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PHYSICOCHEMICAL PROPERTIES AND EATING QUALITY OF PROMISING CROSSBRED UPLAND RICE LINES DEVELOPED FROM SUPERIOR PARENTAL GENOTYPES

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SUMMARY

The ultimate objective of breeding is to produce high-yielding cultivars that are fascinating to the farming community and end users, allowing for easy marketing. Therefore, it is crucial to conduct various tests on milling quality, physicochemical properties, and eating quality to determine the overall rice quality and evaluate the response of potential consumers. The presented study sought the complete rice quality and the consumer acceptance of 12 upland rice lines derived from superior parental genotypes. This research conducted in 2019 performed milling and eating quality assessments on milled and cooked rice, respectively. The milling quality analysis revealed that lines L-04, L-05, and L-06 produced middle-length grains, while others produced full-length grains. Rice from lines L-02, L-09, and L-12 were slender, while the rest were medium-shape. All upland rice lines also met the national standard (SNI 6128-2015) for milling degree (85%–100%), moisture content (9.85%–11.30%), chalky rice (0.06%–1.59%), and yellow rice (0.21%–1.77%). Lines L-03 and L-05 met the Medium-I quality standard with head rice recovery (HRR) values of 84.15% and 84.76%, respectively. However, lines L-01 and L-02 met the Medium-III standard with HRR values of 66.24% and 66.39%, separately. Principal Component Analysis (PCA) revealed four principal physicochemical characteristics, i.e., degree of milling, length, width, and HRR. Partial Least Squares Regression (PLSR) analysis displayed the overall liking as determined by the interaction of four descriptive factors, mostly taste and texture. Cooked rice of line L-12 (cross of cv. Inpago-8 × B11930F-TB-2) was the most liked compared with other cooked rice samples.

Keywords: milling quality, eating quality, hedonic, PCA, PLSR

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Key findings: Upland rice production through cross-breeding of superior parental genotypes hopes rice meets consumer acceptance criteria and the Indonesian National Standard for Quality (SNI 6128–2015). PCA assisted in the clustering of the 12 resultant crossbred lines based on the physicochemical properties of their rice crops. PLSR analysis helped to reveal the correlation between the sensory descriptive scores and overall liking of the cooked rice from the 12 lines.

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INTRODUCTION

Upland rice planting is best in geologically well-drained soils rather than lowland, without surface water accretion. It mostly suits dry conditions and relies on rainfall for moisture, with little or no fertilizer required. Its cultivation accounted for approximately 12% of the global rice production field and had the lowest yield compared with other rice ecosystems, such as, irrigated, rainfed lowland, and deep-water (Bernier *et al*., 2008).

Approximately 75.6% of Indonesia's total geographical area comprised dry land, covering 1,444,732 km^2. Agricultural land development reached 15.9 M ha, while lowland development achieved only about 7.5 M ha (Santoso *et al.*, 2022; Hikmat *et al.*, 2023;). In contrast, the harvested area of upland rice was only 8.65% of the harvested area of lowland rice, equalling 14.7 M ha (Kementan RI, 2020). Nevertheless, upland rice production had the potential to expand and has anticipations to support national output. Further triggering was the limited possibility for lowlands' substantial rice production increases (Sumarno and Hidayat, 2015). Solving dryland issues will eventually maximize the yield potential of the extensive drylands. The majority of land (157.2 M ha) was not optimal due to low natural fertility; however, the 91.9 M ha of land had agricultural potential, including 62.6 M ha of acid land and 7.7 M ha of semiarid dry land (Mulyani and Sarwani, 2013).

Upland rice production improvement can result from upland rice cultivation and productivity per unit area. Upland rice farming has agronomic and economic benefits (Kartina *et al*., 2019; Aung-Nan *et al*., 2021; Syahril *et al*., 2022). The monetary benefit includes the pleasant rice taste that allows fetching premium pricing in urban markets. The drawback of upland rice farming includes low productivity and disease susceptibility (Sumarno and Hidayat, 2015). The Ministry of Agriculture, Indonesia, released 97 rice cultivars from 2007 to 2019. Some were upland rice cultivars with features, viz., acid soil tolerance, drought tolerance, blast disease resistance, and short life span (Sasmita *et al*., 2019). Furthermore, the expected upland rice cultivars crossing with local landraces as parents will incorporate the blast disease resistance, aluminum tolerance, and high productivity (Mulyaningsih *et al*., 2016). In upland rice breeding programs, considering the physicochemical properties and eating quality is necessary (Damardjati and Oka, 1992; Calingacion *et al*., 2014; Mardiah *et al*., 2016).

