International Journal of Agriculture, Environment and Food Sciences
e-ISSN : 2618-5946
www.jaefs.com
JAEFS
edit PUBLISHING

Research Article
Int J Agric Environ Food Sci 6 (2): 294-302 (2022)

Physico-chemical and cooking quality traits of paddy cultivars of japonica sub-species

Hasan Akay[1,*] **Ismail Sezer**[1] **Elif Ozturk**[3]

[1]Ondokuz Mayıs University, Agriculture Faculty, Field Crops Department, Samsun, Türkiye

[*]Corresponding Author: hasan.akay@omu.edu.tr

Citation
Akay, H., Sezer, I., Ozturk, E. (2022). Physico-chemical and cooking quality traits of paddy cultivars of japonica sub-species. International Journal of Agriculture, Environment and Food Sciences, 6 (2), 294-302.
Doi: https://doi.org/10.31015/jaefs.2022.2.13

Received: 10 May 2022
Accepted: 14 June 2022
Published Online: 22 June 2022
Revised: 27 June 2022

Year: 2022
Volume: 6
Issue: 2 (June)
Pages: 294-302

Available online
http://www.jaefs.com
https://dergipark.org.tr/jaefs

Abstract

Paddy, grown on all continents of the world, is an economical source of food and a strategic cereal. Cooking quality of rice is closely related to physico-chemical characteristics of starch constituting about 90% of rice dry matter. Environmental and genetic factors are effective on rice quality and physico-chemical properties. Knowledge on these traits plays an important role in comprehension the changes encountered during cooking. This study was conducted in 2020 to determine physico-chemical and cooking quality traits of rice grains obtained from 18 paddy cultivars. Physical, chemical and cooking quality traits of 18 rice samples were analyzed in 3 replications. Significant differences were observed in investigated traits of paddy cultivars. The thousand-grain weights varied between 20.32-31.00 g; rice grain lengths between 5.88-7.28 mm; grain elongation ratios between 1.40-2.47%; grain water absorptions between 46.96-71.27%; water uptake ratios between 1.91-3.31%; cooking times between 00:17:19-00:23:28 min; protein contents between 5.45-8.89% and amylose contents varied between 16.91-26.25%. According to the biplot graph, Efe, Kale and Galileo cultivars were found to be prominent for more than one trait. The biplot graph also revealed that cooking time was the most distinctive trait. There were highly significant negative correlations between alkali spreading and cooking time parameters. Although it was banned worldwide in rice codex, different rice cultivars, classes, groups and types are compared and served to markets. Although the constellation plot generated through the use of results for investigated parameters allowed primary separation of paddy cultivars, present parameters were not found to be sufficient for a net separation of the cultivars.

Keywords

Rice, Cooking Time, Elongation Ratios, Amylose, Biplot

Introduction

Paddy constitutes the primary nourishment of more than 3 billion people worldwide. It is also consumed as baby food; thus, it is among the most significant cereal grains constituting a source of nourishment for 505 of the world population and a source of income for a hundred million small farmers (90%). According to genetic information derived from archeological excavations, paddy was cultivated between 6200 - 11500 B.C. (Suh et al., 2010). Paddy, which was started to be consumed by 2500 B.C., is thought to spread to the world from China. It is also estimated that paddy passed to Sri Lanka and India-like countries from China (Kün, 1997). An acquaintance of the western world with paddy coincides with the years 300s B.C. Paddy was thought to reach the continent of America by the end of the 17th century and reached Turkey about 500 years ago. Paddy farming is practiced in 119 countries worldwide over 162 million hectares with an annual production of 744 million tons. More than 75% of this production is realized under an aqueous production system (FAO, 2020).

Including wild species, the genus *Oryza* has 21 species. Of these species, the cultivars of *Oryza Glaberrima* species are cultivated only in West African countries, the cultivars of *Oryza sativa* species are cultivated in entire countries of the world. Traditional cultivars of *Oryza sativa* species inhold three sub-species (*Indica*, *Japonica* and *Javanica*) in terms of geographical adaptation, morphological, physiological and chemical characteristics. While *Japonica* and *Japonica x Indica* hybrids are generally cultivated in European countries, *Indica* species are mostly cultivated in South Asian countries. The *Indica* species generally have greater yields than the *Japonica* species (Fan et al., 2017). The paddy grain separated from the hulls, fruit and seed testa is so-called "rice" (Sürek, 2002). Since the quality varies from country to country and region to region, it is quite hard to define the quality of rice. Rice quality is generally designated by genetics and environmental factors (Sezer et al., 2007). While environmental factors largely influence physical quality traits (thousand-grain weight, grain dimensions, head and broken yields), chemical and cooking quality traits (amylose content, gel consistency, gelatinization temperature, water uptake ratio, grain elongation, cooking time) are largely influenced by genetic factors (Bahmaniar and Ranjbar, 2007). However, gelatinization temperature is highly influenced both by genetics and environmental factors (Kishine et al., 2008).

Worldwide, market value, consumer preference and adaptation of new cultivars are the primary factors influencing the quality concept in rice. Physical appearance, physico-chemical characteristics and cooking traits characterize the product and designate direct decisions about the product in consumer markets (Custodio et al., 2009).

In general, rice grain quality could be divided into four categories: nutritional value, industrial quality, compliance with marketing standards, cooking and sensory quality. The factors controlling the cooking quality of rice are mostly related to physico-chemical characteristics of starch constituting about 90% of the dry matter in polished rice grain (Kong et al., 2015). Knowledge of these traits plays significant role in comprehension of the changes encountered during cooking of rice (Custodio et al., 2009). This study was conducted to determine physico-chemical characteristics of nationally and internationally important *japonica* species.

