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Physicochemical, nutritional, and cooking properties of local Karacadağ rice (*Oryza sativa* L.) – Turkey

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Abstract

The present work examined the quality characteristics of Karacadağ rice, which is being slowly forgotten but now cultivated in small restricted areas in the south-eastern Anatolia region in Turkey, and widely consumed by the local people there. Physical, chemical, cooking, and nutritional analyses were performed on 15 rice samples, which were obtained from paddy samples. The unbroken kernel yield ratio in the rice samples ranged from 61.30 to 70.00%, where the rice samples from location 14 had the lowest value. The highest length/width ratio was measured in the rice sample from location 15, and the lowest was in location 14. The ash content was between 0.56 and 1.05%, and the protein content was between 7.94 and 9.93%. The highest ash content was determined in location 1, while the highest protein content was determined in location 10. Among the samples that were investigated, the gel lengths ranged in 62.50 - 77.50 mm, the alkali spreading value was in the range of 3.00 - 7.00, the amylose content was 29.06 - 30.83%, the total dietary fibre was 2.92 - 4.82%, the phytic acid content was 4.22 - 6.35 mg/g, and the cooking time was in the range of 16.00 - 19.00 min. The water uptake ratio ranged between 2.50 and 3.60 and was the highest in location 1, while the cooking loss (ranged from 3.00 to 4.96%) was the lowest in location 4. The volume increase ratio among the samples ranged from 1.08 to 1.24. The total amount of organic matter values ranged from 0.70 to 1.23 g/kg. These values were found to be negatively correlated with amylose content and cooking time.

Introduction

Paddy is an ancient cultivated plant that grows in warm regions, and considered a symbol of civilisation in these regions. Rice paddy holds a special place in agriculture since it is the main nourishment for more than half of the world's population. Rice, which is quite essential especially in the Far East and South Asian countries, is consumed by up to 200 kg per person in some countries, and is the most commonly consumed food in the world after wheat. Although paddy contains low protein, it is the most consumed food in human nutrition after wheat because it is rich in amino acids necessary for nutrition (Dönmez, 2007; TMO, 2017).

Based on 2017 data, the world's rice production was 769 million tons, and the share of Turkey in this was 900 thousand tons. China, India, Indonesia, Bangladesh, and Vietnam are among the countries that produce the highest amounts of rice. Asia utilises more than half of the total rice production and consumption due to traditional eating habits, suitable climate for rice cultivation, and population size. Sixty percent of the world population lives in Asia, 88% (142 million tons of hectares) of total rice fields are located in Asia, and Asia has about 90% of rice production (438 million tons) worldwide (FAO, 2017; TMO, 2017).

Rice farming in Turkey is mostly performed in delta plains and valley bases of rivers because the rainfall in Turkey is not enough to grow paddy. Thus, this plant is cultivated with irrigation in Turkey. Rice is cultivated in 40 provinces in Turkey, and Edirne, Samsun, Balıkesir, Çanakkale, and Çorum have the highest cultivation rates. There is a very high concentration of paddy production on the regional level. Accordingly, 70% of the production is in the Marmara region (northwest of Turkey). The Black Sea region (north of Turkey) has 26% of the production, and these two regions hold 96% of the rice production in Turkey. The remaining 4% is composed of the central Anatolia region (2%), the south-eastern Anatolia region (1%), and other regions (1%). Based on the Turkish Statistical Institute's (TUIK) 2018 data, the paddy cultivation area in the south-eastern Anatolia region was 2,103 ha, and paddy production was around 10,548 tons. Approximately 92% of the region's rice production takes place in Diyarbakır and Şanlıurfa. Diyarbakır , as the leading

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city in paddy production, has in total 7,421 tons of production, while Şanlıurfa has 2,252 tons (FAO, 2017; TUIK, 2018). Even though paddy is cultivated in most regions in Turkey, the only place where rice cultivation takes place in the south-eastern Anatolia region is the Karacadağ region, which is covered by the south-eastern Anatolia Project (GAP) (Şanlıurfa, Diyarbakır, and Mardin triangle). Karacadağ is a dormant volcano in the south-eastern Anatolia region, and it is located in the southwest of Diyarbakır. Karacadağ rice, named after this volcanic mountain, is the most commonly cultivated product, and it is a medium sized rice with low broken kernel rate. Karacadağ rice is a quality product that has adapted to the ecological conditions of the region. It has a high resistance to Karacadağ's cold melting snow. The most important feature of Karacadağ rice is that it is the most sought-after product because of its colour, aroma, taste, and suitability to the taste of the people living in this region (Alp, 2011). Karacadağ rice is a local mixed population. This mixed population feature ensures that the variety is compatible with the ecology and resistant to some stress conditions, especially the diseases and pests that are prevalent in the region. It gives them an advantage in terms of their genetic structure. Due to these properties, it also has value as a breeding material. Since Karacadağ paddy has a yellow straw, light brown husk, yellow or black awns, and the fact that it is found in the population, local people refer to it with different names. In some regions it is called as "yellow paddy" or “karakılçık". Nevertheless, it is generally known as "Karacadağ paddy" or "Karacadağ rice" in the Karacadağ basin.

