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ORIGINAL ARTICLE

Consumer acceptance test and some related properties of selected KDML 105 rice mutants

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Abstract Comparative analysis of the Kao Dawk Mali 105 (KDML 105) premium rice variety, and its six mutants, obtained after low energy ion bombardment, was carried out for sensory and other consumer acceptance related important properties. Consumer acceptance test (n = 200), colour parameters (L*, a*, b*), grain length, and texture parameters of cooked rice and 2-Acetyl-1-pyrroline (2AP), amylose, fat, and protein contents of polished rice were determined. The consumer acceptance test showed that HyKOS3-1 and KDML 105 were equally accepted for every attribute, while HyKOS16 had lower colour liking than KDML 105. Other mutants of KDML 105 were less accepted than KDML 105. Preference mapping (PCA bi-plot) showed that the overall liking of cooked rice was positively correlated to 2AP and fat content and negatively correlated to hardness, cohesiveness, springiness, chewiness, amylose and protein contents. Consumers preferred cooked rice which has good aroma and soft texture. However, only 2AP content might be not enough to explain aroma liking of cooked rice and rice with different texture could be accepted in the same level of KDML 105.

Keywords Texture profile · 2-Acetyl-1-pyrroline (2AP) · Sensory analysis · Preference map

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Introduction

Oryza sativa L. cv. KDML 105 (Khao Dawk Mali 105) is a special variety of rice that has a distinctive texture and fragrance. It is a non-glutinous rice variety with long grain and slender shape. The grain is transparent or clear and contains very few chalky kernels. When cooked, the rice has shinny white colour, soft texture, and a natural fragrant smell of 2-Acetyl-1-pyrroline (2AP) (Phanchaisri et al. 2007; Rice Department 2010).

The plantation area of Thai jasmine rice is about 7.6 million acres and its yield is only 1125–1500 kg/acre (OK Nation 2014). The demand of Thai jasmine rice in the world market is increasing but the annual production does not fulfill the demand of International market (Phanchaisri et al. 2007; Pitiphunpong et al. 2011). The blending of Thai jasmine rice with other rice varieties is being performed in some countries but uncontrolled blending rice resulted in lower cooked rice quality and unfair trade (Pitiphunpong et al. 2011).

Culm height and photoperiod sensitivity are major traits for lowering of the KDML 105 production in Thailand. Due to photoperiod sensitivity, KDML105 can be grown during August–December (Phanchaisri et al. 2007). To improve culm structure and decrease photoperiod sensitivity of KDML 105 rice plants, physical and chemical mutagens have been applied (Boonrueng et al. 2013; Datta 2005).

Low energy ion beam bombardment is a method recently used as physical mutagenic source because of low damage rate, high mutation rate and wide mutation spectrum (Yu et al. 1991). Application of low ion beam bombardment to KDML 105 rice resulted in many new lines with characters that allows higher yields such as photoperiod insensitivity, semi-dwarfism (Boonrueng et al. 2013;

Phanchaisri et al. 2007, 2012), drought resistance (Boonrueng et al. 2013) and blast disease resistance (Mahadtanapuk et al. 2013). This technique also imposed potential health benefit characters such as dark purple/black pericrap (Boonrueng et al. 2013; Phanchaisri et al. 2007; Semsang et al. 2013).

In present study, six high yielding (Hy), mutants of KDML 105 (K) rice, which were capable to grow in off-season season (OS) and photoperiod insensitive, named as HyKOS3, HyKOS3-1, HyKOS7-1, HyKOS16, HyKOS21 and HyKOS22 were selected for sensory and other important consumer acceptance analysis. These mutants yield ranged between 2275 and 4312.5 kg/acre compared to 1307.5 and 1742.5 kg/acre for KDML 105 (Agricultural Research Development Agency, ARDA 2013).

Materials and methods

Low energy ion beam bombardment

Rice seeds of *Oryza sativa* L. cv. KDML 105 were bombarded in vacuum by nitrogen ion beam ($N^+ + N_2^+$) at energy of 60–80 keV (1 eV = 1.6×10^{-19} J) to a beam fluence range of 2×10^{16}–2×10^{17} ions/cm^2 by the modified ion implanter (Mahadtanapuk et al. 2013; Semsang et al. 2013). The bombarded seeds were cultivated and the yields of selected mutants were used as rice samples.