Given the expensive and time-consuming breeding, hopes for the new cultivars' consideration and utilization be according to consumption patterns and public acceptance. Preference studies on the credibility of new rice cultivars have transpired in several regions of Indonesia and other countries. Some traits that influence public acceptance are but are not limited to, color, aroma, texture, and taste (Anang *et al*., 2011; Rahayu, 2012; Hairmansis *et al*., 2015; Ishaq and Ruswandi, 2018; Prayoga *et al*., 2018; Kamath *et al*., 2008; Aoki *et al*., 2017). Following the crossed lines' evaluation was the selection of the desired traits over several generations before being released. For example, the lines may be grown on acid soil to increase tolerance, then evaluating the yield potential of the selected lines ensues at multiple locations on the optimal field. Furthermore, before release, the potential rice cultivars must also undergo screening for rice quality, eating quality, and dominant biotic stress in the uplands.

The pertinent study aimed to determine the quality of 12 crossbred upland rice lines based on the milled rice's physicochemical properties and eating quality. The observed rice lines were derivatives of crossbreeding parental genotypes with either aluminum tolerance or high yield, with their genetic markers identified (Mulyaningsih *et al*., 2016; Anggraheni *et al*., 2020). The output expectation will be complementary data for future superior upland rice varieties that meet national standards and consumer preference.

MATERIALS AND METHODS

Genetic material

The genetic materials used in this study were the 12 resultant crossbred lines from five superior parental genotypes. The rice lines being evaluated were L-01, L-02, L-03, and L-04 (cross of TB368B-TB-25-MR-2 x B11178G-TB-29), L-05, L-06, and L-07 (cross of cv. Situ Patenggang x B11930F-TB-2), and L-08, L-09, L-10, L-11, and L-12 (cross of cv. Inpago-8 x B11930F-TB-2). All parental genotypes came from the Ministry of Agriculture. These rice lines reached planting during the rainfall season in an experimental field at Muara Bogor, West Java, Indonesia. The recorded relative humidity was 78%–88%, the rainfall ranged from 119-593 mm/month, and the daily minimum and maximum temperatures were 22.3 °C–23.4 °C and 29.9 °C–32.1 °C, respectively. The field used for planting has an elevation of 250 masl, with a soil type of latosol reddish brown. The grain samples for the analysis obtained in June 2019 underwent subsequent quality tests conducted during June and September 2019.

Rice milling, physical, and chemical analyses continued at the Indonesian Center for Rice Research (ICRR), Indonesian Agency for Agricultural Research and Development (IAARD), Subang, West Java.

Rice milling analysis

Dehusking of approximately two kg of rice grains for each line used the Satake THU 35A (Satake Engineering Co. Ltd., Higashihiroshima-shi, Japan), then polishing with the Takayama TM-35A (TW Grandeur Machinery Co. Ltd., Taichung, Taiwan). The resultant polished rice followed sorting using a drum grader (Satake TRG-05A, Satake Engineering Co. Ltd., Higashihiroshima-shi, Japan). Determination of milled, head, broken, and groat rice proceeded according to the method of the International Rice Research Institute, Los Baños, Philippines (IRRI, 2006).

Rice physical analysis

The rice's moisture content (MC) acquisition employed a Grain Moisture Tester (TA-5, Crown, Japan). The length and width measurements of rice grains used a micrometer after randomly selecting 20 grains from each rice line. Repeating the assessment twice continued the length-to-width ratio (L/W) computation (IRRI, 2013). The whiteness and transparency estimates used the Satake Milling Meter (MM-1C, Satake Engineering Co. Ltd., Higashihiroshima-shi, Japan). The Indonesian National Standard conversion for milled rice (SNI 6128–2015) was also a means to determine the degree of milling (DOM) (Table 2). As shown in Table 2, the whiteness index was necessary to interpret the conversion table.