Materials and Methods

In the present study, Edirne, Efe, Gala, Halilbey, Kale, Kızıltan, Osmancık-97, Tosya Güneşi and Yatkın cultivars registered bred by Trakya Agricultural Research Institute and Agusto, Arieti, Baldo, Cammeo, Crono, Galileo, Meco, Nembo and Ronaldo cultivars registered in European countries were used (Table 1).

Table 1. List of tested paddy cultivars (*Oriza sativa L. japonica*)

No	Name	Origin
1	Agusto	Italy
2	Arieti	Italy
3	Baldo	Italy
4	Cammeo	Italy
5	Crono	Italy
6	Edirne	Turkey
7	Efe	Turkey
8	Gala	Turkey
9	Galileo	Italy
10	Halilbey	Turkey
11	Kale	Turkey
12	Kızıltan	Turkey
13	Meco	Italy
14	Nembo	Italy
15	Osmancık-97	Turkey
16	Ronaldo	Italy
17	Tosya Güneşi	Turkey
18	Yatkın	Turkey

Rice samples of the present materials were obtained from the cultivar-yield experiments conducted in Bafra Agricultural Research and Implementation Center of Ondokuz Mayıs University Agricultural Faculty during 2020 paddy growing season (15 May – 20 September). Analyses were conducted in accordance with randomized plots designed with 3 replications. Thousand-grain weight, grain length and grain length/width ratio parameters were determined in accordance with the method specified in Akay (2020). Cooked grain length, grain elongation ratio and cooking time (min) were determined in accordance with the method specified in Simonelli et al. (2017); gelatinization temperature was determined with the method Oko et al. (2012) and amylose content was determined with the method Bergman (2019). Experimental results were subjected to ANOVA in accordance with randomized plots design. Principle component analysis was conducted with the use of JMP (2007) statistical software. Significant of differences were identified with F test and means were compared with the use of Tukey's test.

Results and Discussion

Thousand-grain weight is among the most important quality traits of rice. Greater thousand-grain weights indicate larger grains. Large grains are preferred by consumers, thus increasing market value (USDA, 2009; Akay, 2020). There were highly significant differences in thousand-grain weights of 18 paddy cultivars and the values varied between 20.32 g (Crono) – 31.00 g (Baldo). In terms of thousand-grain weight, Baldo (31.00 g) and Edirne (29.63 g) cultivars were in the same statistical group (Table 2). Present findings on thousand-grain weights were similar to the findings of previous studies for Osmancık-97 (25.20 – 27.77 g), Ronaldo (24.70 - 25.38 g), Baldo (31.41 - 32.41 g), Cammeo (29.68- 30.3 g), Efe (27.51- 27.84 g) and Halilbey (27.55 g) cultivars (Akay et al., 2018; Akay, 2020; TTSM, 2015; Simonelli et al., 2016; Yazman, 2014). The thousand-grain weight of rice is affected by environmental factors as well as genetic factors Abiotic stress factors especially in grain-fill period negatively influence thousand-grain weights (Kün, 1997). Thousand-grain weights of rice cultivars were reported as between 15.0 - 22.0 g by Webb et al. (1989), between 23.1 - 23.7 by Khalif et al. (2007), between 13.4 - 18.8 g by Bashir et al. (2010). Thousand-grain weights of different rice genotypes used in paddy breeding programs of Turkey were reported as between 18.3 - 29.9 g (TTSM, 2015) and Safdar et al. (2013) reported thousand-grain weights of paddy cultivars as between 18.0 - 27.0 g. Paddy grain size vary based on being long or short, thin or thick grains and also influence consumer preferences. In Turkey, generally japonica sub-species with long and wide grains are preferred, but indica sub-species with long and thin grains are not preferred (Binodh et al., 2006; Akay, 2020).

Table 2. Mean values for investigated traits of 18 paddy cultivars

Cultivars	TGW **	GL **	GLWR **	CGL **	GER **	RWA **
Agusto	22.51 efg	6.59 cd	2.56 a	13.31 ab	2.02 bc	60.14 b-f
Arieti	23.42 def	6.62 cd	2.52 a	9.26 hı	1.40 g	50.72 fg
Baldo	31.00 a	7.28 a	2.32 bc	12.47 b-d	1.73 c-f	66.88 abc
Cammeo	28.80 b	6.89 bc	2.41 ab	10.78 d-h	1.56 efg	57.37 c-g
Crono	20.32 h	5.98 e	2.27 bcd	8.61 ı	1.44 fg	46.96 g
Edirne	29.63 ab	6.99 ab	2.23 cde	11.95 b-f	1.71 c-f	65.11 a-d
Efe	23.26 def	6.43 d	2.31 bc	11.21 c-g	1.75 cde	57.57 c-f
Gala	22.56 efg	5.96 e	2.23 cde	12.97 abc	2.17 ab	61.77 a-e
Galileo	28.89 b	5.92 e	1.98 f	11.17 c-g	1.88 bcd	57.31 c-g
Halilbey	23.82 de	5.92 e	2.08 ef	11.17 c-g	1.89 bcd	61.77 a-e
Kale	25.34 c	5.94 e	2.11 def	10.20 f-ı	1.72 c-f	59.89 b-f
Kızıltan	21.57 gh	5.94 e	2.22 cde	10.42 e-ı	1.75 cde	56.27 d-g
Meco	23.31 def	5.95 e	2.23 cde	9.72 ghı	1.63 d-g	52.13 efg
Nembo	22.39 efg	5.95 e	2.10 ef	9.97 ghı	1.68 d-g	51.28 fg
Osmancık-97	23.60 def	5.90 e	2.20 cde	12.81 abc	2.17 ab	58.73 b-f
Ronaldo	22.31 fg	5.91 e	2.23 cde	12.25 b-e	2.07 b	61.76 a-e
Tosya Güneşi	23.28 def	5.90 e	2.18 cde	12.64 a-d	2.14 b	71.27 a
Yatkın	24.33 cd	5.88 e	2.12 def	14.52 a	2.47 a	68.84 ab
Ortalama	24.46	6.22	2.24	11.41	1.84	59.21
CV%	2.02	1.72	2.41	5.33	5.49	5.75