Rice samples

Polished rice (13–21 % degree of milling) of KDML 105 and six mutants (HyKOS3, HyKOS3-1, HyKOS7-1, HyKOS16, HyKOS21 and HyKOS22) was supplied by Science and Technology Research Institute, Chiang Mai University, Chiang Mai, Thailand.

Cooking method

The rice was washed, drained and weighed before adding water to make a certain rice and water ratio at 1:1.75 for KDML 105, HyKOS3, HyKOS7-1, HyKOS16 and HyKOS21, and at 1:2.0 for HyKOS3-1 and HyKOS22 because the last two rice mutants were harder than others (Wangcharoen et al. 2015). KDML 105 and related mutant rice kernels were cooked for 16–21 min by using rice cooker (SHARP Model KSH 206, Thai City Electric, Bangkok, Thailand).

Consumer acceptance test of cooked rice

Consumer acceptance test was conducted in pairs between KDML 105 (control) and a sample (selected KDML 105 rice mutants or KDML 105 as a blind control). Twenty gram of each cooked rice was served at 50 ± 5 °C with random 3 digit code number. For each pair, 200 consumers (20–60 year olds) were requested to taste each cooked rice and then evaluate their acceptance scores for colour, appearance, aroma, taste, texture and overall liking by using 9 point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely) (Resurreccion 1998).

2-Acetyl-1-pyrroline and proximate composition of polished rice, colour, texture parameters and grain length of cooked rice

2-Acetyl-1-pyrroline (2AP) content of polished rice was analyzed by Static headspace gas chromatography (SHS-GC) with nitrogen-phosphorus detector (NPD) (Sriseadka et al. 2006). Briefly, rice was chilled at 4°C for 24 h before grinding and screening through a 150 µm sieve. One gram (1 g) of rice powder was placed into a 20 mL headspace vial and 1 µL of 0.5 mg/mL 2,6-dimethylpyridine in benzyl alcohol was added to followed by sealing with a PTFE/silicone septum and aluminum crimp cap. The vials were shaken well at room temperature for 10 min prior to analysis by SHS-GC-NPD. Headspace autosampler conditions used were as follows: oven temperature, 120 °C; vial equilibration time, 9 min with high speed shaking; loop filling time, 0.01 min; pressurizing time, 0.10 min; and injection time, 0.40 min. An HP-5 column (30 m × 0.53 mm i.d. 1.5 µm film thickness) with a splitless injection at 275 °C was used. The column temperature was initially at 50 °C and increased to 125 °C at a rate of 5 °C/min. The carrier gas flow rate was 5 mL/min.

Amylose content of polished rice was analyzed by Spectrophotometer (National Bureau of Agricultural Commodity and Food standard 2003). Briefly, 1 mL 95 % ethanol was added to 0.1 g rice flour before adding 9 mL 2 N NaOH. The mixture was well mixed by magnetic stirrer for 10 min and its volume was adjusted to 100 mL by distilled water to make the starch solution. Two mL 1 N glacial acetic acid and 2 mL iodine solution (0.2 g I_2 and 2 g KI in 100 mL) were mixed with 70 mL of distilled water followed by adding additional 5 mL starch solution. The final volume of the solution was raised up to 100 mL by distilled water. After 10 min, the absorbance at 620 nm was measured by using UV/visible spectrophotometer. Pure potato amylose was used as a standard.

Protein and fat contents of polished rice were analyzed by AOAC official method (AOAC 2005).

Colour parameters (L* a* b*) of cooked rice were measured by Tri-Stimulus Colorimeter (JUKI: model JC801). Grain length of cooked rice was measured by a vernier caliper.