Rice chemical analysis

Chemically analyzing the rice was done by determining amylose concentration, gel consistency, and protein concentration. The milled rice identification of apparent amylose content (AAC) was according to the Indonesian National Standard (SNI 6128-2015). The gel consistency test supplemented the AAC test (Cagampang *et al*., 1973). The protein content appropriation followed the method published by the Association of Official Agricultural Chemists (AOAC, 2000), with a conversion factor of 5.95 (Food and Agriculture and Nutritional Studies No. 24, 1970). All chemical analyses of rice ran in duplicates.

Eating quality analysis

Approximately 250 g of rice underwent delicate washing with water, then drained. This procedure ran twice, followed by adding cooking water to the washed rice in a ratio of 2:3. Rice cooking ensued for 20 min in a rice cooker and allowed to rest for 10 min. Each panelist sampled up to 15 g of cooked rice from each rice line. Thirty panelists used a sequential 5-point scale (1-5) to present the characteristics, namely, color (1 = very white, 2 = white, 3 = slightly white, 4 = off-white, and 5 = very off-white); taste (1 = very tasty, 2 = tasty, 3 = slightly tasty, 4 = plain tasting, and 5 = unpleasant taste); aroma (1 = very aromatic, 2 = aromatic, 3 = slightly aromatic, 4 = neutral aroma, and 5 = unpleasant aroma); and texture (1 = very sticky, 2 = sticky, 3 = slightly sticky, 4 = separate, and 5 = very separate) (Septianingrum and Mardiah, 2020; Rahmawati and Yaniansah, 2021). The obtained data's tabulation was according to the average value of each attribute, thoroughly describing the results. Subsequently, the panelists conducted a hedonic test to determine their overall preference. The hedonic scale ranged from 1 to 5, with 1 = most liked, 2 = liked, 3 = neither liked nor disliked, 4 = disliked, and 5 = most disliked (Septianingrum and Mardiah, 2020).

Statistical analysis

Analysis of variance (ANOVA), principal component analysis (PCA), clustering, and partial least squares regression (PLSR) used the XLSTAT version 2021.1.1 add-on for Microsoft Excel (Addinsoft, New York, USA). ANOVA application occurred on descriptive and hedonic scores obtained from panelists during the sensory assessment of cooked rice. PCA ensued in rice breeding programs to analyze multivariate data sets (Kim *et al*., 2010; Hori *et al*., 2016). The said analysis can reveal patterns of similarity between observed variables and data, extract essential information from the data sets, eliminate redundancy, and generate a new set of orthogonal variables known as principal components (Abdi and Williams, 2010). PCA in this study helped obtain the primary physicochemical properties of upland rice. PLSR analysis investigated the relationship between the descriptive scores and the overall preference for cooked rice (Bhumiratana *et al*., 2019).

RESULTS AND DISCUSSION

Milling properties

The milling quality, including milled rice recovery (MRR) and head rice recovery (HRR), has a significant impact on milled rice value (Bao, 2019). A high percentage of brown rice recovery (BRR) typically results in a higher MRR (Bunna *et al*., 2019). As shown in Table 1, rice line L-07 exhibited the highest BRR but not the highest value for MRR. In addition, the rice line L-12 had the lowest BRR, which did not necessarily imply the lowest MRR. The BRR and MRR values disparity varied by rice lines. This phenomenon may refer to the nature of the hulls, which influences the kernel size and BRR.

Increasing HRR is a direct effort to improve milling quality, increase competitiveness in domestic and international markets, and ensure the sustainability of domestic milling industries (Bao, 2019). Rice lines L-03 (84.15%) and L-05 (84.76%) exhibited higher HRR values, indicating better fissure resistance compared with the other 10 rice lines, resulting in less milling breakage (Table 2). The HRR of lines L-01 and L-02 were 66.24% and 66.39%, respectively, while the remaining rice lines had low HRR values (<60%). Line L-06 exhibited the lowest HRR (21.66%), the highest BRR (70.52%), and the highest GRR (Grout rice recovery) (7.82%), indicating significant breakage during milling, which might be due to low fissure resistance.

The majority of the market community and consumers prefer rice grains that are white, translucent, and free of chalks. An exception is waxy rice, which has a chalky core

Table 1. Brown rice recovery (BRR), milled rice recovery (MRR), and physical quality of rice crops of 12 crossbred upland rice lines.