The present work, which seeks to preserve natural, and local flavours, aims to determine the quality characteristics of the local Karacadağ rice, which is cultivated in limited areas in the south-eastern Anatolia region in Turkey. To date, no studies have been conducted on the physico-chemical, cooking, aroma, and nutritional properties of Karacadağ rice. Therefore, the present work is unique in terms of providing resources for other studies.

Materials and methods

Materials

Karacadağ paddy, which was grown in the ecological conditions of the provinces of Şanlıurfa and Diyarbakır in Turkey, in the 2012 harvest period, was obtained, and the quality characteristics of both the rice and rice paddy were investigated. Paddy samples were taken from 15 locations, and the locations were selected from the Şanlıurfa and Diyarbakır central regions and districts (Table 1).

Table 1. Location numbers and names of rice samples.

Location no.	Location names
1	Kerik/Diyarbakır
2	Akdibek/Diyarbakır
3	Karahan/Diyarbakır
4	Alatosun/Diyarbakır
5	Ortaviran/Diyarbakır
6	Çıkrık/Şanlıurfa
7	Yeşilyurt/Şanlıurfa
8	Kaynak/Diyarbakır
9	Sarıyatak/Diyarbakır
10	Akbaş/Diyarbakır
11	Yarımkaş/Diyarbakır
12	Demirli/Diyarbakır
13	Alankoz/Diyarbakır
14	Devegeçidi/Diyarbakır
15	Büyüksu/Diyarbakır

Methods

Physical analysis

Hectolitre weight

Test was carried out following the AACC Method No: 55-10, and the results were expressed in kilogram/hectolitre (kg/hL) (AACC, 2010).

1,000 kernel weight

Test was carried out following the method described by Danbaba *et al.* (2011), and the results were expressed in grams on a dry matter basis.

Unbroken kernel yield

Test was carried out following the method described by Ravi *et al.* (2012).

Length

Length determination in the rice samples was carried out following the method described by Ravi *et al.* (2012), and the results were classified based on the study conducted by Cruz and Khush (2000). Based on its length, rice was grouped as extra-long (longer than 7.50), long (6.61 to 7.50), medium (5.51 to 6.60), and short (shorter than 5.50) (Cruz and Khush, 2000).

Shape

Shape determination was carried out following the method described by Cruz and Khush (2000), and the rice was classified based on the classification reported by these researchers. In this classification, rice was classified as slender (over 3.0), medium (2.1 to 3.0), bold (1.1 to 2.0), and round (1.0 or less) based on the length/width ratio.

Grain elongation

Grain elongation was determined following the method described by Danbaba *et al.* (2011).

Colour

Colour measurements of the rice were made with a HunterLab MiniScan EZ (Reston, Virginia, USA) model colour measurement device, and the values were expressed based on the CIALAB measurement system on this device. In the HunterLab colour scale, L* = 0 (black), L* = 100 (white); -a* (green), +a* (red); -b* (blue), and +b* (yellow) values were recorded as (D65/10°) in daylight. Colour measurements were made in three replicates, and the result was expressed as the average of the three values.

Chemical and physicochemical analyses

Total ash

The total ash value was determined with an ash oven at 900°C following the ICC- standard no: 104 (ICC, 2002).

Protein

Protein was determined in the rice samples following the ICC- standard no: 105 (ICC, 2002). The factor to be used in the calculation was 5.95 for rice.

Gelatinisation temperature and gel consistency

The method described by Oko *et al.* (2012) was followed to determine the gelatinisation temperature and gel consistency.

Amylose content

Amylose content was determined following the method described by Bhonsle and Krishnan (2010a).

Total dietary fibre

Total dietary fibre (TDF, %) of rice samples was determined by using a Megazyme Total Dietary Fibre Assay Kit (Megazyme International Ireland Limited, Wicklow, Ireland). The method for this kit was created by modifying the methods by Lee *et al.* (1992).

Phytic acid

This method was based on the spectrophotometric measurement of the colour formed by bipyridine and Fe^{+3}. The phytic acid present in the sample was precipitated in the form of iron phytate. The free Fe^{+3} is bonded with bipyridine and measured in spectrophotometer (Haug and Lantzsch, 1983).

Aroma

Aroma determination was conducted with an Agilent Technologies 7890B gas chromatography (California, USA) attached to an Agilent 5977A MS, following the method described by Petrov *et al.* (1996).

Rice cooking tests

In the analysis, a certain amount of rice was cooked in a 400 mL beaker at a constant temperature on a hot plate in a certain amount of water for a time until gelatinisation in the kernel centre was complete by occasional stirring. Cooking time (min), water uptake ratio, and volume increase ratio were determined as described by Fofana *et al.* (2011). Cooking loss (%) was calculated following the method described by Ravi *et al.* (2012). The total organic matter (TOM) amount of rice samples was determined following the ICC- standard no: 153 (ICC, 2002).

Statistical analysis

The analyses were carried out with two replicates, and the results were statistically analysed by using the SPSS (SPSS 15.0 for Windows) software. One-way ANOVA was used to determine the differences between the groups' means, and significance levels were determined by Duncan's test on the level of $p < 0.05$.