**= $p < 0.01$; Means indicated with the same letter are not significantly different at 5% level. TGW= Thousand-grain weight (g), GL= Grain length (mm), GLWR= Grain length/width ratio (%); CGL= Cooked grain length (mm), GER= Grain elongation ratio (%), RWA= Rice water absorption (%), CV%= Coefficient of variation.

Grain lengths of the investigated cultivars varied between 5.88 (Yatkın) – 7.28 mm (Baldo) with a general mean of 6.22 mm (Akay, 2020; Beşer et al., 2015; Simonelli et al., 2017). According to Tukey's multiple comparison test results, Baldo (7.33 mm) and Edirne (6.99 mm) cultivars had the greatest grain length values (Table 2). Beşer et al. (2015) reported the mean grain length of Baldo cultivar as 6.9 mm. In TTSM (2015) report, grain lengths of Osmacık-97, Halilbey, Ronaldo and Cammeo cultivars were respectively reported as 6.4, 6.4, 6.5 and 7.3 mm. Yazman (2014) reported the grain lengths of Baldo and Osmancık-97 cultivars respectively as 6.33 and 6.96 mm.Grain length is not a sole indicator of quality, but together with length to width ratio, it turns into a significant physical quality parameter for national and international classification.

The length/width ratio is closely related to the appearance of rice grain and significantly influences consumer preferences. High length/width ratios indicate long thin grains and low ratios indicate round rice grains. The rice grains with a length/width ratio of greater than 3 are classified as thin grains, the ones with a length/width ratio of between 2 -3 are classified as medium and the ones with a length/width ratio of lower than 2 are classified as round grains. In Turkey, consumers generally prefer rice grains with a length/width ratio of between 2 - 3. In the present study, length/width ratios of the paddy cultivars varied between 1.98 (Galileo) – 2.56 (Agusto) and differences in length/width ratios of the cultivars were found to be significant (Table 2). In previous studies, length/width ratios of rice grains were reported as between 1.50 - 3.50 (Shilpa and Krihnan, 2010); between 2.22 - 2.27 (Yazman, 2014); between 1.55 - 3.43 (Şişman, 2016) and between 2.11 - 2.44 (Akay, 2020). Grain length/width ratio is closely related to grain shape. Consumer preferences may vary with the shape and appearance of the grains. While some countries prefer short blunt grains, some others prefer medium long or thin rice grains. The cultivars with thin long grains are generally preferred in Southeast Asian countries and the cultivars with short grains are generally preferred in countries of temperate climate zone (Sürek, 2002). In Turkey, cultivars with long-medium length/width ratios (between 2-3) are preferred. Grain length/width ratio is also closely related to paddy species (indica and japonica type), indica-type paddies generally have thin grains with length/width ratios of greater than 3.

Cooked grain length is directly related to water absorption, elongation ratio and water uptake ratio of rice grain. Cooked grain length is influenced by genetic and environmental factors (Şişman, 2016). The present study, cooked grain lengths varied between 8.61 (Crono) and 14.52 mm (Yatkın) with a general mean of

11.41 mm. According to Tukey's multiple comparison test results, Agusto, Gala, Tosya Güneşi and Yatkın cultivars had the greatest cooked grain length (Table 2).

There were significant differences in grain elongation ratios of the paddy cultivars. The greatest value was observed in Yatkın (2.47%) cultivar and the lowest in Arieti (1.40%) cultivar (Table 2). Similar to the present findings, Akay et al. (2018) reported grain elongation ratios as between 1.55 - 2.02% and Akay (2020) as between 1.58 - 1.99%. According to Tukey's multiple comparison test results on grain elongation ratios, Yatkın, Osmancık-97 and Gala cultivars were placed into the first group. Danbaba et al. (2011) indicated that grain elongation ratios were influenced by amylose content of the cultivars. Flexibility of amylopectin bonds indicates high water uptake capacity of the cultivars (Sürek, 2002; Şişman, 2016; Akay, 2020).

Water absorption ratios of the rice samples varied between 46.96% (Crono) and 71.27% (Tosya Güneşi) and differences in water absorption ratios of the cultivars were found to be significant (Table 2). Similar to the present findings, Şişman (2016) reported that water absorption ratios of paddy cultivars as between 44.37 - 71.07%.