Lines	BRR (%)	MRR (%)	Rice size			Whiteness (%)	Translucency (%)
			Length (mm)*	Width (mm)	L/W Ratio**		
L-01	76.79	68.98	6.68	2.34	2.85	46.60	2.13
L-02	76.94	68.28	7.26	2.27	3.20	48.00	2.67
L-03	77.33	69.39	6.62	2.33	2.84	47.30	2.68
L-04	76.79	68.08	6.38	2.33	2.74	46.90	1.84
L-05	76.23	62.98	6.31	2.35	2.69	47.20	2.30
L-06	75.85	65.49	5.99	2.33	2.57	50.90	1.89
L-07	78.09	67.73	6.68	2.59	2.58	53.90	2.48
L-08	76.40	64.96	6.84	2.69	2.54	60.50	2.06
L-09	76.51	67.28	7.37	2.17	3.40	50.20	1.98
L-10	76.10	64.42	7.09	2.46	2.88	57.00	2.49
L-11	76.76	66.01	6.76	2.44	2.77	58.00	1.98
L-12	75.52	66.23	7.23	2.36	3.06	52.70	2.12

*On the basis of grain length, milled rice was categorized as extra-long (>7.5 mm), full-length (6.6–7.5 mm), middle (5.51–6.6 mm), and short (5.5 mm) (IRRI, 2013).
**On the basis of the L/W ratio, milled rice was categorized as slender (> 3.0), medium (2.1–3.0), bold (1.1–2.0), or round (1.0). (IRRI, 2013).

Table 2. Milling quality of 12 upland rice lines in comparison with National Standard for Milled Rice (SNI 6128-2015).

Quality Components*	Indonesian National Standard (SNI 6128-2015)				Rice Lines											
	P	I	II	III	L-01	L-02	L-03	L-04	L-05	L-06	L-07	L-08	L-09	L-10	L-11	L-12
DOM (% min)	100	95	90	80	85	89	86	86	86	93	98	100	92	100	100	96
MC (% max)	14	14	14	14	10.80	10.35	10.35	11.30	10.00	10.50	9.85	10.75	10.70	10.07	10.60	10.75
HRR (% min)	95	78	73	60	66.24	66.39	84.15	57.50	84.76	21.66	50.24	45.49	59.90	47.41	53.69	57.48
BkRR (% max)	5	20	25	35	32.79	31.65	15.63	39.68	15.05	70.52	48.24	53.38	37.53	50.97	44.84	40.50
GRR (% max)	0	2	2	5	0.97	1.96	0.22	2.82	0.19	7.82	1.52	1.13	2.57	1.62	1.47	2.02
CR (% max)	0	2	3	5	0.27	0.41	0.21	0.60	0.06	0.79	0.43	0.57	0.41	1.47	1.59	0.61
YR (% max)	0	2	3	5	0.32	0.85	1.01	0.70	0.73	0.55	0.61	0.34	0.67	0.21	0.27	1.77
Quality Classification					III	III	I	Uc	I	uc	uc	uc	uc	uc	uc	uc

*DOM = degree of milling, MC = moisture content, HRR = head rice recovery, BkRR = broken rice recovery, GRR = grout rice recovery, CR = chalky rice, YR = yellow rice, P = premium, I = medium I, II = medium 2, III = medium 3, and uc = uncategorized.

expectation (Bergman, 2019). The presented results further revealed that the whiteness and DOM of the milled rice were higher than 46.60% and 85%, respectively, while the SNI 6128-2015 minimum DOM requirement is 80% (Tables 1 and 2) (BSN, 2015). Furthermore, the clearness of the studied rice lines ranged from 1.84% (L-04) to 2.68% (L-03), while chalky rice (CR) ranged from 0.06% (L-05) to 1.59% (L-11). Consumers value rice lacking in discoloration, such as yellow grains. However, in the relevant study, all the rice lines contained a negligible amount of yellow rice (YR) (Table 2). Yellow rice is indirectly affected by MC because it is a crucial interactive co-factor for storage temperature or duration that accelerates discoloration via Maillard reaction or microbial contamination (Shad and Atungulu, 2019). The MC of the 12 milled rice lines ranged from 9.85% to 11.30% (Table 2). These results were consistent with SNI 6128-2015, which specifies a maximum MC of 14% in milled rice (BSN, 2015).

