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TECHNOLOGICAL CHARACTERISTICS OF CHICKPEA (*Cicer arietinum* L.) CULTIVARS GROWN UNDER NATURAL CONDITIONS

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ABSTRACT

Technological characteristics (dry weight, dry volume, wet weight, wet volume, water absorption capacity, water absorption index, hydration coefficient, swelling capacity, swelling index, cooking time, number of destructed seeds after cooking) of 27 chickpea cultivars grown under natural conditions (without the use of chemical/organic fertilizers) were investigated in this study. Except for water absorption index and hydration coefficients, effects of cultivars on investigated characteristics were found to be significant. The wet weight, wet volume and water absorption capacity characteristics on PC1 explained 49.33% of total variation and swelling capacity, swelling index and unit weight characteristics on PC2 explained 25.79% of total variation (both explaining 75.12% of total variation). Dry weight had highly significant positive correlations with wet weight (r=0.9776), wet volume (r=0.9653) and water absorption capacity (r=0.9317). In terms of investigated characteristics, cultivars were clustered under three groups in scatter plot and dendrogram was composed of three sub-clusters under two main clusters.

Key words: Chickpea, Cooking time, Hydration coefficient, Natural conditions, Technological characteristics.

INTRODUCTION

Edible legumes constitute an important source of protein in nutrition and daily diets of millions of people worldwide (Ramakrishna et al., 2006). Protein ratios of legume grains vary between 17-40%. Such ratios vary between 7-13% in cereal grains and between 18-25% in meat (de Almeida Costa et al., 2006). A hundred grams of raw chickpea (*Cicer arietinum* L.) kernels contain 357 calorie, 4.5–15.69% moisture, 14.9–24.6 g protein, 0.8–6.4% oil, 2.1–11.7 g fiber and 2.0–4.8 g ash (Bibi et al., 2007). Chickpea was reported as an important tool in prevention of bronchitis, cholera and constipation. Besides, regular consumption of legumes like chickpea may prevent diabetes and reduce the risk of heart diseases (Jukanti et al., 2012). Therefore, among the legumes, chickpea is considered to be the most hypercholesteremic agent (Zia-Ul-Haq et al., 2007). In terms of world productions, chickpea has the third place among edible legumes after beans and peas. Chickpea seeds exhibit changes in shape, size and color based on cultivars. Therefore, based on seed color and geographical distribution, chickpeas are divided into two types as of desi (India-originated) and kabuli (Mediterranean and Central Asia-originated) types. Kabuli chickpeas are large with white and cream seed coat color. Desi chickpeas on the other hand are small with reticulated surface and brown, black or green seed coat color (Chavan et al., 1987). Besides differences in seeds, various other factors including cooking time, cultivar characteristics, location, soil properties, environmental factors and storage conditions influence cooking quality of chickpeas (Wang et al., 2017). Cooking times of chickpea varies between 55 – 200 minutes (Williams et al., 1983) and cooking times of kabuli chickpeas vary between 33–72 minutes (Ozer et al., 2010). Cooking time is an inherited attribute and exhibits large variations among the cultivars. Long cooking time is considered as a significant disadvantage limiting the potential use of edible legumes (Kaur et al., 2005). The pulses with high hydration and swelling coefficients cook in a shorter time, thus they are more suitable for consumer demands (Bishnoi and Khetarpaul, 1993). While assessing technological characteristics of the pulse cultivars, generally high wet weight, wet volume, water absorption capacity, water absorption index, swelling capacity and swelling index and short cooking time are desired (Gulumser et al., 2008).

In this study, technological characteristics of 27 chickpea cultivars, registered by public and private organizations of Turkey grown under naturel conditions without using chemical fertilizers, were investigated.

MATERIALS AND METHODS

Climate of the study area

Monthly average temperature (°C), relative humidity (%) and precipitations of the experimental years and long-term averages are shown in Table 1.

Table 1. Climate data for experimental years (2018 and 2019) and long-term (1931 – 2019) averages