Table 3. Mean values for investigated traits of 18 paddy cultivars

Cultivars	WRR **	CT **	PC **	AC **		DA
Agusto V1	2.57 cde	00:18:36 def	7.55 fg	25.26 ab	High	<69.5 °C
Arieti V2	2.05 ef	00:20:47 b	6.66 ı	26.25 a	High	<69.5 °C
Baldo V3	3.05 abc	00:17:57 e-h	6.90 hı	20.84cde	Moderate	<69.5 °C
Cammeo V4	2.34 def	00:18:31 d-g	7.56 fg	24.04abc	Moderate	<69.5 °C
Crono V5	1.91 f	00:20:16 bc	8.02 de	27.40 a	High	<69.5 °C
Edirne V6	2.89 a-d	00:17:29 fgh	8.33 cd	19.63 def	Low	<69.5 °C
Efe V7	2.40 def	00:18:47 de	8.00 de	19.60 def	Low	<69.5 °C
Gala V8	2.68 a-e	00:17:19 h	8.52 abc	17.98 ef	Low	<69.5 °C
Galileo V9	2.36 def	00:19:23 cd	8.36 cd	21.47cde	Moderate	<69.5 °C
Halilbey V10	2.63 b-e	00:17:32 fgh	8.03 de	19.72 def	Low	<69.5 °C
Kale V11	2.53 c-f	00:17:13 h	5.45 j	19.07 def	Low	<69.5 °C
Kızıltan V12	2.33 def	00:17:23 gh	8.49 bc	19.60 def	Low	<69.5 °C
Meco V13	2.12 ef	00:17:38 fgh	7.21 gh	21.76bcd	Moderate	<69.5 °C
Nembo V14	2.09 ef	00:17:51 e-h	8.78 ab	20.73cde	Moderate	<69.5 °C
Osmancık-97 V15	2.39 def	00:17:31 fgh	7.72 ef	16.91 f	Low	<69.5 °C
Ronaldo V16	2.64 b-e	00:23:28 a	7.92 ef	21.29cde	Moderate	>74 °C
Tosya GüneşiV17	3.31 a	00:18:28 d-g	7.20 gh	25.91 a	High	<69.5 °C
Yatkın V18	3.22 ab	00:19:26 cd	8.89 a	20.13 def	Moderate	<69.5 °C
Ortalama	2.53	00:18:39	7.76	21.53		
CV%	8.22	1.98	1.62	5.52		

**= p< 0.01; Means indicated with the same letter are not significantly different at 5% level. WRR= Water uptake ratio (%), CT= Cooking time (min), PC= Protein content (%), AC= Amylose content; DA= Alkali spreading (gelatinization temperature), CV%= Coefficient of variation.

Differences in water uptake ratios of the cultivars were found to be significant ($p<0.01$) (Table 3). The water absorption ratios of the cultivars varied between 1.91% (Crono) and 3.31% (Tosya Güneşi). Complying with the present findings, Anıl and Koca (2006) reported water uptake ratios of the paddy cultivars as between 1.75 - 1.98% and Danbaba et al. (2011) reported water uptakes of rice grains as between 1.74 - 2.98%.

The cultivars with shorter cooking times are generally preferred by the consumers. Cooking time was reported to have positive correlations with amylose content and alkali spreading (gelatinization temperature) (Akay, 2020). The cooking time of the present cultivars varied between 00:17:19 (Gala) – 00:23:28 min (Ronaldo). The Baldo, Edirne, Gala, Halilbey, Kale, Kızıltan, Meco, Nembo and Osmancık-97 cultivars had the shortest cooking times (Table 3). Present findings on cooking times comply with the findings of previous studies (Akay et al., 2018; Akay, 2020; Danbaba et al., 2011; Fofana et al., 2011; Thomas et al., 2013; Şişman, 2016).

Protein contents of rice samples varied between 5.45% (Kale) and 8.89% (Yatkın) with a mean value of 7.76% (Table 3). Present findings on grain protein contents comply with the findings of earlier studies (Koca and Anıl, 1997; Thomas et al., 2013).

Amylose content significantly influences cooking time and eating quality of rice. The grains of rice with high amylose contents (25-33%) are hard and dry cooking tendency. The ones with moderate amylose contents (20-25%) have a softer and sticky cooking tendency and the ones with low amylose contents (< %20; 12 -13%) are quite soft and sticky. The *Japonica* sub-species generally have moderate and low amylose content (Juliano et al., 1981; Bao et al., 2006; Hossaina et al., 2009; Akay, 2020; Danbaba et al., 2011). Present amylose contents varied between 16.91% (Osmancık-97) and 26.25% (Arieti) and the differences in amylose contents of the cultivars were found to be significant (Table 3). Cultivars were classified based on amylose content with the use of an internationally recognized scale: Agusto, Arieti, Crono and Tosya Güneşi cultivars as high amylose containing cultivars, Baldo, Cammeo, Galileo, Meco, Nembo, Ronaldo and Yatkın as moderate amylose containing cultivars and the rest as low amylose containing cultivars (Table 3) (Cruz and

Khush, 2000; Kasai et al., 2007). Present amylose contents comply with the findings of previous studies (Akay et al., 2018; Akay, 2020; Anıl and Koca, 2006; Donduran, 2014; Simonelli et al., 2016; Şişman, 2016; Thomas et al., 2013).

Gelatinization temperature is a temperature at which rice starch started to swell and lose crystallinity in an irreversible fashion. In other words, it is a physicochemical characteristic of the starch (Sürek, 2002). Rice starch generally gelatinizes between 65 - 85 °C temperatures (Bakshi and Singh, 2019). High gelatinization temperatures result in softening of rice when cooked. In Turkey, cultivars with low gelatinization temperatures are generally preferred (Akay, 2020). Rice gelatinization temperatures are classified as follows: <69.5 °C (tannins are all disintegrated), 70-74 °C (4-5 grains are disintegrated) and >74 °C (3 and more grains are disintegrated) (Juliano, 1979; 1985). In terms of gelatinization temperatures of the present cultivars, only the Ronaldo cultivar is classified as >74 °C and the rest as <69.5 °C (Table 3).