Grain measurement showed that rice lines L-04, L-05, and L-06 produced middle-length grains, while the rest produced full-length grains. Milled rice from lines L-02, L-09, and L-12 were slender, with their L/W ratio greater than three, while rice from other lines was medium (Table 1). Based on SNI 6128-2015, lines L-03 and L-05, with respective HRR values of 84.15% and 84.76%, belonged in the Medium quality-I category. In addition, rice lines L-01 and L-02 had a Medium quality-III classification, with HRR values of 66.24% and 66.39%, respectively.

Chemical properties

The AAC of the 12 studied rice lines varied between 16.64% and 25.16% (Table 3). Based on Bergman's (2019) classification, these rice lines belonged to three distinct classes, with the intermediate class (20%–24% AAC) being the most prevalent. The majority of the upland rice lines exhibited a medium gel consistency. However, line L-06 was the only line that displayed a hard gel consistency and the highest AAC. Line L-09 had the maximum distance (78.0 mm) despite having the smallest AAC, indicating a low gel consistency. According to the International Network for Quality Rice (INQR), the ideal gel consistency was low or medium, implying a supple texture in high amylose rice cultivars (Calingacion *et al*., 2014).

The protein content of rice grains has strong influences from numerous factors, such as fertilizer use (Calingacion *et al*., 2014), climate (Tamaki *et al*., 1989; Champagne *et al*., 2004), and genetic makeup of the genotypes (Wang *et al*., 2017). According to Tamaki *et al*. (1989), the protein content tends to decrease when the ambient temperature in the field during the generative phase ranges from 20 °C to 26 °C. Appearing in Table 3, the protein content of the 12 upland rice lines varied between 8.16% and 10.85%. The study period's ambient temperature most likely affected the protein content. However, additional research is necessary to compare the protein content of rice crops in Muara-Bogor with those of other regions with varying daily temperatures. A study on lowland rice grown in four West Sumatran cities confirmed the effect of temperature (T) on rice protein content. Similar protein content in rice crops emerged when the cultivation area had parallel daily temperatures. Rice harvested from the Districts of Agam (T = 20 °C–30 °C) and Solok (T = 21 °C–31 °C) had a protein content of 6.16% and 5.99%, respectively. Rice from warmer areas, such as, Pariaman (T = 24 °C–34 °C) and Pesisir Selatan (T = 25 °C–35 °C), showed a higher protein content of 8.56% and 7.73%, respectively (Andesmora *et al*., 2020).

The minimum difference in protein percentages that may contribute to recognizable textural parameters by trained panelists varied for each textural parameter, for instance, 1% for roughness/slickness and 2% for stickiness (Champagne *et al*., 2009). The maximum protein difference among the 12 studied upland rice lines was 2.69%. The protein and AAC differences combined resulted in a maximum texture score difference of 1.2, as assessed using a descriptive score by panelists (Table 3).

Table 3. Chemical analysis of 12 crossbred upland rice lines.

Rice Lines	AAC (%)	Rice Type*	Gel Length (mm)	Gel Consistency Type **	Protein Content (%)
L-01	21.51	intermediate	56.0	medium	9.71
L-02	22.16	intermediate	54.0	medium	8.99
L-03	21.91	intermediate	48.5	medium	9.80
L-04	23.97	intermediate	46.0	medium	9.23
L-05	23.82	intermediate	58.0	medium	10.85
L-06	25.16	high	39.0	hard	8.57
L-07	22.20	intermediate	55.0	medium	9.19
L-08	19.97	low	57.0	medium	8.63
L-09	16.64	low	78.0	low	9.66
L-10	20.33	intermediate	53.5	medium	9.06
L-11	20.86	intermediate	52.5	medium	8.16
L-12	18.51	low	51.0	medium	8.48

*Based on AAC, milled rice is classified as waxy (0%), very low (2%–12%), low (13%–19%), intermediate (20%–24%), and high (>25%) (Bergman, 2019).

**Based on gel length, gel consistency of rice was classified as low (>50 mm), medium (36–49 mm), and hard (27–35 mm) (Cagampang *et al.*, 1973).