	Monthly average temperature (°C)			**Monthly average relative humidity (%)**			**Monthly total precipitation (mm)**		
Months	**2018**	**2019**	**1931-2019**	**2018**	**2019**	**1931-2019**	**2018**	**2019**	**1931-2019**
January	1.2	-0.8	-1.6	81.9	74.8	76.6	73.6	50.7	35.9
February	5.5	3.3	0.2	66.6	66.7	73.7	16.5	23.5	35.8
March	***10***	**5.6**	***4.8***	***61.2***	**59.3**	***67.9***	***100.4***	***23.1***	***42.4***
April	***12.7***	**9.2**	***10.5***	***51.7***	**66.4**	***62.1***	***21.4***	***35.5***	***51.3***
May	***16.7***	**17.4**	***15.0***	***61.2***	**50.2**	***61.0***	***51.9***	***23.7***	***51.5***
June	***20.4***	**21.3**	***19.0***	***56.7***	**55.8**	***55.8***	***78.8***	***55.2***	***40.2***
July	***24.1***	**21.6**	***22.2***	***45***	**49.1**	***49.3***	***0.6***	***35.9***	***10.6***
August	***22.9***	**22.3**	***22.0***	***42.3***	**50.3**	***49.1***	***-***	***12.1***	***8.7***
September	***19.2***	**17.4**	***17.4***	***45.5***	**51.2**	***53.7***	***2.9***	***10.6***	***14.5***
October	13.2	14.4	11.8	62.8	59.6	63.4	40.0	33.7	28.0
November	6.8	7.1	5.5	69.6	58.8	71.4	18.2	20.5	32.1
December	6.0	3.0	0.6	76.9	78.9	77.1	1.7	38.4	37.5
Total	**158.7**	**141.8**	**-**	**721.4**	**721.1**	**-**	**406**	**362.9**	**-**
Average	**13.2**	**11.8**	**10.6**	**60.1**	**60.1**	**63.4**	**36.9**	**30.2**	**32.4**

*Data were supplied from Kayseri Provincial Directorate of Meteorology

In the first year, average temperatures during the vegetation period (March-September) were greater than the long-term averages and relative humidity values were relatively lower than the long-term averages. In the second year, monthly average temperatures varied between 5.6 - 22.3 °C and monthly average relative humidity values varied between 49.1 and 66.4%. Total precipitation throughout the vegetation period was measured as 256 mm in the first year, 196.1 mm in the second year and long-term average was 219.2 mm. Precipitations especially in June, July and August of the second year prolonged the vegetation duration of chickpea.

Soil characteristics of the study area

Before to set up the experiments, soil samples were taken from 0-30 cm soil profile of different points as to represent the study area. Soil samples were sieved through 2 mm sieve and analyzed for different traits. Analyses results are provided in Table 2.

Table 2. Soil physico-chemical characteristics of the study area

Parameter	**Years**	**pH**	**Organic matter (%)**	**Lime (%)**	**Texture**	**P_2O_5 kg da-1**	**EC mmhos/cm**
Analysis value	**2018**	7.93	0.30	1.59	Sandy-loam	7.826	0.109
	2019	7.91	0.31	1.59	Sandy-loam	7.84	0.112

Experimental soils were sandy-loam in texture. Available phosphorus levels of the experimental soils varied between 6.785 - 7.826 kg da^{-1}.

In present experiments, 27 kabuli chickpea registered varieties (Akca, Akcin 91, Aksu, Aziziye 94, Azkan, Cevdetbey 98, Cagatay, Cakır, Damla 89, Dikbas, Er 99, Gokce, Gulumser, Hasanbey, Ilgaz, Isık 05, Inci, Izmir 92, Kusmen 99, Menemen 92, Osmanbey, Sarı 98, Seckin, Sezenbey, Uzunlu 99, Yasa 05 and Zuhal) in Turkey were used as the plant material. But registration information regarding the Osmanbey variety could not be reached.

Method

Cultivars were sown in 2018 and 2019 growing seasons over the experimental fields of Erciyes University Agricultural Research and Implementation Center in randomized blocks design (RCBD) with 3 replications. Experimental plots had 6 plant rows with 30 cm row spacing and 5 cm on-row plant spacing. Experiments were set up over the fields where agricultural activities were not practiced for couple years. Neither chemical nor organic fertilizers were applied throughout both growing seasons and present observations and data will have contributions to organic-farming practicing farmers. But since the present cultivars are sensitive to anthracnose and disease Incidence is encountered suddenly and it is hard to get organic control agents instantly, two fungicide treatments were practiced throughout the entire growing season.

Technological characteristics

Dry weight, wet weight, water absorption capacity, water absorption index, dry volume, wet volume, swelling capacity, swelling index and cooking time were determined in accordance with the methods specified by Gulumser et al. (2008); hydration coefficient, with Savage et al. (2001), unit weight with Singh et al. (2010) by using the following equations.

1. **Dry weight (g):** A hundred seeds were randomly selected from each plot and weighed to get dry weight.

2. **Wet weight (g):** About 150 ml distilled water was placed into an Erlenmeyer, then 100 seeds were placed into

the water and kept in water for 16 hours. Seeds were removed from the water, roughly dried with drying paper and weighed to get wet weight. Later on, these samples were used in determination of cooking time.

3. Water absorption capacity (g seed^{-1}):

$$\boldsymbol{Water\ absoription\ capacity\ (g\ kernel-1) = \frac{(Wet\ weight - Dry\ weight)}{100 - number\ of\ non-swelling\ seeds}}$$

4. Water absorption index (%)

$$\boldsymbol{Water\ absorption\ index}\ (\%) = \frac{\boldsymbol{Swelling\ capacity\ (g/seed)}}{(\boldsymbol{Dry\ weight/100})}$$

5. Dry volume (ml): Hundred (100) seeds were placed into 100 mil cylinder. Then distilled water was added into the cylinder and the added value was subtracted from the recorded value to get dry volume.