Correlation coefficients for the relationships between investigated physicochemical parameters are provided in Table 4. There were highly significant correlations between thousand-grain weight and grain length (r = 0.66**); between grain length and length/width ratio (r = 0.63**); rice grain length/width ratio and amylose content (r = 0.51*); between rice water absorption and cooked grain length (r=0.83**), grain elongation ratio (r=0.71**), water uptake ratio (r=0.99**); between cooked grain length and grain elongation ratio (r = 0.89**), water uptake ratio (r=0.81**); between grain elongation ratio and water uptake ratio (r = 0.69**). On the other hand, there were highly significant negative correlations between cooking time and alkali spreading (r = -0.76**). In previous studies, positive correlations were reported between amylose content and rice grain length/width ratio (Akay, 2020; Julinao and Villareal, 1993; Khatun et al., 2003; Sheng et al., 2015). Positive relationships were also reported between cooked grain length and elongation ratio (Akhter et al., 2017; Akay, 2020).

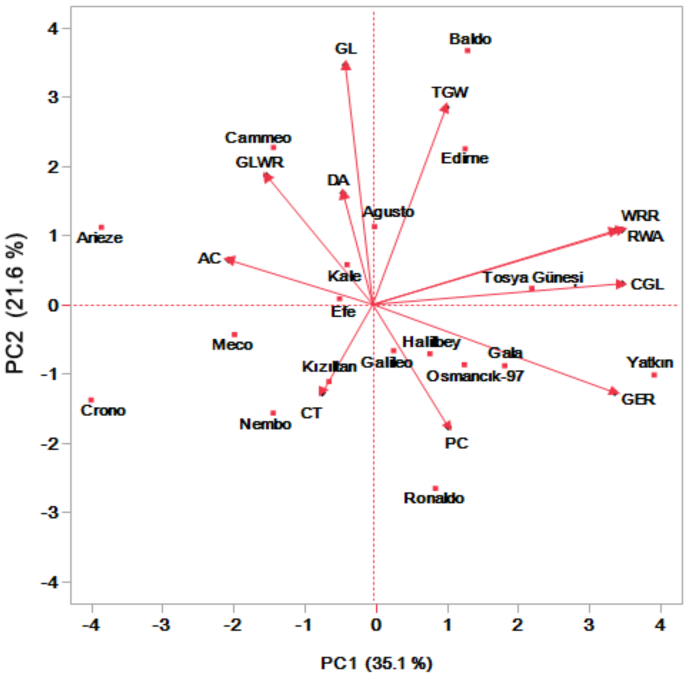
Table 4. Correlations coefficients between the investigated traits

	TGW	*GL*	*GLWR*	*RWA*	*CGL*	*GER*	*WRR*	*CT*	*PC*	*AC*
GL	0.66**									
GLWR	-0.07	0.63**								
RWA	0.39	0.14	-0.19							
CGL	0.19	0.05	-0.04	0.83**						
GER	-0.12	-0.40	-0.32	0.71**	0.89**					
WRR	0.36	0.14	-0.17	0.99**	0.81**	0.69**				
CT	-0.22	-0.07	0.21	-0.13	-0.05	0.01	-0.11			
PC	-0.18	-0.23	-0.29	0.01	0.27	0.35	0.03	0.05		
AC	-0.17	0.19	0.51*	-0.27	-0.34	-0.40	-0.20	0.45	-0.22	
DA	0.18	0.17	0.02	-0.10	-0.13	-0.20	-0.07	-0.76**	-0.05	0.02

*= p< 0.05, **= p< 0.01; TGW= Thousand-grain weight (g), GL= Grain length (mm), GLWR= Grain length/width ratio (%), RWA= Rice water absorption (%), CGL= Cooked grain length (mm), WRR= Water uptake ratio (%), CT= Cooking time (dk), PC= Protein content (%), AC= Amylose content; DA= Alkali spreading (gelatinization temperature).

Biplot graph was generated for a better visual assessment of the relationships between investigated physicochemical parameters of the cultivars (Figure 1). While correlations coefficients present the relationships between two parameters, biplot allows an overall assessment of the relationship among the entire parameters (Sharifi and Ebadi, 2018). According to biplot analysis, the first principal component explained 35.1% and the second principal component explained 21.6% of total variation (both explained 56.7%) (Figure 1). Besides conventional data analysis approach, ANOVA and multiple comparison tests for single variables and correlations analysis for relationships between two variables of agricultural experiments, biplot analysis method and constellation graph allowing multivariate analysis of several physicochemical parameters were also used in present study. Such analyses were thought to contribute overall assessment of concrete outcomes.

Thousand-grain weight, water uptake ratio, water absorption and cooked grain length vectors were placed in the upper-right section of the biplot group and vector angles between these traits were smaller than 90^{o} indicating significant positive relationships among thousand-grain weight, water uptake ratio, water absorption and cooked grain length. These traits were seen to act in reverse direction of cooking time vector, which was placed in lower-left section of the biplot graph. Grain length, length/width ratio, alkali spreading and amylose content vectors were placed in upper-left section of the biplot graph indicating positive relationships among them. The traits with negative relationships with these parameters (grain elongation ratio and protein content) were placed in lower-right section of the biplot graph indicating positive relationships between them. Since cooking time had the shortest vector length, it was identified as the most distinctive trait. The cultivars placed close to origin of the biplot graph were prominent for more than one traits. Kale cultivar was prominent for grain length/width ratio; Efe cultivar for amylose content; Kızıltan cultivar for cooking time; Galileo cultivar for protein content; Gala cultivar for grain elongation ratio; Tosya Güneşi cultivar for cooked grain length; Baldo cultivar for thousand-grain weight and Agusto cultivar was prominent for grain length (Figure 1).