Results and discussion

Some physical and chemical properties of the rice samples are given in Table 2. The mean 1,000 kernel weight on a dry matter basis in 15 samples was determined as 21.57 g, and varied between 20.38 g and 23.90 g (Table 2). In a study by Koca and Anıl (1997) on the quality characteristics of rice varieties, the 1,000 kernel weight varied between 22.53 and 29.62 g. The mean weight of 1,000 kernels in the present work was found to be lower than those results. The difference could be due to the samples' unique characteristics and location differences. As a result of the statistical analysis comparing the samples in terms of 1,000 kernel weight, the samples were found to be significantly different from each other ($p < 0.05$). The hectolitre weight of the samples ranged from 80.75 to 85.35 kg/hL, and the mean value was found to be

Table 2. Some physical and chemical properties of milled rice samples.

Location no	Hectolitre weight (kg/hL)	1000 kernel weight (g)*	Unbroken yield (%)	Ash (%)*	Protein (%)*	Total dietary fibre (%)*	Phytic acid (mg/g)*
1	84.75 ± 1.77^{ab}	20.55 ± 0.07^{g}	65.2 ± 0.00^{cd}	0.80 ± 0.01^{f}	7.94 ± 0.00^{f}	3.19 ± 0.19^{g}	5.20 ± 0.04^{de}
2	85.10 ± 0.14^{a}	20.38 ± 0.18^{g}	64.5 ± 0.00^{de}	0.79 ± 0.03^{fg}	8.46 ± 0.35^{cde}	2.92 ± 0.15^{h}	4.75 ± 0.04^{gh}
3	83.70 ± 2.55^{cd}	22.10 ± 0.14^{c}	65.2 ± 0.00^{cd}	0.75 ± 0.00^{h}	8.00 ± 0.07^{ef}	3.02 ± 0.05^{h}	4.54 ± 0.13^{hi}
4	83.10 ± 2.69^{de}	20.65 ± 0.21^{fg}	65.2 ± 0.00^{cd}	1.05 ± 0.01^{a}	8.59 ± 0.11^{bcd}	4.45 ± 1.59^{c}	6.35 ± 0.06^{a}
5	82.30 ± 1.70^{fg}	22.70 ± 0.14^{b}	70.1 ± 0.00^{a}	0.89 ± 0.01^{de}	8.20 ± 0.28^{def}	2.96 ± 0.09^{h}	4.96 ± 0.08^{efg}
6	83.60 ± 1.98^{cde}	21.15 ± 0.28^{ef}	66.0 ± 0.00^{bc}	0.87 ± 0.02^{e}	8.52 ± 0.16^{cd}	4.77 ± 0.97^{ab}	5.08 ± 0.13^{def}
7	81.60 ± 2.69^{h}	21.33 ± 0.11^{de}	63.3 ± 0.00^{f}	0.90 ± 0.01^{cd}	8.51 ± 0.13^{cd}	3.72 ± 0.05^{e}	5.17 ± 0.21^{de}
8	81.85 ± 1.63^{gh}	20.88 ± 0.18^{efg}	67.0 ± 0.00^{b}	0.97 ± 0.03^{b}	8.53 ± 0.06^{cd}	4.82 ± 0.07^{a}	6.06 ± 0.13^{bc}
9	80.75 ± 2.47^{i}	23.90 ± 0.14^{a}	67.1 ± 0.00^{b}	0.72 ± 0.01^{i}	9.93 ± 0.00^{a}	2.96 ± 0.13^{h}	4.22 ± 0.11^{j}
10	84.20 ± 2.55^{bc}	22.10 ± 0.14^{c}	64.0 ± 0.00^{ef}	0.81 ± 0.00^{f}	9.05 ± 0.34^{b}	4.01 ± 0.03^{d}	5.24 ± 0.06^{d}
11	85.35 ± 1.63^{a}	21.20 ± 0.21^{e}	66.2 ± 0.00^{bc}	0.92 ± 0.01^{c}	8.84 ± 0.20^{bc}	3.46 ± 0.03^{f}	5.86 ± 0.13^{c}
12	83.10 ± 2.69^{de}	21.83 ± 0.11^{cd}	66.3 ± 0.00^{bc}	0.77 ± 0.02^{gh}	8.93 ± 0.11^{bc}	4.61 ± 0.20^{bc}	4.90 ± 0.08^{fg}
13	83.50 ± 2.12^{cde}	21.80 ± 0.00^{cd}	65.2 ± 0.00^{cd}	0.89 ± 0.01^{de}	8.45 ± 0.35^{cde}	4.74 ± 0.45^{ab}	6.12 ± 0.13^{ab}
14	82.90 ± 2.26^{ef}	21.88 ± 0.18^{c}	61.3 ± 0.00^{g}	0.90 ± 0.00^{cd}	8.89 ± 0.18^{bc}	4.82 ± 0.31^{a}	6.14 ± 0.15^{ab}
15	83.85 ± 0.92^{c}	21.10 ± 0.14^{ef}	66.1 ± 0.00^{bc}	0.56 ± 0.01^{j}	9.83 ± 0.14^{a}	$4.61^{b} \pm 0.59^{c}$	4.43 ± 0.06^{ij}

Means with the same superscript letter within columns are not significantly different at 5%. * = Calculated in dry matter.