Texture parameters of cooked rice were evaluated by Lloyd Universal testing machine (Model LR10 K, Lloyd Instruments, Hampshire PO15 5TT, UK). Rice (150 g) was cooked as described above and kept in the cooker until cooled to room temperature. A 100 N load cell, a 10 mm diameter steel cylinder probe with a flat end and test speed at 100 mm/min were used. The whole cooked rice was compressed to 75 % of its original height, held for 3 s., released and compressed again to complete the two-cycle compression test (Wangcharoen et al. 2015). Texture parameters including hardness, cohesiveness, adhesiveness, springiness and chewiness were derived from the instrument software.

Chemical analysis parameters reported were average of triplicate data, while physical measurements were average of ten observations.

Statistical analysis

Consumer acceptance data were analyzed by dependent *t* test, while those of chemical and physical properties were analyzed by analysis of variance with completely randomized design (CRD) and their means were compared by Tukey (a)'s w test. A preference map (PCA bi-plot) was created from consumer acceptance data (the difference of control and sample/blind control from each panel) by principal component analysis. Other properties were added by the correlation between rice positions and their property means (Greenhoff and MacFie 1994). All statistical analysis was done by R version 3.2.1 (R Core Team 2015).

Results and discussion

Consumer acceptance test

The rice and water ratio used for cooking were changed from 1:1.75 to 1:2.0 for HyKOS3-1 and HyKOS22 because of higher grain hardness that ranged between 11.2 and 15.4 N, compared to 6.1–7.2 N of rest four mutants and wild type KDML 105 rice (Wangcharoen et al. 2015). Higher grain hardness of HyKOS3-1 and HyKOS22 resulted in long cooking time from 16 to 18 min for normal rice to 19–21 min. The moisture content of cooked rice were ranged between 60.7 and 65.4 %. The consumer acceptance test of cooked KDML 105 and 6 mutants showed that a blind control of KDML 105 and HyKOS3-1 were equally accepted to KDML 105 for all sensory attributes, while HyKOS16 was also accepted equally to KDML 105 for all attributes except color. Other varieties had lower acceptable sensory scores than KDML 105 (Table 1).

2-Acetyl-1-pyrroline and proximate composition of polished rice, colour, texture parameters and grain length of cooked rice

For polished rice, the highest accumulation of 2AP was found in KDML 105, followed by HyKOS16 and HyKOS3, HyKOS7-1 and HyKOS3-1, while 2AP was not detected in HyKOS21 and HyKOS22 (Table 2). 2AP is not produced during cooking or postharvest processes. 2AP is

Table 1 Consumer acceptance test of cooked KDML 105 (control) and samples (selected KDML 105 rice mutants or KDML 105, blind control)