6. Wet volume (ml): Hundred (100) seed samples were placed into 250 mL Erlenmeyer and then supplemented with 100 ml distilled water. Samples were kept in water for 16 hours. Seeds were removed from the water, roughly dried with drying paper. Then the samples were placed into 250 ml cylinder. Then distilled water was added into the cylinder and the added value was subtracted from the recorded value to get wet volume.

7. Swelling capacity (ml seed^{-1})

$$Swelling\ capacity\ (ml\ seed-1) = \frac{[Wet\ volume - Dry\ volume]}{100 - Number\ of\ non-swelling\ seeds}$$

8. Swelling index (%)

$$Swelling\ index\ (\%) = \frac{Wet\ volume}{Dry\ volume}$$

9. Cooking time (min): Hundred (100) wetted seeds were placed into 150 ml boiling water in an Erlenmeyer on heater set at 220 °C. For cooking controls, in every 10 minutes later, seed coat was removed and seeds were split into two halves, then disappearance of white spot in the middle of cotyledon was checked. As the white spot got smaller, control intervals were reduced initially to 5 minutes, then to 1 minute and the time passed until full disappearance of white spot was recorded as the cooking time.

10. Hydration coefficient (%):

$$Hydration\ coefficient\ (\%) = \frac{[Wet\ weight - Dry\ weight]}{Dry\ weight} x100$$

11. Unit weight (g ml^{-1}):

$$Unit\ weight\ (g/ml) = \frac{Dry\ weight}{Dry\ volume}$$

12. Number of seeds destructed after cooking: Following the determination of cooking time, number of destructed seeds was counted.

Statistical analysis

Experimental data on technological characteristics of chickpea cultivars were subjected to analysis of variance by using JMP 13.0 (SAS Institute Inc., Cary, NC, USA) statistical software. Significant means were compared with the use of Tukey's test ($p \leq 0.05$) (Steel and Torrie, 1980; Chen et al., 2020).

RESULTS AND DISCUSSION

The greatest dry weight (49.35 g) was obtained from Ilgaz genotype and the lowest value (37.17 g) was obtained from Menemen 92 genotype. In terms of dry weight, Damla 89, Hasanbey, Inci, Izmir 92 and Kusmen cultivars were placed into the greatest statistical group (Table 3). Williams et al. (1983) reported dry weights of Kabuli type chickpeas as between 9.2 - 54.1 g. Kaur et al. (2005) reported average dry weight as 21.94 g. Seed weight and volume significantly influence consumer preferences and cooking quality (Sastry et al., 2019).

In terms of dry volumes, while Uzunlu (41,67 ml) and Akca (41,33 ml) cultivars had the greatest values, Menemen 92 (25.67ml) genotype had the lowest value (Table 3). Present findings were complying the results of Kaya et al. (2016). Kaur et al. (2005) reported average dry volume as 17.0 ml.

The greatest wet weight (103.85 g) was obtained from Ilgaz genotype and the lowest value (78.41 g) was obtained from Menenmen genotype. Besides, except for Damla 89, Hasanbey, Inci, Izmir 92 and Yasa 05 cultivars, the others were placed into the greatest group (Table 3). Kaya et al. (2016) reported wet weights as between 72.06-132.82 g. Wetting is an important issue for both domestic uses and industrial processes. In humans and ruminants, gas production through anaerobic digestion / fermentation of oligosaccharides by intestine bacteria with the partial leakage of substrate may be reduced (Wood and Harden, 2006).