83.31 kg/hL (Table 2). As a result of the statistical analysis that compared the hectolitre weights of the samples, the samples were found to be significantly different from each other ($p < 0.05$), and the rice obtained from location 11 had a higher hectolitre weight. In some previous studies, the hectolitre weight in rice varieties grown in Malaysia and India was found to be between 77.00 and 88.00 kg/hL (Singh *et al.,* 2005; Thomas *et al.,* 2013).

Rice yield is considered to be one of the most important quality criteria especially in the processing of rice, and this quality criterion is defined as broken and unbroken kernel yield. However, commercially, unbroken kernel yield is more important (Koca and Anıl, 2001). As shown in Table 2, the unbroken kernel yield mean of the rice samples was 65.5%, and ranged from 61.3 to 70.1%. This distribution was statistically significant ($p < 0.05$). Dipti *et al.* (2002) reported that a quality rice should have at least 70% unbroken kernel yield. From this point of view, it may be stated that the local Karacadağ rice is of medium quality.

The ash content of the samples varied between 0.56 and 1.05% (mean 0.84%). There was a significant difference among the samples in terms of ash content ($p < 0.05$) which could be due to the peeling process during the processing of rice. The lowest ash value was determined in rice sample obtained from location 15, while the highest ash value was found in rice sample obtained from location 4. The results are parallel with those of a previous study (Thomas *et al.,* 2013).

The protein content of the rice samples varied between 7.94 and 9.93% and there was a significant difference among the protein contents ($p < 0.05$). These agree with previous studies (Juliano and Villareal, 1993; Koca and Anıl, 1997; Fofana *et al.,* 2011; Ravi *et al.,* 2012; Thomas *et al.,* 2013).

The total dietary fibre (TDF) and phytic acid contents in rice, which may be defined as nutritional components, are given in Table 2. The TDF content of the rice samples ranged between 2.92 and 4.82%. Significant differences in TDF were observed between the locations ($p < 0.05$) which could be due to the peeling operation during rice production. The highest TDF belonged to the rice sample obtained from location 14, while the lowest TDF belonged to the rice sample obtained from location 2. Thomas *et al.* (2013) reported that six important rice varieties sold in the Penang region of Malaysia as having TDF between 7.07 and 8.47%. There was a significant difference ($p < 0.05$) among the samples (locations) in terms of their phytic acid content as shown in Table 2. The highest amount of phytic acid (6.35 mg/g) was found in the rice sample obtained from location 4, while the lowest amount of phytic acid (4.22 mg/g) was found in the rice sample obtained from location 9. Although phytic acid has very important functions for the plants, it has some negative effects on the human body. The most important of these effects is that it creates a complex with some essential minerals such as Ca, Fe, Zn, and Mn, thus preventing their absorption into the body.

Additionally, it can bind a large part of phosphorous as phytate phosphorous or interact with some amino acids (Egli *et al.,* 2004). From this point of view, it is desirable for food to have a low amount of phytic acid. However, recent studies on the effect of phytic acid on human health have shown that phytic acid has positive effects due to its anticancer and antioxidant activities (Tolay *et al.,* 2005). The phytic acid contents were found to be 3.99, 6.79, and 7.34 mg/g in a study where the phytic acid and mineral contents of three rice varieties were examined (Wang *et al.,* 2011). The phytic acid content reported in the present work are consistent with the literature.

The size and shape of rice kernel are the first quality criterion that is taken into consideration in standardisation and classification of rice and paddy, development of new varieties, effective operation of cleaning and classification equipment, and drying and processing (Juliano, 1985). The kernel length in the rice samples varied between 4.90 and 5.14 mm (5.00 mm mean; Table 3), and significantly different ($p < 0.05$) from each other. In a study on eight varieties of rice, the rice lengths ranged from 3.60 to 6.50 mm (Dipti *et al.,* 2002). In another study, the rice kernel length was found to be 5.7 mm as the mean value in the Salem samba variety, which is a local Indian rice variety (Ravi *et al.,* 2012). The mean length values reported in the present work are compatible with those reported in the previous studies.

The rice samples were significantly different in terms of the length/width ratio ($p < 0.05$). In the rice samples from 15 locations, the length/width ratio (L/W) ranged from 1.60 to 1.67 (Table 3). Koca and Anil (1997) reported that the L/W ratio in rice samples varied between 1.67 and 2.72. In a study conducted to compare the physicochemical, cooking, and sensory properties of 23 different rice samples taken from different locations, the length/width ratio was found be in the range of 2.65 - 4.55 (Singh *et al.,* 2005). The results obtained in the present work are lower than those in other studies. The reason for the low values was that all the samples analysed in the present work were short kernels. According to Cruz and Khush's (2000) classification, all specimens were identified as bold (elliptical) grain rice.