Paired test	Colour liking	Appearance liking	Aroma liking	Taste liking	Texture liking	Overall liking
KDML 105	$7.32^a \pm 1.02$	$6.99^a \pm 1.25$	$7.10^a \pm 1.21$	$7.19^a \pm 1.34$	$7.06^a \pm 1.60$	$7.36^a \pm 1.15$
HyKOS3	$6.39^b \pm 1.56$	$6.21^b \pm 1.51$	$6.60^b \pm 1.44$	$6.60^b \pm 1.42$	$6.35^b \pm 1.66$	$6.63^b \pm 1.47$
KDML 105 ns	6.79 ± 1.47	6.49 ± 1.48	6.81 ± 1.44	6.79 ± 1.62	6.54 ± 1.65	6.87 ± 1.40
HyKOS3-1	6.83 ± 1.43	6.61 ± 1.44	6.59 ± 1.54	6.56 ± 1.58	6.39 ± 1.75	6.72 ± 1.48
KDML 105	$6.92^a \pm 1.14$	$6.61^a \pm 1.33$	$6.80^a \pm 1.26$	$6.82^a \pm 1.34$	$6.73^a \pm 1.53$	$6.90^a \pm 1.16$
HyKOS7-1	$6.64^b \pm 1.33$	$6.48^a \pm 1.30$	$6.55^b \pm 1.45$	$6.49^b \pm 1.46$	$6.30^b \pm 1.56$	$6.68^b \pm 1.28$
KDML 105	$6.58^a \pm 1.28$	$6.22^a \pm 1.24$	$6.51^a \pm 1.44$	6.34a ± 1.57	$6.14^a \pm 1.69$	$6.49^a \pm 1.28$
HyKOS16	$6.33^b \pm 1.45$	$6.25^a \pm 1.36$	$6.65^a \pm 1.46$	6.30a ± 1.61	$6.09^a \pm 1.77$	$6.37^a \pm 1.48$
KDML 105	$7.06^a \pm 1.16$	$6.85^a \pm 1.26$	$6.99^a \pm 1.33$	6.93a ± 1.29	$6.75^a \pm 1.47$	$7.08^a \pm 1.20$
HyKOS21	$6.00^b \pm 1.71$	$5.93^b \pm 1.60$	$6.12^b \pm 1.65$	6.23b ± 1.64	$6.10^b \pm 1.80$	$6.39^b \pm 1.61$
KDML 105	$6.75^a \pm 1.19$	$6.52^a \pm 1.30$	$6.93^a \pm 1.31$	6.68a ± 1.41	$6.44^a \pm 1.63$	$6.84^a \pm 1.26$
HyKOS22	$6.52^b \pm 1.24$	$5.99^b \pm 1.39$	$5.90^b \pm 1.56$	5.88b ± 1.76	$5.76^b \pm 1.88$	$6.03^b \pm 1.53$
KDML 105 ns	6.75 ± 1.28	6.48 ± 1.31	6.70 ± 1.61	6.62 ± 1.54	6.48 ± 1.67	6.84 ± 1.27
KDML 105(blind control)	6.79 ± 1.24	6.50 ± 1.52	6.82 ± 1.42	6.68 ± 1.59	6.46 ± 1.61	6.83 ± 1.29

1 = Dislike extremely, 5 = Neither like nor dislike, 9 = Like extremely

[a, b] Means with different letters in each pair were significantly different ($p \leq 0.05$)

[ns] Means of this pair were not significantly different ($p > 0.05$)

Table 2 2-Acetyl-1-pyrroline (2AP), amylose, protein and fat contents of polished KDML 105 and its 6 selected mutants*

Variety	2AP (ppm)	Amylose (%)	Protein (%)	Fat (%)
KDML 105	$13.77^{a} \pm 2.46$	$12.87^{c} \pm 0.95$	$4.19^{e} \pm 0.40$	$0.30^{b} \pm 0.12$
HyKOS3	$6.88^{b} \pm 1.04$	$12.99^{c} \pm 0.83$	$5.18^{d} \pm 0.36$	$0.28^{b} \pm 0.06$
HyKOS3-1	$1.54^{d} \pm 0.47$	$19.19^{b} \pm 2.44$	$7.74^{abc} \pm 0.59$	$0.43^{b} \pm 0.13$
HyKOS7-1	$3.48^{c} \pm 0.32$	$13.51^{c} \pm 0.61$	$6.66^{c} \pm 0.98$	$0.78^{a} \pm 0.20$
HyKOS16	$6.93^{b} \pm 0.31$	$12.85^{c} \pm 0.57$	$7.04^{bc} \pm 0.32$	$0.70^{a} \pm 0.16$
HyKOS21	Not detected	$12.95^{c} \pm 0.62$	$8.45^{a} \pm 0.76$	$0.63^{a} \pm 0.25$
HyKOS22	Not detected	$20.99^{a} \pm 0.26$	$8.07^{ab} \pm 0.71$	$0.40^{b} \pm 0.17$

[a, b] Means with different letters in the same column were significantly different ($p \leq 0.05$)

* Data were reported on the basis of 14 % grain moisture content

synthesized in aerial parts of rice plants during growing and development (Yoshihashi 2002) and transported into rice kernels where it was stored in both starch bound and free forms (Yoshihashi et al. 2005). In addition, suitable nutrient elements could enhance the 2AP production (Monggoot et al. 2014) and 2AP could decrease by storage time and condition (Maneenuam et al. 2014; Tulyathan and Leeharatanaluk 2007; Yoshihashi et al. 2005). Furthermore, other volatiles (such as heptanal, 1-octen-3-ol, octanal) were also reported as key aroma compounds in rice kernels (Griglione et al. 2015). Therefore, starch bound and free forms of 2AP and other key aroma compounds might be responsible for insignificantly differential liking of cooked KDML 105, HyKOS3-1 and HyKOS16 which contained varied accumulation of 2AP contents (Tables 1, 2).