* TGW= Thousand-grain weight (g), GL= Grain length (mm), GLWR= Grain length/width ratio (%), RWA= Rice water absorption (%), CGL= Cooked grain length (mm), WRR= Water uptake ratio (%), CT= Cooking time (dk), PC= Protein content (%), AC= Amylose content; DA= Alkali spreading (gelatinization temperature).

Figure 1. Biplot grouping of investigated traits relations of paddy cultivars with investigated traits.

In the constellation plot, present cultivars were divided into 2 main groups and 8 sub-groups (Figure 2). Osmancık-97, Gala, Halilbey and Galileo cultivars were placed into the 1st group; Meco, Efe, Nembo and Kızıltan cultivars into the 2nd group; Kale cultivar into the 3rd group; Agusto cultivar into the 4th group; Cammeo, Edirne and Baldo cultivars into the 5th group; Arieti and Crono cultivars into the 6th group; Tosya Güneşi and Yatkın cultivars into the 7th group and Ronaldo cultivar was placed into the 8th group(Figure 2; Table 1; 2).

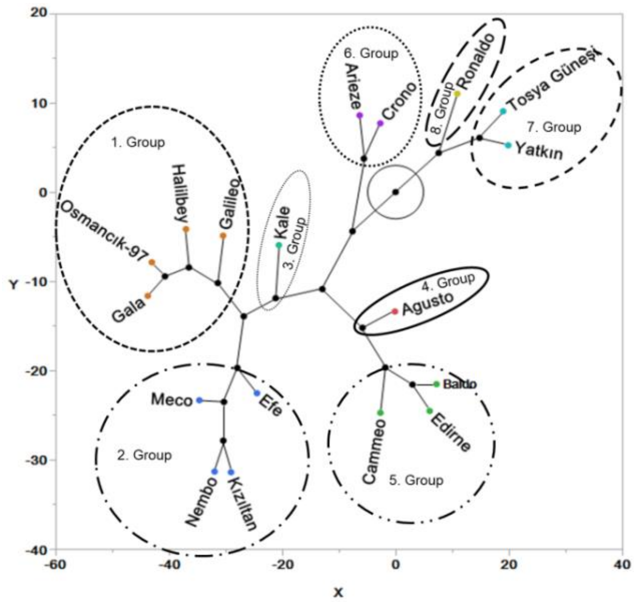


Figure 2. Constellation plot graph of cultivars based on investigated traits.

While the first group of cultivars (Osmancık-97, Gala, Halilbey and Galileo) had high protein contents, the second group of cultivars (Meco, Efe, Nembo and Kızıltan) had the lowest grain length values. The 3rd group of cultivars (Kale) had lower cooking time and grain protein content than the other cultivars. The 4th group of cultivars (Agusto) had greater grain length/width ratio than the other cultivars. The 5th group of cultivars (Cammeo, Edirne and Baldo) had the greatest thousand-grain weight values. The 6th group of cultivars (Arieti and Crono) had the lowest water absorption, cooked grain length, grain elongation ratio and water uptake ratios. The 7th group of cultivars (Tosya Güneşi and Yatkın) had the greatest water absorption, cooked grain length, grain elongation ratio and water uptake ratio. The 8th group of cultivars (Ronaldo) had the greatest cooking time and the greatest alkali spreading temperature (Figure 2; Table 1; 2).

Conclusion

Although it is inconvenient to compare both physical and chemical quality traits of the rice grains obtained from different cultivars, the physically-close rice grains are generally compared with each other. Comparison of highly different cultivars was banned in both national and international rice codex. It is quite hard to separate such a physical mixture. Therefore, physicochemical characteristics are used for separation of cultivars. In present study, some physical and chemical characteristics and cooking parameters of 18 paddy cultivars belonging to Japonica sub-species and registered in Turkey and European countries were investigated. There were highly significant negative correlations between alkali spreading and cooking time. The Efe, Kale and Galileo cultivars approaching to the origin of biplot graph were found to be prominent for more than one trait. According to biplot graph, cooking time was identified as the least distinctive trait. While Ronaldo, Tosya Güneşi and Yatkın cultivars were placed into one main group in terms of some physical and chemical characteristics, the other cultivars were all placed into the other main group. But that main group had 8 sub-groups. The cultivars constituting the sub-groups were close to each other in terms of several traits. Present groupings revealed that investigated cultivars had close physicochemical characteristics to each other and it is possible to separate the cultivars of the same with the use of genetic markers.

Compliance with Ethical Standards

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal.

All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Ethics committee approval is not required.

Funding

No financial support was received for this study.

Data availability

Not applicable.

Consent for publication

Not applicable.

References

Akay, H (2020). Determination of physical, chemical, and cooking properties of some paddy varieties. Anadolu Journal of Agricultural Sciences, 35(3), 438-445. http://dx.doi.org/10.7161/omuanajas.789227

Akay, H, Mut, Z, Erbaş Köse, OD, Sezer, İ (2018). Determination of seed quality of some rice varieties grown in Turkey. International Agriculture, Environment and Health Congress, Vol I, 1123 - 1131, 26 - 28 October, Aydın.

Bashir, MU, Akbar, N, Iqbal, A, Khan, HZ, Hanif, MK, Bashir, MU (2010). Effect of different sowing dates on yield and yield components of direct seeded coarse rice (*Oryza sativa* L.). Pak. J. Agri. Sci 47.4 (2010): 361-365.