Colour in rice is an important sensory parameter. Colour evaluations in rice are generally made on pearled kernels, and the colour may vary from white to dark grey and even pink (Koca and Anıl, 2001; Lamberts *et al.,* 2007; Mohapatra and Bal, 2014). The L* values of the rice samples varied between 89.56 and 90.84 (Table 3). The approximation of L* value to 100 indicates that the sample is whiter. Based on this situation, it may be stated that the samples were very close to white. The L* values of the samples were significantly different ($p < 0.05$). As shown in Table 3, the a* values of the rice samples were found to have negative (-) values in contrast to

Table 3. Length (L), width (W), L/W ratio, and colour characteristics of milled rice samples.

Location no.	Length (mm)	Length property	Width (mm)	L/W ratio	Shape property	Colour properties		
						L*	a*	b*
1	5.00 ± 0.2^{bc}	Short	3.09 ± 0.2^{cde}	1.62 ± 0.0^{bcd}	Bold	90.65 ± 0.48^{abc}	-0.18 ± 0.02^{gh}	6.06 ± 0.02^{h}
2	5.00 ± 0.2^{bc}	Short	3.01 ± 0.1^{fgh}	1.66 ± 0.0^{ab}	Bold	90.19 ± 0.08^{cde}	-0.09 ± 0.02^{de}	7.13 ± 0.04^{de}
3	5.05 ± 0.2^{b}	Short	3.14 ± 0.1^{abc}	1.61 ± 0.0^{cd}	Bold	90.74 ± 0.01^{ab}	-0.19 ± 0.01^{h}	6.62 ± 0.04^{g}
4	5.04 ± 0.3^{b}	Short	3.04 ± 0.1^{efg}	1.66 ± 0.0^{ab}	Bold	89.95 ± 0.04^{def}	-0.14 ± 0.01^{f}	7.97 ± 0.01^{bc}
5	5.12 ± 0.2^{a}	Short	3.16 ± 0.2^{ab}	1.62 ± 0.0^{bcd}	Bold	90.74 ± 0.20^{ab}	-0.05 ± 0.01^{bc}	6.60 ± 0.01^{g}
6	4.91 ± 0.3^{d}	Short	3.02 ± 0.1^{fgh}	1.63 ± 0.0^{bcd}	Bold	89.88 ± 0.10^{ef}	-0.33 ± 0.01^{j}	8.41 ± 0.08^{a}
7	5.01 ± 0.2^{bc}	Short	3.09 ± 0.1^{cde}	1.62 ± 0.0^{bcd}	Bold	90.29 ± 0.06^{bcde}	-0.10 ± 0.01^{e}	6.94 ± 0.00^{ef}
8	4.75 ± 0.3^{e}	Short	2.96 ± 0.2^{h}	1.61 ± 0.0^{cd}	Bold	90.16 ± 0.07^{cde}	-0.21 ± 0.01^{h}	7.80 ± 0.10^{c}
9	4.95 ± 0.2^{cd}	Short	3.06 ± 0.1^{def}	1.62 ± 0.0^{bcd}	Bold	90.28 ± 0.03^{bcde}	-0.06 ± 0.03^{cd}	6.79 ± 0.03^{fg}
10	4.95 ± 0.3^{cd}	Short	2.99 ± 0.1^{gh}	1.65 ± 0.0^{abc}	Bold	89.65 ± 0.18^{f}	-0.28 ± 0.01^{i}	8.11 ± 0.06^{b}
11	5.04 ± 0.2^{b}	Short	3.05 ± 0.2^{efg}	1.65 ± 0.0^{abc}	Bold	90.42 ± 0.06^{abcd}	-0.20 ± 0.00^{h}	6.97 ± 0.04^{ef}
12	5.14 ± 0.2^{a}	Short	3.19 ± 0.1^{a}	1.61 ± 0.0^{cd}	Bold	90.84 ± 0.07^{a}	-0.15 ± 0.01^{fg}	6.92 ± 0.01^{ef}
13	5.13 ± 0.2^{a}	Short	3.12 ± 0.2^{bcd}	1.65 ± 0.0^{abc}	Bold	90.42 ± 0.00^{abcd}	-0.02 ± 0.01^{b}	7.07 ± 0.02^{de}
14	4.90 ± 0.2^{d}	Short	3.07 ± 0.2^{def}	1.60 ± 0.0^{d}	Bold	89.56 ± 0.07^{f}	0.11 ± 0.01^{a}	7.31 ± 0.02^{d}
15	4.96 ± 0.3^{cd}	Short	2.97 ± 0.2^{h}	1.67 ± 0.0^{a}	Bold	90.06 ± 0.10^{def}	0.01 ± 0.03^{a}	7.10 ± 0.00^{de}

Means with the same superscript letter within columns are not significantly different at 5%.

the L* values. The a* values were significantly different ($p < 0.05$). The a* values of rice samples ranged from -0.33 to 0.11. The highest a* value was determined to be 0.11 in the rice sample obtained from location 15, and the lowest a* value was determined to be -0.33 in the rice sample obtained from location 6. The b* value, which is of great importance in cereal products in terms of colour, refers to a yellow colour. The b* values of the rice samples ranged from 6.06 to 8.41. When the b* value is close to zero, this means that the yellowness decreases, therefore, the samples had very little yellow colour. The b* values were significantly different ($p < 0.05$). These findings are consistent with those reported in previous studies (Lamberts *et al.,* 2007; Mohapatra and Bal, 2014; Ahmad *et al.,* 2017).