Table 3. Technological characteristics of chickpea cultivars

	Dry weight (g)*	Dry volume (ml)*	Wet weight (g)	Wet volume (%)*	Water absorption capacity (g/seed)	Water absorption index (%)	Hydration coefficient (%)	Swelling capacity (ml/seed)	Swelling index (%)	Unit weight (g/ml)	Cooking time (min)	Number of destructed seeds after cooking
Akca	46,05 ab	41,33 a	99,79 a-d	93,33 abc	0,537 a	1,17	117,00	0,520 b-g	2,268 def	1,115 f	43,00 a-g	8,67 ab
Akcin 91	44,48 abc	39,00 abc	94,14 a-e	86,67 a-e	0,497 abc	1,12	111,55	0,477 fg	2,222 def	1,140 def	35,67 fgh	10,67 ab
Aksu	43,01 a-d	36,67 a-e	90,78 a-f	84,00 b-f	0,478 a-d	1,11	111,15	0,473 fg	2,292 c-f	1,172 def	39,83 c-h	7,33 ab
Aziziye 94	45,08 abc	32,33 d-h	94,70 a-e	86,33 a-e	0,496 abc	1,10	110,18	0,540 a-f	2,688 ab	1,402 ab	46,00 abc	4,00 ab
Azkan	46,75 ab	38,33 a-d	101,22 abc	95,33 ab	0,545 a	1,16	116,47	0,570 a-d	2,498 b-f	1,225 c-f	44,00 a-e	8,67 ab
Cevdetbey 98	47,33 ab	35,67 a-g	99,82 a-d	92,67 abc	0,525 ab	1,11	111,18	0,570 a-d	2,615 abc	1,332 abc	37,83 d-h	6,67 ab
Cagatay	44,09 abc	32,67 c-h	93,33 a-e	87,00 a-e	0,493 a-d	1,12	111,77	0,543 a-f	2,667 ab	1,352 abc	39,33 c-h	6,00 ab
Cakır	44,50 abc	39,33 ab	95,24 a-e	87,67 a-e	0,507 abc	1,14	114,15	0,483 efg	2,228 def	1,128 ef	45,33 a-d	10,00 ab
Damla 89	41,76 bcd	29,67 ghı	86,86 def	80,67 def	0,451 bcd	1,08	107,68	0,510 c-g	2,755 ab	1,433 a	46,17 abc	9,33 ab
Dikbas	46,49 ab	35,67 a-g	99,08 a-d	91,67 a-d	0,526 ab	1,13	113,02	0,560 a-e	2,608 abc	1,322 abc	35,00 gh	1,33 b
Er 99	43,64 abc	38,67 a-d	91,88 a-e	84,33 b-f	0,482 a-d	1,11	111,30	0,457 g	2,183 f	1,125 ef	45,83 a-d	7,33 ab
Gokce	45,26 abc	34,33 b-g	93,76 a-e	87,33 a-e	0,485 a-d	1,07	107,13	0,530 b-g	2,548 a-d	1,322 abc	46,33 abc	4,67 ab
Gulumser	45,09 abc	33,00 b-h	92,31 a-e	86,00 b-e	0,472 a-d	1,05	105,38	0,530 b-g	2,623 abc	1,372 ab	43,67 a-f	2,00 b
Hasanbey	42,57 bcd	38,00 a-e	89,34 b-f	83,00 c-f	0,468 a-d	1,10	109,82	0,450 g	2,185 f	1,120 f	39,17 c-h	12,00 ab
Ilgaz	49,35 a	36,33 a-f	103,85 a	98,00 a	0,545 a	1,10	110,40	0,617 a	2,705 ab	1,362 abc	45,33 a-d	8,00 ab
Isık 05	44,86 abc	35,67 a-g	94,76 a-e	87,67 a-e	0,499 abc	1,12	111,55	0,520 b-g	2,473 b-f	1,262 b-e	47,17 abc	2,67 ab
Inci	42,09 bcd	30,00 f-ı	88,74 c-f	82,67 c-f	0,467 a-d	1,11	110,63	0,527 b-g	2,770 ab	1,417 a	50,17 a	6,00 ab
Izmir 92	39,17 cd	27,67 hı	82,80 ef	76,00 ef	0,436 cd	1,11	111,05	0,483 efg	2,763 ab	1,422 a	42,67 a-h	12,00 ab
Kusmen	42,75 bcd	33,67 b-h	91,95 a-e	85,33 b-e	0,492 a-d	1,15	114,92	0,517 b-g	2,542 a-e	1,275 bcd	50,00 a	3,33 ab
Menemen 92	37,17 d	25,67 ı	78,41 f	73,00 f	0,412 d	1,11	111,10	0,473 fg	2,867 a	1,458 a	41,83 b-h	14,67 a
Osmanbey	45,95 ab	33,00 b-h	98,57 a-d	92,00 a-d	0,526 ab	1,16	115,60	0,590 abc	2,803 ab	1,395 ab	36,33 e-h	2,67 ab
Sarı 98	47,73 ab	36,00 a-g	102,09 ab	95,33 ab	0,544 a	1,14	113,85	0,593 ab	2,655 ab	1,328 abc	49,00 ab	4,67 ab
Seckin	43,21 a-d	34,33 b-g	90,86 a-f	84,00 b-f	0,477 a-d	1,10	110,22	0,497 d-g	2,477 b-f	1,273 bcd	44,83 a-d	8,00 ab
Sezenbey	45,08 abc	33,67 b-h	96,18 a-d	90,67 a-d	0,511 abc	1,13	113,47	0,570 a-d	2,720 ab	1,350 abc	44,00 a-e	6,67 ab
Uzunlu 99	46,22 ab	41,67 a	98,88 a-d	92,00 a-d	0,527 ab	1,14	114,05	0,503 d-g	2,208 ef	1,108 f	34,83 h	10,00 ab
Yasa 05	43,35 a-d	31,67 e-ı	89,91 b-f	82,33 c-f	0,466 a-d	1,07	107,42	0,507 d-g	2,612 abc	1,372 ab	40,00 c-h	12,00 ab
Zuhal	43,59 abc	32,67 c-h	92,88 a-e	87,33 a-e	0,493 a-d	1,13	113,15	0,547 a-f	2,680 ab	1,338 abc	41,83 b-h	5,33 ab
						Averages						
1st year	45,23	35,06	96,55 A	89,78 A	0,513 A	1,14 A	113,60 A	0,547 A	2,586	1,302	52,43 A	4,15 B
2nd year	43,42	34,32	91,02 B	84,47 B	0,476 B	1,10 B	109,75 B	0,501 B	2,500	1,285	33,14 B	10,27 A
						F values						
Year (Y)	5,338	1,329	14,527*	15,221*	25,045*	11,633*	11,633*	21,799*	7,316	2,272	71,396*	21,238*
Genotype (G)	4,642**	10,756**	5,611**	6,748**	4,937**	1,150	1,150	8,134**	11,602**	18,126**	9,892**	2,341*
Y x G	4,352**	4,842**	3,899**	4,410**	2,884**	1,556	1,556	3,377**	2,872**	4,193**	10,660**	2,088*