Akhter, M, Sher, H, Raza, MA, Haider, Z, Saleem, U, Khan, RAR, Mahmood, A (2017). Multivariate analysis of physico-chemical, grain shape and cooking quality parameters of some advance Indica Rice (Oryza Sativa L) lines under Irrigated Condition. Int J Nutr Sci & Food Tech. 3:2, 53-56. https://doi.org/10.25141/2471-7371-2017-3.0053

Anıl, M, Koca, AF (2006). Effect of different packaging type and storage time on rice quality. Turkey 9th Congress of Food, Volume I, 883-886, 24-26 May, Bolu.

Bahmaniar, MA, Ranjbar, GA (2007). Response of rice (*Oryza sativa* L.) cooking quality properties to nitrogen and potassium application. Pakistan journal of Biological sciences, 10(11), 1880-1884. https://doi.org/10.3923/pjbs.2007.1880.1884

Bakshi, AS and RP Singh, RP (2019). Kinetics of water diffusion and starch gelatinization during rice parboiling Journal of Food Science, 45 (1980), pp. 1387-1392. https://doi.org/10.1111/j.1365-2621.1980.tb06561.x

Bao J, Shen S, Sun M, Corke H (2006). Analysis of genotypic diversity in the starch physicochemical properties of nonwaxy rice: apparent amylose content, pasting viscosity and gel texture. Starch.; 58(6):259–67. https://doi.org/10.1002/star.200500469

Bergman, CJ (2019). Rice end-use quality analysis. In Rice (pp. 273-337). AACC International Press. https://doi.org/10.1016/B978-0-12-811508-4.00009-5

Beşer, N, Surek, H, Kaya, S (2015). Yield and yield components, morphological and quality characteristics of aromatik-1 rice variety: the first aromatic rice in Turkey. Ekin Journay Crop Breed and Genetic, 1(1):42-46.

Binodh, A, K, Kalaiyarasi, R, Thiyagarajan, K, Manonmani, S (2006). Physicochemical and cooking quality characteristics of promising varieties and hybrids in rice. Indian J Genet Plant Breed 66(2):107–112.

Cruz, ND, Khush GS (2000). Rice grain quality evaluation procedures. In: Aromatic rices R.K. Singh, U.S. Singh and G.S. Khush(eds.), Oxford and IBH publishing Co. Pvt. Ltd., New Delhi, Calcutta, pp. 15-28.

Custodio, MC, Cuevas, RP, Ynion, J, Laborte, AG, Velasco, ML and M, Demont (2009). Rice quality: How is it defined by consumers, industry, food scientists, and geneticists? Trends in Food Science and Technology, Vol. 92, Elsevier Ltd. (2019), pp. 122-137. https://doi.org/10.1016/j.tifs.2019.07.039

Danbaba, N, Anounye, JC, Gana, AS, Abo, ME, Ukwungwu, MN (2011). Grain quality characteristics of Ofada rice (*Oryza sativa* L.) Cooking and eating quality. International Food Research Journal, 18(2).

Donduran, D (2014). Investigation of quality and bioactive properties of some rice varieties processed in our country. Master Thesis, Çanakkale Onsekiz Mart University, Institute of Science, s98, Çanakkale.

Fan, M, Wang, X, Sun, J, Zhang, Q, Xu, Z, and Xu, Q (2017). Effect of indica pedigree on eating and cooking quality in rice backcross inbred lines of indica and japonica crosses. Breeding science, 67(5), 450-458. https://doi.org/10.1270/jsbbs.16191

FAO (2020). United Nations food and agriculture organization. htpp: //www.fao.gov/ (Access date: 18.12.2020).

Fofana, M, Futakuchi, K, Manful, JT, Yaou, IB, Dossou, J, Bleoussi, RTM (2011). Rice grain quality: A comparison of imported varieties, local varieties with new varieties adopted in Benin. Food Control, 22(12): 1821-1825. https://doi.org/10.1016/j.foodcont.2011.04.016

Hossaina MS, Singh AK, Fasih-uz-Zaman (2009). Cooking and eating characteristics of some newly identified inter sub-specific (indica/japonica) rice hybrids. ScienceAsia. 2009;35(4):320. http://doi.org/10.2306/scienceasia1513-1874.2009.35.320

JMP (2007). JMP User Guide, Release 7 Copyright© 2007, SAS Institute Inc., Cary, NC.

Juliano, BO (1979). The chemical basis of rice grain quality. Chemical aspects of rice grain quality, 69-90.

Juliano, B. O., Villareal, C. P., 1993. Grain quality evaluation of world rices. Retrieved from http://books.irri.org/9712200396_content.pdf

Juliano, BO, CM, Perez, AB, Blakeney, DT, Castillo, N, Kongseree, B, Laignelet (1981). International cooperative testing on the amylose content of milled rice Starch/Stärke, 33 (1981), pp. 157-162. https://doi.org/10.1002/star.19810330504

Juliano, BO (1985). Criteria and test for rice grain qualities. In: Rice Chemistry and Technology, B.O. Juliano (ed.), 2nd ed., AACC, St Paul, MN., pp. 443-524.

Kasai, M, Lewis, AR, Ayabe, S, Hatae, K, Fyfe, CA (2007). Quantitative NMR imaging study of the cooking of Japonica and Indica rice. Food Research International, 40: 1020–1029.

