking time trait of rice reduces the amount of fuel consumption (Chatterjee & Maiti, 1981) [9]. According to the study carried out by Danbaba *et al*. (2012) [12], Rice with soft gel consistency cook more tenderly and remain soft even after cooling. Likewise in the study Rate, Tude and Dude Anadi were found to have longer gel length, it suggests that they remains soft even after cooling for long time.

Rice being a staple crop the cooking quality has been given more importance by the consumer. Rice with good cooking traits are more preferable to the consumer thus fetches higher price in the market. Among the cooking traits, optimum cooking time is mostly selected by the breeder as lower cooking time saves the significant amount of fuel. According to the study carried out by (Juliano *et al*., 2002) [16], small and slender grains cooks faster than big, round grains. In our experiment most of the slender varieties like Mansara, Dhabe Jarneli were found to have short cooking time. Bhat & Riar, (2017) [2] in an experiment found that local landraces were found to have higher Water Uptake Ratio, in our experiment, most of the landraces were found to have higher WUR. In a study carried out by Subedi *et al*. found that higher the bulk density higher will be the corresponding WUR. In our experiment Tude and Kathe Gurdi were found to have higher WUR but Ekle is found to have lower WUR, which may be due to lesser degree of milling. Thus, the result from our study is in accordance with the similar studies related to the grain quality characterization of rice varieties.

5. Conclusion

The result revealed the significant differences among the landraces were found in physical, Physico-chemical and cooking traits. The grain quality study on the twenty landraces concluded that some of the rice landraces are superior in some traits and these landraces can be used in modern breeding programs for the improvement in the eating qualities of rice. Most of the studied rice landraces are in the verge of obsolete as they are not preferred by the farmers for cultivation either due to their low productivity or high influx of hybrid varieties, such varieties are found to be with good traits in case of gelatinization temperature, cooking Time elongation ratio, WUR and softness after cooking; breeding program should be focused for the conservation of such varieties. Hence, the further study of the landraces need to be done using molecular marker so that the variability in these traits could be exploited in the rice breeding programs to improve the grain quality.

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7. References

1. Anjum KI, Hossain MA. Nutritional and cooking properties of some rice varieties in Noakhali region of Bangladesh. Research in Agriculture Livestock and Fisheries 2019;6(2):235-243. https://doi.org/10.3329/RALF.V6I2.43046
2. Bhat FM, Riar CS. Studies on effect of temperature and time on textural and rheological properties of starch isolated from traditional rice cultivars of Kashmir (India). Journal of Texture Studies 2017;48(2):151-159. https://doi.org/10.1111/JTXS.12226
3. Bhattacharya KR. Rice Quality. In Woodhead Publishing Series in Food Science, Technology and Nutrition. Woodhead Publishing 2013. http://www.sciencedirect.com/science/article/pii/B9781845694852500039
4. Bhattacharya KR, Sowbhagya CM, Swamy YMI. Importance of insoluble amylose as a determinant of rice quality. Journal of the Science of Food and Agriculture 1978;29(4):359-364. https://doi.org/10.1002/JSFA.2740290410
5. Bhattacharya KR, UKR. Influence of Varietal Difference on Properties of Parboiled Rice. Journal of Cereal Chemistry, 1987. https://www.cerealsgrains.org/publications/cc/backissues/1987/Documents/64_315.pdf
6. Bhonsle SJ, Sellappan K. Grain Quality Evaluation and Organoleptic Analysis of Aromatic Rice Varieties of Goa,

India. Journal of Agricultural Science 2010;2(3):99-107. https://doi.org/10.5539/jas.v2n3p99