*:p<0.05, **:p<0.01. There is no differences same letters in same column (p<0.05).

Wet volumes of the chickpea cultivars varied between 98.00% (Ilgaz) - 73.00% (Menemen 92). As can be seen in Table 3, 16 cultivars were placed into the greatest groups. Present findings similar with the values of Kaya et al. (2016).

In terms of water absorption capacity, while Menemen 92 genotype had the lowest value (0.412 g/seed), except for Damla 89 (0.451g $seed^{-1}$) and Izmir 92 (0.436 g $seed^{-1}$) cultivars, the rest were placed into the same group with Azkan and Ilgaz (0.545 g $seed^{-1}$) which had the greatest values (Table 3). Present findings on water absorption capacity were greater than the values of Yalcın et al. (2018), but similar with the values of Ozer et al. (2010); Sastry et al. (2019), Kaya et al. (2016).

Water absorption index and hydration coefficients of the cultivars were not found to be significant. In terms of both parameters, Akca genotype had the greatest values and Gulumser genotype had the lowest values. Water absorption index values varied between 1.17 - 1.05% and hydration coefficients varied between 117.0 and 105.38% (Table 3). Present water absorption capacity values were similar with the values of Sastry et al. (2019), Kaya et al. (2016).

The greatest swelling capacity (0.617 ml $seed^{-1}$) was obtained from Ilgaz genotype and the lowest value (0.450 ml $seed^{-1}$) was obtained from Hasanbey genotype. The others had values in between them (Table 3). Present swelling capacity values were greater than the values of Ozer et al. (2010); Sastry et al. (2019), but similar with the values of Kaya et al. (2016).

Swelling index values varied between 2.867 and 2.183%. Menemen 92 genotype had the greatest value and 16 other cultivars were placed into the same group (Table 3). Present swelling index values were greater than the values of Sastry et al. (2019), but similar with the values of Kaya et al. (2016).

Unit weight expresses seed weight per unit volume and the greatest values were respectively obtained from Menemen 92 (1.458 g ml^{-1}), Damla 89 (1.433 g ml^{-1}), Izmir 92 (1.422 g ml^{-1}) and Inci (1.417 g ml^{-1}) cultivars. Akca (1.115 g ml^{-1}), Hasanbey (1.120 g ml^{-1}) and Uzunlu 99 (1.108 g ml^{-1}) cultivars were placed into the lowest unit weight group (Table 3). Bibi et al. (2007) reported unit weights as between 1.17 - 1.32 g $ml^{-1}$and Kaur et al. (2005) reported average unit weight as 1.29 g ml^{-1}.

In terms of cooking times, the shortest cooking time (34.83 min) was observed in Uzunlu genotype and the longest cooking times were observed in Inci and Kusmen cultivars (50.17 and 50.00 min, respectively). Akca, Aziziye 94, Azkan, Cakır, Er 99, Gokce, Gulumser, Ilgaz, Isık 05, Izmir 92, Sarı 98, Seckin and Sezenbey cultivars were placed into the longest cooking time group (Table 3). Present cooking times similar with the values of Ozer et al. (2010). Cooking time is a significant parameter used for the assessment of cooking quality of pulses. Cooking time is also an important parameter for energy requirements in developing countries (Nadeem et al., 2020). The longer the cooking time is, the greater the nutrient loss and energy consumptions are (Haileslassie et al. (2019). Wang, et al. (2010) reported that cooking influenced nutritional composition of chickpeas.

In terms of number of destructed seeds, the lowest destructions were observed in Dikbas and Gulumser cultivars and the other cultivars were placed into the same group with Menemen 92 genotype which had the greatest destruction (14.67 seeds) (Table 3). Besides cooking time, kernel texture after cooking is also another important quality trait of pulses. Cooking results in various physico-chemical changes in pulses such as gelatinization of starch, denaturation of protein, relative decomposition of polysaccharides and softening and destruction of jointing material of cotyledons (Bishnoi and Khetarpaul, 1993).