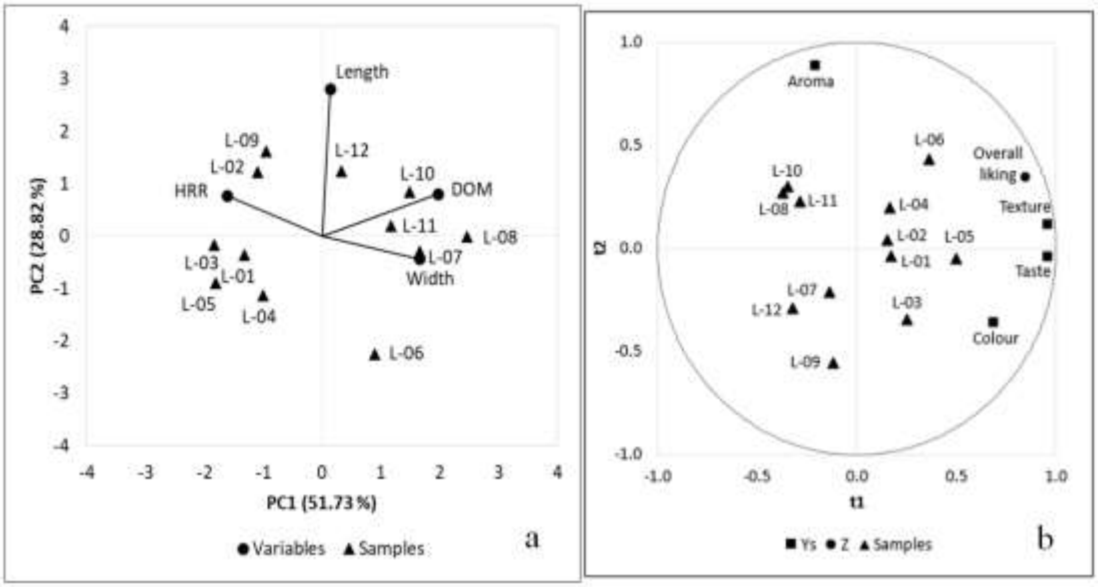

Figure 1. a) PCA biplot of the physicochemical properties of milled rice from the 12 crossbred upland rice lines, and b) PLSR biplot for the descriptive (Ys) and hedonic scores (Z) of cooked rice samples of 12 upland rice lines.

PCA of rice quality data

A Pearson correlation test before the PCA of rice quality occurred. Selecting one variable for further analysis followed when the absolute values of the correlation between two variables were at least 0.70. For instance, DOM use represented both variables when the correlation between chalky rice and DOM was 0.71. This elimination left the subsequent PCA with four variables. According to the PCA, the top two principal components (PC) accounted for 80.56% of the total variance, with each eigenvalue exceeding 1. The PCA biplot (Figure 1a) shows the anchoring of rice lines according to their similarities and magnitudes on specific variables. The clustering of rice lines L-07, L-08, L-10, and L-11 was because of their DOM and width better than most studied rice lines. Line L-07 most likely carried the parental traits of B11930F-TB-2, just like lines L-08, L-10, and L-11. Contrastingly, lines L-01, L-03, L-04, and L-05 had low values for length and DOM, placed in the opposite position of lines L-07, L-08, L-10, and L-11. Line L-05 had different parental genotypes from lines L-01, L-03, and L-04. Therefore, the genetic factor leading to similarity in their physicochemical properties was inconclusive in this study (no further genetic analysis ensued). Lines L-02, L-09, and L-12 had the utmost length compared with other rice lines, while line L-06 stood apart due to its low HRR and length values.

PLSR analysis of descriptive and hedonic scores

The ultimate objective of breeding is to create new cultivars that are superior and consumer-acceptable. Quality and consumer acceptance testing always precede releasing the new superior rice cultivars to the public. Sensory research assessment determined consumers' acceptance levels of colored, fortified, and organic rice (Poomipak *et al*., 2018; Woods *et al*., 2020; Liu *et al*., 2022). Organoleptic testing relies on the senses, while hedonic testing relies on consumer preference. The latter was more subjective, with influences from culture, religion, and lifestyle options (Yousif and Al-Kahtani, 2014). In Indonesia, people's preference for cooked rice heavily relies on the culture of each region.

The panelists' evaluations for the color of cooked rice prepared from 12 rice lines ranged from 1.57 to 2.07, with very white to white being the most prevalent. The white color of each line corresponds to the white color trait of the parental genotypes (TB368B-TB-25-MR-2, B11178G-TB-29, B11930F-TB-2, cv. Situ Patenggang, and cv. Inpago 8). Cooked rice of Line L-07 was more aromatic (descriptive score = 2.90) than the others and most likely inherited the trait from cv. Situ Patenggang parent. Cooked rice of Line L-10 was the least fragrant (descriptive score = 3.63) and was faintly different from most cooked rice.