The amylose content of HyKOS22 was the highest, followed by HyKOS3-1, and others (Table 2). The harder texture of HyKOS22 and HyKOS3-1 may be associated with higher amylose content in these rice mutants. The increase of hardness of cooked rice was positively correlated with amylose content (Jinshui et al. 1998). The positive correlation between hardness and amylose content was also reported in rice-based fries (Kadan et al. 1997).

KDML 105 had the lowest protein content, while HyKOS21, HyKOS22 and HyKOS3-1 contained the highest protein content. The correlation between protein content and eating quality of cooked rice was not found (Kexin et al. 2014), but positive correlation between protein content and hardness was found in rice-based fries (Kadan et al. 1997). Fat contents of HyKOS7-1, HyKOS16 and HyKOS21 were higher than those of others (Table 2), and the positive correlation between fat content and eating quality of cooked rice was reported earlier (Kexin et al. 2014). The positive correlation between fat content and overall acceptability as well as its related attributes (aroma, taste and texture liking) was also found in the preference map (PCA bi-plot) of this work (Fig. 1) since fat contributes to the texture, flavor and aroma of foods (Drewnowski and Almiron-Roig 2010).

In case of cooked rice, only HyKOS21 had different values of L*(dark–light) and a*(green–red) compared to KDML 105 because of its purple pigment left from washing process before cooking. For b* values (blue–yellow), those of KDML 105, HyKOS3-1, HyKOS7-1 and HyKOS22 were not different but b* value of HyKOS22 was more towards negative value (blue) than of HyKOS3-1 and HyKOS7-1. The grain length of HyKOS16, HyKOS21 and HyKOS22 was short as compared to KDML 105 (Table 3).

For texture parameters of cooked rice, it seemed that only HyKOS3 and HyKOS16 had similar texture to KDML 105. HyKOS3-1 was more adhesive, springy and chewy. HyKOS7-1 was less springy and HyKOS21 was softer. HyKOS22 was more cohesive, springy and chewy (Table 4). These differences were mostly influenced by chemical components, especially amylose content (Jinshui et al. 1998; Mohapatha and Bal 2006), and its leaching during cooking (Leelayuthsoontorn and Thipayarat 2006). Hardness, cohesiveness and adhesiveness were reported to have positive correlation to the amylose content (Jinshui et al. 1998; Mohapatha and Bal 2006). The leaching of amylose from starch granule during cooking caused the decrease of cooked rice hardness and higher amylose leaching caused the increase of adhesiveness (Leelayuthsoontorn and Thipayarat 2006). For springiness and chewiness, they were positively correlated to hardness and cohesiveness.

Preference mapping

Principle component analysis was used to reduce consumer acceptance data (the difference of control and sample/blind control from each panel) to 2 principle components (PCs) with 73.3 % explained variance. The PC1 (44.5 % explained variance) was positively correlated to aroma, taste, texture and overall liking, and the PC2 (28.8 % explained variance) was positively correlated to colour and appearance liking. These 2 PCs were used to create a preference map (PCA bi-plot) of KDML 105 and its 6 selected mutants. Other properties were then added by the