When the effects of years on technological characteristics of chickpea cultivars were assessed, it was observed that effects of years on dry volume and unit weights were not significant, but effects of years on the other characteristics were found to be significant. Except for number of destructed seeds after cooking, the greatest values of all parameters were observed in the first year. When the entire findings were assessed together, it was observed that except for water absorption index and hydration capacity, significant variations were observed in all the other characteristics of the cultivars. Such a case was also reported by several other researchers (Bibi et al., 2007). As explained in detail above, present findings were similar with the results of some literatures and significantly different from the others. Such differences were mostly attributed to climate and soil conditions, cultivars and growing techniques. Thusly, Yalcın et al. (2018) reported significant year x cultivar interactions for water absorption capacity and hydration coefficient; Koksel et al. (1993) reported significant effects of growing conditions on entire technological characteristics of chickpeas.

Eigen values, variance, total variance, significance levels and component weights for investigated characteristics of chickpea cultivars are provided in Table 4. In terms of investigated characteristics, 9 independent principle components (PC) with eigen values greater than 0 were identified. Eigen values of these principle components varied between 0.0001 and 5.92 explained 100% of total variation. For efficient use of principle component analysis and accurate interpretation of the results, the first two or three principle components should explain at least 25% of total variations (Mohammadi and Prasanna, 2003). While identification of number of principle components, 2/3 of total variance was taken into consideration. Present analysis revealed that 100% of total variance was explained. Considering the 2/3 of total variance as 66.66%, two principle component axes explained 75.12% of total variation. Component weights were considered to be significant when the value is greater than 0.3 (Gozen, 2008). Weights of investigated characteristics on principle components (Table 4) revealed that the wet weight, wet volume and water absorption capacity characteristics with the greatest weights on PC1 axis explained 49.33% of total variation. The swelling capacity, swelling index and unit weight characteristics with the greatest weights on PC2 explained 25.79% of total variation. In biplot analysis, narrowing vector angles indicate closeness of the characteristics and enlarging vector angles indicate weakened relationships among the characteristics (Yan, 2014). Wet weight, wet volume, dry weight and water absorption capacity had close relationships with each other. Besides, unit weight and swelling capacity had greater impact on PC2, thus had positive correlations with each other. According to present findings, dry weight, dry volume, wet volume and water absorption characteristics on PC1 and swelling capacity, swelling index and unit weight characteristics on PC2 were found to be sufficient in definition of technological characteristics of chickpea cultivars (Fig. 1).

Table 4. Eigen values, variance, total variance, probabilities for investigated characteristics and Principle component analysis results

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
Eigen value	5,9194	3,0944	1,4549	0,9735	0,5343	0,0187	0,0038	0,0009	0,0001
Variance (%)	49,328	25,786	12,124	8,113	4,452	0,156	0,032	0,007	0,001
Total variance(%)	49,328	75,115	87,239	95,351	99,804	99,96	99,992	99,999	100
Prob>ChiSq	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	null	null	null	null

Principle component analysis results

Characteristics	PC1	PC2	PC3	PC4	PC5
Dry weight (gr)	0.36961	0.13948	-0.28275	-0.06375	0.12470
Dry volume (ml)*	0.32384	-0.32118	-0.19132	0.06359	0.03591
Wet weight (gr)	0.39667	0.10737	-0.12483	-0.04212	0.10990
Wet volume (%)*	0.39398	0.12734	-0.09310	-0.04477	0.15274
Water absorption capacity (g/seed)	0.40533	0.07992	-0.00220	-0.02435	0.09651
Water absorption index (%)	0.26103	-0.09692	0.61902	0.07386	-0.09415
Hydration coefficient (%)	0.26103	-0.09692	0.61902	0.07386	-0.09415
Swelling capacity (ml/seed)	0.23210	0.45620	0.04791	-0.11623	0.17021
Swelling index (%)	-0.14451	0.50269	0.22008	-0.14105	0.08268
Unit weight (g/ml)	-0.19792	0.48512	0.09941	-0.13993	0.06338
Cooking time (min)	-0.06594	0.17020	-0.00443	0.91594	0.35632
Number of destructed seeds after cooking	-0.16467	-0.31519	0.17940	-0.29099	0.86829

Seed weight, seed volume, swelling index and hydration capacity are related to cooking time and such relationships result in long, medium and short cooking times of chickpea cultivars (Williams et al., 1983). Correlations for technological characteristics of chickpea cultivars grown under natural conditions and scatter plot of the cultivars are presented in Figure 2. The cultivars clustered in three main colors in the dendrogram generated with the colored dots for the cultivars within a colored elliptical circles were similar with each other. Dry weight had highly significant positive correlations with wet weight (r=0.9776), wet volume (r=0.9653) and water absorption capacity (r=0.9317). Wet volume had highly significant negative correlations with swelling index (r=-0.8437) and unit weight (r=-0.8966). Water absorption capacity had highly significant positive correlations with wet volume (r=0.9834) and wet weight (r=0.9873). The greatest correlations were observed between water absorption index and hydration coefficient (r=1.000). There was a highly significant correlation between swelling index and unit weight (r=0.9774). Cooking time did not exhibit significant correlations with the other parameters. There were significant correlations between number of destructed seeds after cooking and swelling capacity (r=-0.5471) (Fig. 2 and supportive Fig. 1). Gil et al. (1996) reported that seed weight had significant positive correlations with hydration capacity and swelling capacity of the chickpea cultivars. Williams et al. (1983) and Singh et al. (1992) also reported significant positive correlations between seed weight and hydration capacity of chickpeas.