7. Bocevska M, Aldabas I, Andreevska D, Ilieva V. Gelatinization Behavior Of Grains And Flour In Relation To Physico-Chemical Properties Of Milled Rice (*Oryza sativa* L.). Journal of Food Quality 2009;32(1):108-124. https://doi.org/10.1111/J.1745-4557.2008.00239.X
8. Cagampang GB, Perez CM, Juliano BO. A gel consistency test for eating quality of rice. Journal of the Science of Food and Agriculture 1973;24(12):1589-1594. https://doi.org/10.1002/JSFA.2740241214
9. Chatterjee BN, Maiti S. Principles & practices of rice growing. Principles & Practices of Rice Growing, 1981.
10. Chemutai LR, Musyoki MA, Kioko WF, Mwenda NS, Muriira KG, Piero NM. Physicochemical Characterization of Selected Rice (*Oryza sativa* L.) Genotypes Based on Gel Consistency and Alkali Digestion, 2016. https://doi.org/10.4172/2161-1009.1000285
11. Dahdouh L, Hounsou M, Matignon B, Ricci J, Madodé Y, Hounhouigan J, *et al*. Role of dough viscoelastic properties and rice variety in the thermal expansion and the quality of unconventional rice-based bread: case of steamed-cooked 'Ablo.' International Journal of Food Science and Technology 2021;*56*(9):4615-4626. https://doi.org/10.1111/IJFS.15157
12. Danbaba N, Anounye JC, Gana AS, Abo ME, Ukwungwu MN, Maji AT. Physical and Pasting Properties of 'Ofada' Rice (*Oryza sativa* L.) Varieties. Nigerian Food Journal 2012;30(1):18-25. https://doi.org/10.1016/S0189-7241(15)30009-6
13. Hettiarachchy'x NS, Griffin VK, Gnanasambandam R, Moldenhauer K, Siebenmorgen T. Physicochemical properties of three rice varieties. All Rights Reserved. Copyright 1997;20:279-289.
14. Horna JD, Smale M, von Oppen M. Farmer willingness to pay for seed-related information: rice varieties in Nigeria and Benin. EPTD Discussion Papers, 2005. https://ideas.repec.org/p/fpr/eptddp/142.html
15. IRRI. Chemical Aspect of Rice Grain Quality 1979. http://books.irri.org/9711040107_content.pdf
16. Juliano BO, Bautista GM, Lugay JC, Reyes AC. Rice Quality, Studies on Physicochemical Properties of Rice. Journal of Agricultural and Food Chemistry 2002;12(2):131-138. https://doi.org/10.1021/JF60132A010
17. Kim JM, Song JY, Shin M. Physicochemical properties of high amylose rice starches purified from Korean cultivars. Starch/Staerke 2010;62(5):262-268. https://doi.org/10.1002/STAR.200900230
18. Mané I, Bassama J, Ndong M, Mestres C, Diedhiou PM, Fliedel G. Deciphering urban consumer requirements for rice quality gives insights for driving the future acceptability of local rice in Africa: Case study in the city of Saint-Louis in senegal. Food Science and Nutrition 2021;9(3):1614-1624. https://doi.org/10.1002/FSN3.2136
19. Maniñgat CC, Juliano BO. Alkali Digestibility Pattern, Apparent Solubility and Gel Consistency of Milled Rice. Starch - Stärke 1978;30(4):125-127. https://doi.org/10.1002/STAR.19780300406
20. Meas P, Paterson AHJ, Cleland DJ, Bronlund JE, Mawson AJ, Hardacre A, *et al*. Effects of different solar drying methods on drying time and rice grain quality. International Journal of Food Engineering 2011;7(5). https://doi.org/10.2202/1556-3758.2378
21. Noda T, Nishiba Y, Sato T, Suda I. Properties of starches from several low-amylose rice cultivars. Cereal Chemistry 2003;80(2):193-197. https://doi.org/10.1094/CCHEM.2003.80.2.193
22. Ohtsubo K, Nakamura S. Evaluation of Palatability of Cooked Rice. Advances in International Rice Research 2017. https://doi.org/10.5772/66398
23. Oko Ubi, Dambaba. Rice Cooking Quality and Physico-Chemical Characteristics: a Comparative Analysis of Selected Local and Newly Introduced Rice Varieties in Ebonyi State, Nigeria. Food and Public Health 2012;2(1):3-49. https://doi.org/10.5923/J.FPH.20120201.09
24. PA, Pal US, Panda MK, Sahoo G, Nayak R, Rayaguru K, *et al*. Standardisation of cooking and conditioning methods for preparation of quick cooking germinated brown rice. Journal of the Indian Chemical Society 2021;98(8). https://doi.org/10.1016/J.JICS.2021.100093
25. Patil AHPVSMDM. Identification of Elite Rice Germplasm lines for protein content SSR Based Genotyping and DNA fingerprinting. International Journal of Plant, Animal and Environmental Sciences 2014;4(3). https://www.researchgate.net/publication/314371847_Identification_Of_Elite_Rice_Germplasm_Lines_For_Grain_Protein_Content_Ssr_Based_Genotyping_And_Dna_Fingerprinting
26. Pokhrel A, Dhakal A, Sharma S, Poudel A. Evaluation of Physicochemical and Cooking Characteristics of Rice (*Oryza sativa* L.) Landraces of Lamjung and Tanahun Districts, Nepal. International Journal of Food Science, 2020. https://doi.org/10.1155/2020/1589150
27. Sidhu JS, Gill MS, Bains GS. Milling of paddy in relation to yield and quality of rice of different Indian varieties. Journal of Agricultural and Food Chemistry. 2002;23(6):1183-1185. https://doi.org/10.1021/JF60202A035
28. Subedi U, Mishra A, Shrestha MB. Quality Assessment of Some Rice Varieties Newly Adopted in NARC. Journal of Food Science and Technology Nepal. 2016;9:48-54. https://doi.org/10.3126/jfstn.v9i0.12407
29. Thomas R, Bhat R. Physiochemical properties, proximate composition, and cooking qualities of locally grown and imported rice varieties marketed in Penang, Malaysia. International Food Research Journal. 2013;20(3):1345-1351.
30. Véronique Vidal, Brigitte Pons, Judith Brunnschweiler, Stephan Handschin, Xavier Rouau, Christian Mestres. Cooking Behavior of Rice in Relation to Kernel Physicochemical and Structural Properties. Journal of Agricultural and Food Chemistry. 2006;55(2):336-346. https://doi.org/10.1021/JF061945O
31. Waters DLE, Henry RJ, Reinke RF, Fitzgerald MA. Gelatinization temperature of rice explained by polymorphisms in starch synthase. Plant Biotechnology Journal. 2006;4(1):115-122. https://doi.org/10.1111/J.1467-7652.2005.00162.X
32. Xangsayasane P, Vongxayya K, Phongchanmisai S, Mitchell J, Fukai S. Rice milling quality as affected by drying method and harvesting time during ripening in wet and dry seasons 2018;*22*(1):98-106. *Http://Www.Tandfonline.Com/Action/AuthorSubmission?JournalCode=tpps20&page=instructions*. https://doi.org/10.1080/1343943X.2018.1544463
33. Young. Physiochemical factors affecting cooking and eating quality of nonwaxy rice, 1987. [Iowa State University]. https://core.ac.uk/download/pdf/38902648.pdf
34. Yu M, Shin M. Improving gel formation of rice starch added with cross-linked resistant starch prepared from rice starch. Starch/Staerke 2015;67(9-10):829-837. https://doi.org/10.1002/STAR.201400223