Fig. 1 A preference map (PCA bi-plot) of KDML 105 and its 6 selected mutants

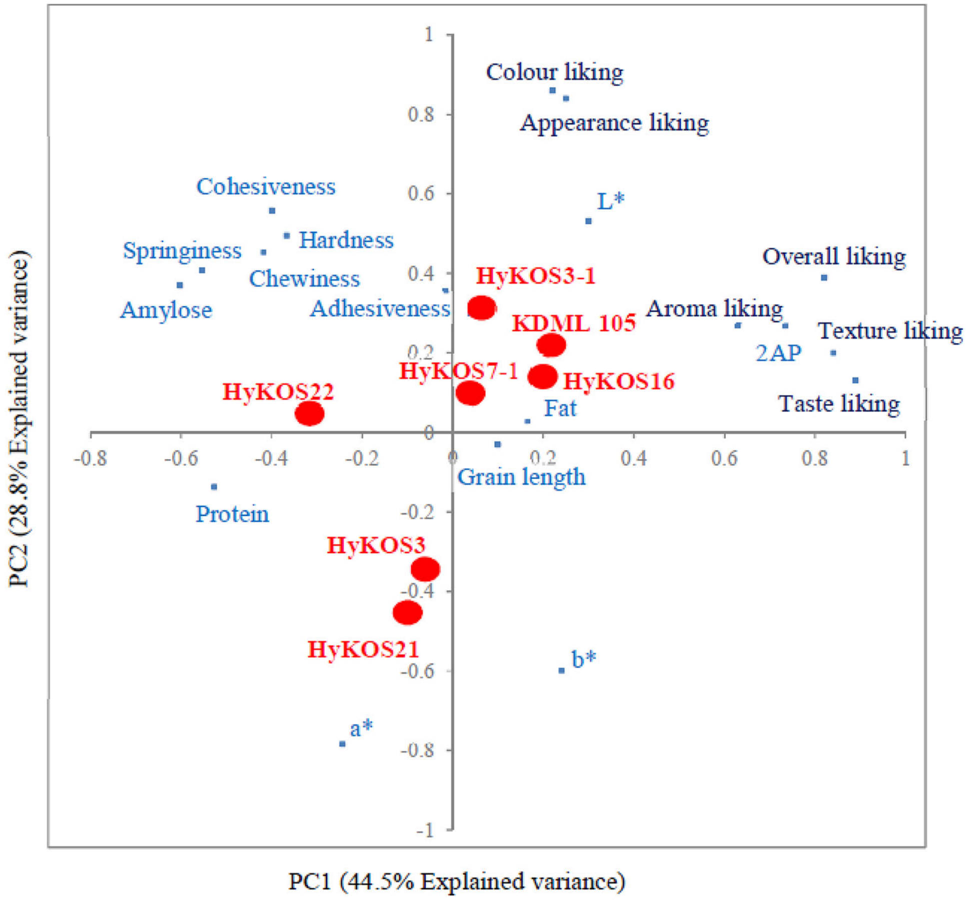

Table 3 Colour parameters (L*, a*, b*) and grain length of cooked KDML 105 and its 6 selected mutants

Variety	L*	a*	b*	Grain length (mm.)
KDML 105	72.11^{ab}±0.91	$2.01^{b} \pm 0.41$	$-0.82^{cd} \pm 0.66$	$9.56^{ab} \pm 0.52$
HyKOS3	$72.97^{a} \pm 0.30$	$2.86^{b} \pm 0.39$	$1.06^{ab} \pm 0.23$	$10.24^{a} \pm 0.36$
HyKOS3-1	$70.20^{b} \pm 1.83$	$1.90^{b} \pm 0.55$	$0.06^{bc} \pm 0.55$	$9.67^{ab} \pm 0.51$
HyKOS7-1	$72.01^{ab} \pm 0.27$	$2.12^{b} \pm 0.71$	$0.03^{bc} \pm 0.83$	$9.32^{bc} \pm 0.76$
HyKOS16	$71.68^{ab} \pm 1.25$	$2.16^{b} \pm 0.55$	$1.14^{ab} \pm 0.67$	$8.50^{d} \pm 0.69$
HyKOS21	$62.06^{c} \pm 1.74$	$7.17^{a} \pm 0.46$	$1.43^{a} \pm 0.39$	$8.71^{cd} \pm 0.43$
HyKOS22	$70.40^{b} \pm 0.69$	$2.03^{b} \pm 0.43$	$-1.34^{d} \pm 0.64$	$8.75^{cd} \pm 0.53$

[a, b] Means with different letters in the same column were significantly different ($p \leq 0.05$)