Khalif, AA, Wahab, AAE, El-Ekhtyar, AM, Zaed, BA (2007). Response of some hybrid rice varieties to irrigation intervals under different dates of sowing. African Crop Science Conference Proceedings. 8:67-74.

Khatun, M, Hazrat Ali, M, Quirino, DC, D (2003). Correlation studies on grain physicochemical characteristics of aromatic rice. Pakistan Journal of Biological Sciences, 6: 511-513. https://doi.org/10.3923/pjbs.2003.511.513

Kishine, M, Suzuki, K, Nakamura, S, Ohtsubo, KI (2008). Grain qualities and their genetic derivation of 7 new rice for Africa (NERICA) varieties. Journal of agricultural and food chemistry, 56(12), 4605-4610. https://doi.org/10.1021/jf800141y

Koca, AF, Anıl, M (1997). Quality characteristics of some paddy varieties grown in Samsun ecological conditions. Journal of Ondokuz Mayıs University Faculty of Agriculture, 12 (2): 61-71.

Kong, X, P, Zhu, Z, Sui, J (2015). Physicochemical properties of starches from diverse rice cultivars varying in apparent amylose content and gelatinisation temperature combinations. Food Chemistry,172 (2015), pp. 433-440. https://doi.org/10.1016/j.foodchem.2014.09.085

Kün, E (1997). Cereals-II (Hot climate cereals). Ankara University Faculty of Agriculture Publications: 1452 Textbook: 432 Ankara University Press, 97, Ankara.

Oko, AO, Ubi, BE, Dambaba, N (2012). Rice cooking quality and physico-chemical characteristics: a comparative analysis of selected local and newly introduced rice varieties in Ebonyi State, Nigeria. Food Public Health, 2(1): 43-49. https://doi.org/10.5923/j.fph.20120201.09

Safdar ME, Noorka IR, Tanveer A, Tariq SA, Rauf S (2013). Growth and Yield of Advanced Breeding Lines Of Medium Grain Rice As Influenced By Different Transplanting Dates. The Journal of Animal & Plant Sciences, 23(1): 227-23.

Sezer, İ, Mut, Z, Öner, F (2007). Factors affecting fracture yield in paddy (*Oryza sativa* L.). Turkey VII. Field Crops Congress, Vol I, 145-148, 25-27 June, Erzurum.

Sharifi, P, Ebadi, AA (2018). Relationships of rice yield and quality based on genotypes by trait (GT) biplot. An Acad Bras Cienc, 90 (1), 343-356. https://doi.org/10.1590/0001-3765201820150852

Sheng, W, Zhou, l, Wu, L, Bai, B, Deng, Q (2015). Evaluation of genetic effect on physiochemical properties changes of Wx near isogenic lines of Y58S in Rice. Chılean Journal of Agrıcultural Research 75(4). http://dx.doi.org/10.4067/S0718-58392015000500002

Shilpa, JB, Krishnan, S (2010). Grain quality evaluation of traditionally cultivated rice varieties of Goa, India. Recent Research in Science and Technology, 2(6): 88-97.

Simonelli, C, Abbiati, A, Cormegna, M (2016). Physicochemical characterization of some Italian rice varieties. The Journal of Food Science and Nutrition, 45(1), 9-23.

Simonelli, C, Galassi, L, Cormegna, M, Bianchi, P (2017). Chemical, physical, textural and sensory evaluation on Italian rice varieties. Universal J. Agril. Res, 5(2), 104-112. http://dx.doi.org/10.13189/ujar.2017.050204

Suh, P, Jeung, JU, Lee, JI, Choi, YH, Yea, YD, Virk, PS, Mackill, DJ, Jena, KK (2010). Identification and analysis of QTLs controlling cold tolerance at the reproductive stage and validation of effective QTLs in cold-tolerant genotypes of rice (*Oryza sativa* L.). Theor Appl Genet 120: 985–995. http://dx.doi.org/10.1007/s00122-009-1226-8

Sürek, H (2002). Paddy farming. Hasat publishing Ltd. Şti, 85-105, İstanbul.

Şişman, A (2016). Determination of grain quality parameters of some rice genotypes grown in Turkey. Master Thesis. Ondokuz Mayıs University, Institute of Science, 188s, Samsun.

Thomas, R, Wan-Nadiah, WA, Bhat, R (2013). Physiochemical properties, proximate composition, and cooking qualities of locally grown and important rice varieties marketed in Penang, Malaysia. Int Food Res J, 20(3): 1345-1351.

TTSM (2015). Seed Registration and Certification Center Directorate. Retrieved from http://www.tarim.gov.tr/BUGEM/TTSM/Belgeler/Duyuru%20Belgeleri/2015%20tescil/S%C4%B1cak%20%C4%B0klim/%C3%A7eltik/2015 (Date of access: 25.08.2020).

USDA (2009). United States Department of Agriculture. United States Brass Standards. Federal Grain Inspection Service. http://www.gipsa.usda.gov/fgis/standards/ricestanda rds.pdf (Date of access: 16 Ocak 2021).

Webb BD, Bollich CN, Jackson BR, Kanter DG, Linscombe SD, Moldenhauer KAK, Tseng ST, Petersen HD (1989). Evaluation of rice quality components for named varieties grown in performance trails in Arkansas, Louisiana, Mississippi, Texas and California, 1986-1988. Beaumont Texas, Cooperative rice quality annual crop report 1989-1.

Yazman, MM (2014). Determination of adulteration in rice according to its quality characteristics and determination of the conformity of rice in the market to the Turkish food codex. Master Thesis, Harran University, Institute of Science, 130s, Şanlıurfa.