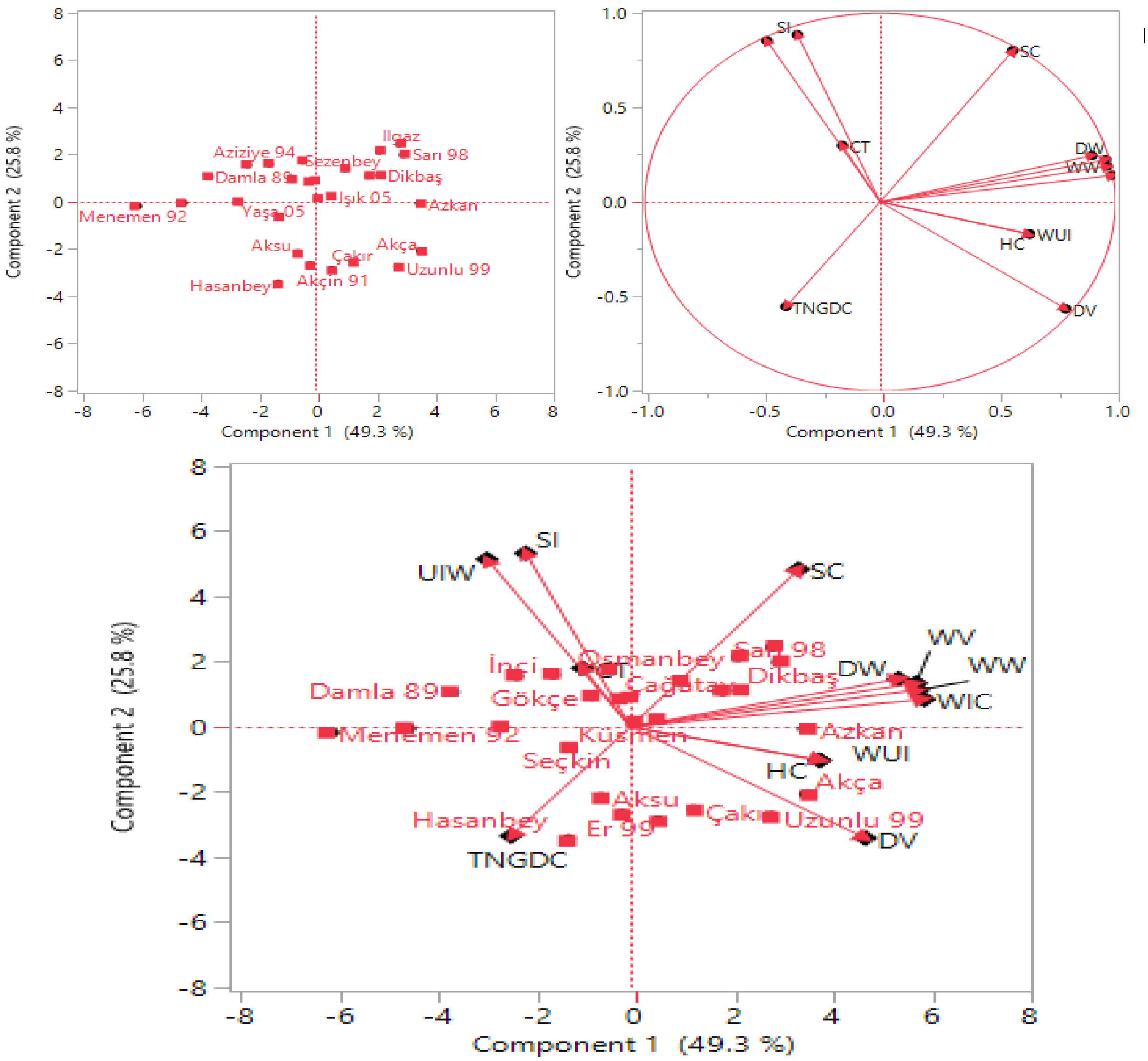

Fig. 1. Principle component analysis for technological characteristics of chickpea cultivars

Dry weight:DW, dry volume:DV, wet weight:WW, wet volume:WV, water absorption capacity:WIC, water absorption index:WUI, hydration coefficient:HC, swelling capacity:SC, swelling index:SI, unit weight:UIW cooking time:CT, number of destructed seeds after cooking:TNGDC