Gel consistency is a chemical property that determines the density of cooked rice. It is the factor that affects the hardness or softness of cooked rice. If the gel consistency is hard, the cooked rice tends to be less sticky. A hard gel consistency means that the cooked rice is hard, and this is undesirable. Rice with a soft gel consistency is generally preferred (Khush *et al.,* 1979). From Table 4, it is observed that the highest gel consistency value belonged to the rice sample obtained from location 4, while the lowest gel consistency value was in the rice sample obtained from location 2. Considering the gel consistency, our samples were found to be in the soft rice class. Significant differences were observed between the samples in terms of gel length.

The classification of rice samples based on the alkaline spreading values and gelatinisation temperature is given in Table 4. Generally, the spreading value in alkaline in 15 samples ranged between 3.00 and 7.00 (4.93 mean). Koca and Anıl (1997) found the alkaline spreading value between 4.50 and 6.00. Juliano and Villaeral (1993) examined the quality of 195 rice, and they classified the gel gelatinisation temperature as low. In determining the time required for cooking, the gelatinisation temperature of rice is one of the most effective factors. The gelatinisation temperature is the point when the starch in the rice starts absorbing water and swell, and it is measured by the spreading factor in alkaline. It is reported that a high gelatinisation temperature causes rice to be very soft. The gelatinisation temperature in a high-quality rice should not be high or low; it should be medium (70 to 74°C). Rice in this class is the most frequently preferred (Khush *et al.,* 1979). The gelatinisation temperature was found to be moderate in 8, low in 5, and high-medium in 2 samples (Table 4).

The amount of amylose is a chemical property that determines whether the rice is dry and brittle or moist and sticky. If the amount of amylose is high, the rice is dry, hard, and brittle, and if it is low, the rice is moist and sticky (Khush *et al.,* 1979). Based on its amylose content, rice is grouped as waxy (0 to 2%), very low (3 to 9%), medium level (20 to 25%), and high (more than 25%) amylose contents (Cruz and Khush, 2000). In the present work, the amylose

Table 4. Physicochemical properties of milled rice samples.

Location no.	Gel consistency		Gelatinisation temperature			Amylose (%)*
	Gel length (mm)	Classification	Alkali spreading value	Temperature (°C)	Classification	
1	66.50 ± 2.1^{ef}*	Soft	5.00 ± 0.0^{b}	70 to74°C	Medium	30.4 ± 0.2^{abc}
2	62.50 ± 3.5^{g}	Soft	5.00 ± 0.0^{b}	70 to 74°C	Medium	30.0 ± 0.0^{bcde}
3	67.50 ± 3.5^{e}	Soft	4.00 ± 0.0^{b}	70 to 74°C	Medium	29.7 ± 1.0^{def}
4	77.50 ± 3.5^{a}	Soft	6.00 ± 0.0^{a}	less than 69°C	Low	29.7 ± 0.6^{ef}
5	71.50 ± 0.7^{cd}	Soft	3.00 ± 0.0^{c}	75°C	High-Medium	30.2 ± 0.2^{abc}
6	65.00 ± 0.0^{f}	Soft	6.00 ± 0.0^{a}	less than 69°C	Low	30.4 ± 0.3^{ab}
7	76.50 ± 2.1^{ab}	Soft	6.00 ± 0.0^{a}	less than 69°C	Low	30.8 ± 0.2^{a}
8	66.00 ± 1.4^{ef}	Soft	5.00 ± 0.0^{b}	70 to 74°C	Medium	30.4 ± 0.4^{ab}
9	75.00 ± 7.1^{b}	Soft	3.00 ± 0.0^{c}	75°C	High-Medium	29.0 ± 0.3^{g}
10	62.50 ± 3.5^{g}	Soft	7.00 ± 0.0^{a}	less than 69°C	Low	29.5 ± 0.5^{ef}
11	75.00 ± 7.1^{b}	Soft	4.00 ± 0.0 ^{b}	70 to 74°C	Medium	29.9 ± 0.2^{bcdef}
12	65.00 ± 0.0^{f}	Soft	5.00 ± 0.0^{b}	70 to 74°C	Medium	30.1 ± 0.5^{bcde}
13	70.00 ± 0.0^{d}	Soft	4.00 ± 0.0^{b}	70 to 74°C	Medium	29.9 ± 0.4^{cdef}
14	65.50 ± 0.7^{ef}	Soft	5.00 ± 0.0^{b}	70 to 74°C	Medium	29.0 ± 0.6^{g}
15	72.50 ± 3.5^{c}	Soft	6.00 ± 0.0^{a}	less than 69°C	Low	29.4 ± 1.2^{fg}