Cooked rice from lines L-08, L-10, L-11, and L-12 were tasty (descriptive score ranged from 1.90 to 2.00). Cooked rice from other rice lines displayed decreasing tastiness, with cooked rice from L-05 receiving the lowest score (2.97). On texture, cooked rice from lines L-08 and L-10 met the sticky criterion, while cooked rice from other rice lines was less sticky, with cooked rice from line L-06 being the least sticky (descriptive score = 3.17). The hedonic assessment showed that the 12 studied rice lines were generally acceptable to the panelists, with line L-12 as the most preferred (Table 4).

The ANOVA results depicted in the biplot PLSR analysis, demonstrating the distribution of the 12 tested rice lines across all four quadrants, indicate that eating quality has more than a single characteristic determining it, but rather by the interaction among the color, aroma, taste, and texture (Figure 1b). Among the four descriptive scores, texture and taste had a superior influence on overall liking. It can be visible from the PLSR biplot as texture and taste anchored closer to general preference, compared with the color and aroma. This finding aligns with the ANOVA results (Table 4) that texture and taste had more indexation groups. On the descriptive score and hedonic scale, a minimum score indicates better descriptive properties or was more preferred. Line L-12 had the lowest scores of the four descriptive scores, making L-12 the most accepted (the lowest hedonic value of 1.97). Therefore, the position of L-12 in the PLSR biplot was the farthest from the four descriptive scores and the overall accepted. According to the research conducted by Suryana *et al*. (2022), rice cultivars significantly affected color, aroma, texture, stickiness, flavor, and general acceptability. Thus, the comprehensive acceptance of rice cultivars by the panelists in this study indicates having been affected by genetic factors inherited by their parental rice cultivars/genotypes. Although, the direct evaluation occurred on rice color, aroma, texture, and flavor.

Table 4. Descriptive and hedonic scores of cooked rice samples from 12 crossbred upland rice lines.

Rice Lines	Descriptive scores				Hedonic scores
	Color	Aroma	Taste	Texture	
L-01	1.90ab	3.23ab	2.60bcd	2.67bcde	2.43abc
L-02	2.00ab	3.43ab	2.57bcd	2.50abcd	2.30ab
L-03	2.00ab	2.97ab	2.60bcd	2.83cde	2.60bc
L-04	1.90ab	3.40ab	2.33abc	2.90cde	2.60bc
L-05	2.00ab	3.13ab	2.97d	3.17e	2.70bc
L-06	1.87ab	3.53ab	2.80cd	3.03de	2.87c
L-07	1.57a	2.90a	2.40abc	2.43abc	2.30ab
L-08	1.63ab	3.57ab	2.00a	1.97a	2.20ab
L-09	2.07b	3.07ab	2.17ab	2.07a	2.23ab
L-10	1.70ab	3.63b	1.93a	2.00a	2.27ab
L-11	1.73ab	3.53ab	1.90a	2.20ab	2.33ab
L-12	1.73ab	3.07ab	1.97a	2.10ab	1.97a

CONCLUSIONS

Twelve crossbred upland rice lines were derivatives from superior parental genotypes. The PCA of the resultant milled rice consisted of four principal variables, namely, HRR, length, width, and DOM. These variables and other milling properties are prerequisites for determining the quality of rice grains at the national level (SNI 6128-2015). None of the 12 observed rice samples met the premium rice criterion, which required a minimum HRR of 95%. Two rice lines (L-03 and L-05) were Medium-I quality, two (L-01 and L-02) were Medium-III quality, and the rest were uncategorized. The panelists generally liked the cooked rice of the 12 observed lines. The descriptive factors mainly influencing the overall liking were texture and taste. Cooked rice from a line L-12 received the best general acceptability, displaying better scores across all descriptive factors (texture, taste, color, and aroma) versus cooked rice from other lines. Further studies involving genetic markers might contribute to developing upland rice cultivars with more satisfying eating quality. Nevertheless, the knowledge generated from this study hopes to complement the existing data on upland rice breeding programs.

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