The dendrogram generated for technological characteristics of chickpea cultivars grown under natural conditions is composed of three sub-clusters under two main clusters. The primary cultivars with similar technological characteristics were identified as Cagatay and Zuhal. The Menemen 92, Izmir 92, Gulumser, Gokce, Inci, Yasa 05 and Damla 89 cultivars were placed into the first main cluster. Also, Izmir 92 and Menemen 92 cultivars were clustered in the first sub-cluster of the first main cluster and exhibited significant differences from the other cultivars. The Akca, Azkan, Cakır, Uzunlu 99, Akcin 91, Hasanbey, Aksu, Er 99 and Seckin cultivars were placed into the second sub-cluster of the second main cluster, the remaining cultivars (Aziziye 94, Isık 05, Kusmen, Cagatay, Zuhal, Sezenbey, Cevdetbey 98, Dikbas, Osmanbey, Ilgaz and Sarı 98) were placed into the first sub-cluster of the second main cluster (Fig. 2).

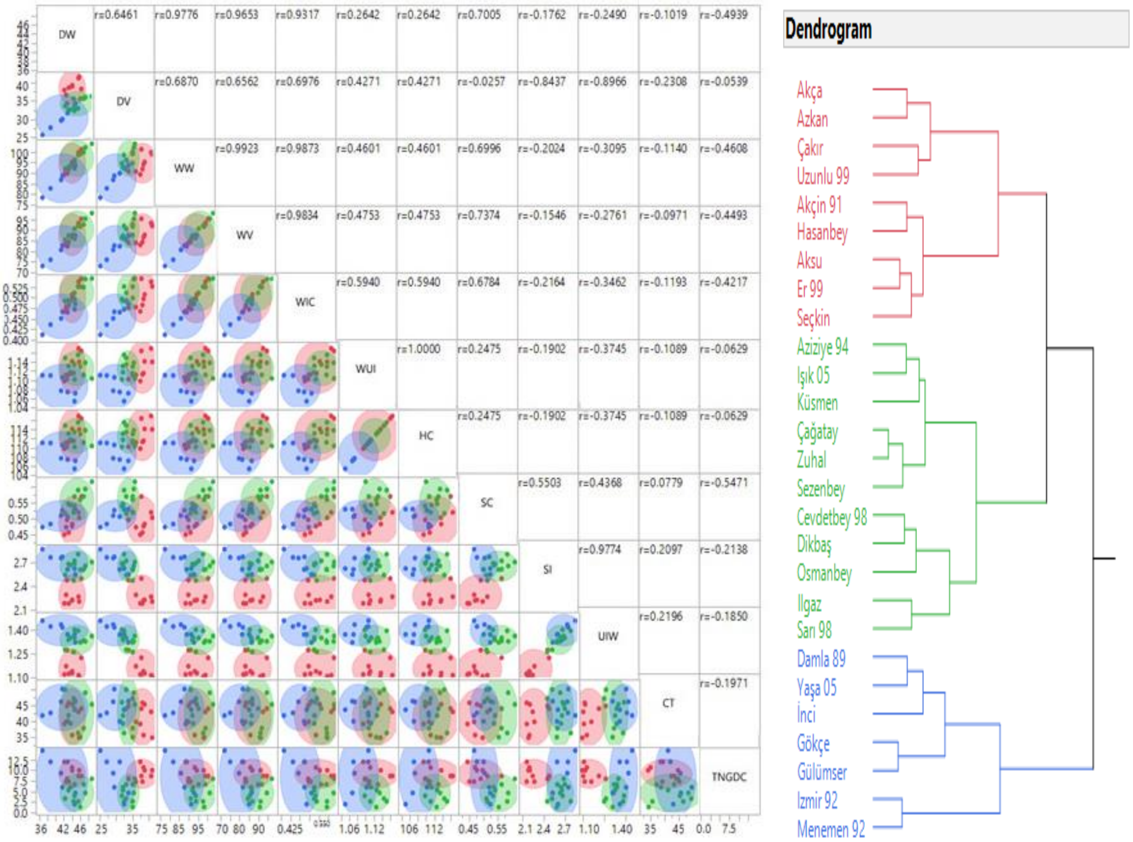

Fig. 2. Correlation coefficients, scatter plots and dendrogram for technological characteristics of chickpea cultivars

Dry weight:DW, dry volume:DV, wet weight:WW, wet volumeWV, water absorption capacity:WIC, water absorption index:WUI, hydration coefficient:HC, swelling capacity:SC, swelling index:SI, cooking time:CT, number of destructed seeds after cooking:TNGDC

CONCLUSIONS

Technological characteristics of 27 Kabuli cultivars were investigated in this study and Dikbas genotype had low cooking time and number of destructed seeds after cooking and high values for the other characteristics. Apart from cooking time, for the other characteristics, Cagatay, Osmanbey and Cevdetbey cultivars with low cooking time and high wet weight, wet volume, water absorption capacity, water absorption index, swelling capacity could also be recommended to be cultivated under natural farming conditions without the use of any fertilizers and chemicals since they were placed into the same statistical group and clustered in the same cluster with Dikbas genotype.

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