Means with the same superscript letter within columns are not significantly different at 5%. * = Calculated in dry matter.

content of the rice samples varied between 29.0 and 30.8%, and the difference was statistically significant ($p < 0.05$). Based on these results, it may be stated that the local Karacadağ rice has high amylose content, and therefore it can be dry, hard, and fragile after cooking. The amylose content values obtained in the present work are parallel with the values found in other studies (Dipti *et al.,* 2002; Anıl and Koca, 2006; Fofana *et al.,* 2011; Oko *et al.,* 2012; Thomas *et al.,* 2013). In general, there was a difference among the locations in terms of the physicochemical properties. It was estimated that this difference was due to the mixed population of Karacadağ rice, as well as from genetic and environmental factors (temperature, fertilisation, precipitation, planting method and time, altitude of cultivation areas, processing of paddy rice, and *etc.*).

Aroma is one of the important quality characteristics in rice and may significantly affect consumer preference. It was reported that the main flavour component was 2-acetyl-1-pyrroline in aromatic rice varieties such as Basmati, and the amount of this component varied depending on the variety and climatic conditions. Aroma improvement in non-aromatic rice may be achieved by addition of *pandan* plant leaves which contain ten times more 2-acetyl-1-pyrroline during cooking. Aldehydes, which are effective in cooked rice aroma, are formed by peroxidation of lipids containing linoleic acid [(E, E) -2,4-decadienal, hexanal, (E) -2-nonenal] or peroxidation of oleic acid-containing lipids (nonanal, octanal, decanal). Phenolic odorants (4-vinylguaiacol, 4-vinylphenol) are formed by thermal degradation of *p*-coumaric and ferulic acid whose concentrations vary significantly based on the type of rice (Kotancılar and Karaoğlu, 2003; Bhonsle and Krishnan, 2010b).

The general composition of the volatile components (aroma components) detected in the local Karacadağ rice is shown in Figure 1. Alcohols, aldehydes, ketones, esters, hydrocarbons, organic acids, and heterocyclic compounds were identified as the volatile components in the rice samples. Hydrocarbon compounds were found to be most abundant followed by aldehydes, alcohols, ketones, organic acids, esters, and heterocyclic compounds. These results are consistent with the results of the study by Lin *et al.* (2010).

The results of the cooking analysis of the local Karacadağ rice samples obtained from different locations are shown in Table 5. The cooking time of the samples ranged from 16.00 to 19.00 min with a mean value of 17.63 min. Singh *et al.* (2005) compared 23 different kinds of rice samples to compare their physicochemical, cooking, and sensory properties, and they determined the cooking time to be in the range of 13.3 - 24.0 min. The cooking time values determined in the present work are almost similar to those reported in other studies (Danbaba *et al.,* 2011; Fofana *et al.,* 2011; Thomas *et al.,* 2013). The statistical analysis of the samples in terms of cooking time showed that there was a significant difference between the cooking times ($p < 0.05$).

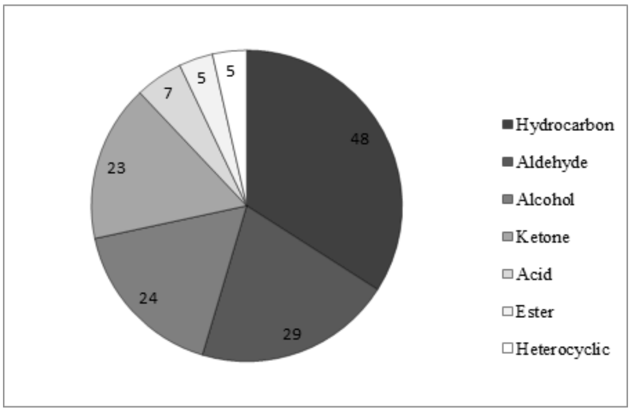

Figure 1. Number of volatile components detected in rice samples.

Total organic matter (TOM) is an evaluation criterion that has been developed to estimate the quality of pasta and has a significant positive relationship with sensory test findings (D'egidio *et al.,* 1982). According to D'egidio *et al.* (1982), pasta is classified as high quality if the TOM is less than 14 g/kg, medium quality if between 14 and 23 g/kg, and poor quality if more than 23 g/kg. TOM values obtained from rice cannot be expected to be similar to pasta. However, in a study conducted by Yazman (2014), it was found out that TOM values were significantly correlated with amylose content and cooking time, thus indicating that this test could be used in rice. Cooking time showed a negative correlation with TOM (r = -0.654, $p < 0.01$). Amylose content was also negatively correlated with TOM (r = -0.484, $p < 0.05$). As a result of the statistical analysis comparing the Karacadağ rice samples in terms of TOM, it was determined that there was a difference among the samples ($p < 0.05$) (Table 5). TOM values of the rice samples varied between 7.05 and 12.3 g/kg, and the lowest and highest TOM values belonged to the samples from locations 6 and 15, respectively.

The water uptake ratio of the rice samples ranged from 2.50 to 3.60, and the difference was statistically significant ($p < 0.05$). In a study that examined the effect of different packaging types and storage time on rice quality, the water uptake ratio ranged between 1.75 and 1.98 (Anıl and Koca, 2006).