Table 4 Texture parameters of cooked KDML 105 and its 6 selected mutants

Variety	Hardness (N)	Cohesiveness	Adhesiveness(N.mm)	Springiness (mm)	Chewiness (N.mm)
KDML 105	$9.71^{abc} \pm 1.67$	$0.18^{bc} \pm 0.03$	$1.86^{b} \pm 0.69$	$8.42^{cd} \pm 1.52$	$14.02^{b} \pm 3.24$
HyKOS3	$9.12^{bc} \pm 1.86$	$0.18^{bc} \pm 0.02$	$2.45^{b} \pm 1.37$	$6.98^{de} \pm 0.69$	$11.67^{b} \pm 3.33$
HyKOS3-1	$10.69^{ab} \pm 1.77$	$0.23^{ab} \pm 0.05$	$7.26^{a} \pm 2.26$	$12.24^{b} \pm 1.70$	$30.30^{a} \pm 12.55$
HyKOS7-1	$7.94^{cd} \pm 1.18$	$0.19^{abc} \pm 0.04$	$3.73^{b} \pm 1.77$	$6.36^{e} \pm 1.03$	$10.00^{b} \pm 3.53$
HyKOS16	$7.65^{cd} \pm 0.98$	$0.20^{abc} \pm 0.03$	$2.26^{b} \pm 1.37$	$9.02^{c} \pm 0.61$	$13.63^{b} \pm 3.73$
HyKOS21	$6.18^{d} \pm 1.18$	$0.16^{c} \pm 0.02$	$3.14^{b} \pm 1.77$	$7.21^{cde} \pm 0.96$	$7.75^{b} \pm 3.14$
HyKOS22	$11.96^{a} \pm 3.43$	$0.24^{a} \pm 0.07$	$2.65^{b} \pm 0.78$	$14.13^{a} \pm 2.15$	$43.35^{a} \pm 26.28$

[a, b] Means with different letters in the same column were significantly different ($p \leq 0.05$)

correlation between rice positions and their property means (Fig. 1).

Fig. 1 shows that HyKOS16 and HyKOS3-1 were closely related to KDML 105, followed by that of HyKOS7-1, while that of HyKOS3, HyKOS21 and HyKOS22 were faraway. It indicated the consumer acceptance for KDML 105, HyKOS3-1 and HyKOS16 were close to each other, while HyKOS7-1 and others had less acceptability than KDML 105.

The colour and appearance scores were positively correlated to each other, while aroma, taste, texture and overall acceptability scores were positively correlated to each other. It reflected that aroma, taste and texture influenced the overall acceptability score rather than colour and appearance did, as shown by the consumer acceptance test of cooked KDML 105 and HyKOS7-1 or HyKOS16 (Table 1).

Amylose and protein contents, hardness, cohesiveness, springiness and chewiness were positively correlated to each other, while they were negatively correlated to 2AP and fat contents (Fig. 1). Amylose and protein contents influenced on hardness, cohesiveness, springiness and chewiness, and high amylose and protein rice might contain low 2AP and fat contents. L* was negatively correlated to a* and b*.

The location of different properties and sensory attribute showed that L* was positively correlated to colour and appearance scores, while a* and b* were negatively correlated to them. The results reflected that consumers preferred white cooked rice (no colour but light). The overall acceptability and other sensory attributes (aroma, taste and texture liking), were positively correlated to 2AP and fat contents, but negatively correlated to amylose and protein contents, hardness, cohesiveness, springiness and chewiness. This clearly reflected that consumers preferred good aroma and soft texture of cooked rice.

Conclusion

Present study demonstrated that consumers preferred cooked rice which has white colour, good aroma, and soft texture, but aroma, taste and texture are more important than colour and appearance. Aroma of cooked rice mutants, such as HyKOS3-1 and HyKOS16, with lower 2AP content could be accepted in the same as of cooked KDML 105. Therefore, only 2AP content could not be used for explaining aroma liking of cooked rice. In addition, the rice and water ratio could improve the texture of cooked rice and different texture profile could be accepted in the same level of KDML 105 such as HyKOS3-1 which was more adhesive, springy and chewy rice, while the similar texture to KDML 105 such as HyKOS3 could be less accepted because of higher protein and lower 2AP contents.

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