Table 5. Cooking properties of milled rice samples.

Location no.	Cooking time (min)	Cooking loss (%)*	Total organic matter (g/kg)*	Water uptake ratio	Volume increase ratio
1	19.00 ± 0.00^{a}*	5.0 ± 0.62^{a}	7.14 ± 1.12^{h}	3.60 ± 0.09^{a}	1.08 ± 0.00^{c}
2	17.50 ± 0.00^{bcd}	3.6 ± 0.01^{cde}	11.08 ± 1.12^{b}	3.08 ± 0.01^{def}	1.16 ± 0.00^{b}
3	17.00 ± 0.00^{cde}	3.9 ± 0.41^{bc}	12.27 ± 0.56^{a}	2.81 ± 0.01^{gh}	1.16 ± 0.00^{b}
4	17.75 ± 0.35^{bcd}	3.0 ± 0.07^{f}	8.34 ± 0.56^{fg}	2.50 ± 0.00^{i}	1.14 ± 0.00^{b}
5	18.00 ± 0.00^{abc}	3.2 ± 0.11^{ef}	8.75 ± 1.12^{ef}	2.78 ± 0.03^{gh}	1.15 ± 0.02^{b}
6	18.50 ± 0.00^{ab}	3.2 ± 0.33^{def}	7.05 ± 1.11^{h}	$2.89 \pm 0.13f^{gh}$	1.16 ± 0.00^{b}
7	16.75 ± 0.35^{de}	3.3 ± 0.40^{def}	8.25 ± 0.56^{fg}	3.30 ± 0.19^{bc}	1.18 ± 0.00^{b}
8	17.00 ± 0.00^{cde}	3.7 ± 0.25^{cd}	7.49 ± 0.56^{gh}	2.51 ± 0.02^{i}	1.09 ± 0.00^{c}
9	18.00 ± 0.00^{abc}	4.3 ± 0.42^{b}	9.90 ± 0.56^{cd}	3.27 ± 0.04^{bcd}	1.08 ± 0.00^{c}
10	17.00 ± 0.00^{cde}	3.4 ± 0.19^{def}	9.56 ± 1.13^{cde}	2.92 ± 0.02^{fgh}	1.17 ± 0.02^{b}
11	19.00 ± 0.00^{a}	3.7 ± 0.19^{cd}	7.21 ± 0.83^{gh}	2.70 ± 0.07^{hi}	1.16 ± 0.00^{b}
12	17.00 ± 0.00^{cde}	3.4 ± 0.27^{def}	10.26 ± 0.00^{bc}	2.93 ± 0.02^{efg}	1.17 ± 0.02^{b}
13	18.00 ± 0.00^{abc}	3.6 ± 0.14^{cde}	9.83 ± 0.56^{cde}	3.38 ± 0.10^{b}	1.18 ± 0.00^{b}
14	18.00 ± 0.00^{abc}	4.0 ± 0.02^{bc}	9.00 ± 0.55^{def}	3.40 ± 0.19^{ab}	1.24 ± 0.00^{a}
15	16.00 ± 0.00^{d}	3.3 ± 0.11^{def}	12.30 ± 0.56^{a}	3.14 ± 0.08^{cde}	1.16 ± 0.03^{b}

Means with the same superscript letter within columns are not significantly different at 5%. * = Calculated in dry matter.

In their study on the cooking and eating quality of Ofa rice, Danbaba *et al.* (2011) determined the water uptake ratio to be in the range of 1.74 - 2.11. In comparison to the literature, it is understood that the local Karacadağ rice used in the present work had a very high-water uptake ratio. As a result of the statistical analysis comparing the samples in terms of the water uptake ratio, the samples were found to be significantly different from each other ($p < 0.05$). It was observed that the water uptake ratios of all rice samples (at least 1 to 2.50) were quite high, and the highest water uptake ratio (3.60) belonged to the rice sample obtained from location 1. In their study on the quality characteristics of 12 paddy varieties, Koca and Anil (1997) determined the volume increase ratio to be between 1.22 and 1.91.

Conclusion

Some quality characteristics of Karacadağ paddy and rice, which are cultivated in restricted areas in south-eastern Anatolia, and widely consumed by the people in this region, are highlighted in the present work. However, other features should also be examined in detail for consumers' acceptance analysis. While Karacadağ rice is cultivated in the province of Diyarbakır , the broken rice which is one of the by-products of paddy and rice processing is used in baby foods and rice soup, whereas the by-products of the peeling and pearling process are used in animal feeds. Therefore, it should not be ignored that rice by-products may be utilised in production of high value products in the food industry. Since Karacadağ rice has proved its compatibility with the conditions of the region, it has as an important agricultural potential. Paddy factories and consumers prefer pure Karacadağ rice, even at higher prices. In this sense preserving natural flavours is important. Furthermore, due to the deficiencies in meeting quality rice raw material needed by Turkey's developing rice industry, the necessary precautions should be taken for its cultivation in the region. It should be kept in mind that even small increases in rice production will contribute significantly to the regional and national economy.

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