Chemical and physical properties of early, mid-time and late ripening apricot cultivars

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Chemische und physikalische Eigenschaften von früh-, mittel- und spätreifenden Aprikosensorten

1 Introduction

Apricots are cultivated around the world mainly for their high-quality fruit, which is consumed fresh, processed by the food industry (frozen apricot, jam, jelly, marmalade, pulp juice, nectar, extrusion products etc.), or preserved by drying (Mirzaee et al., 2009). In addition, apricot kernels are used in the production of oils, benzaldehyde, cosmetics, active carbon, and aroma perfume (Mandal et al., 2007). Apricot fruit is a source of minerals and vitamins and has the potential to contribute greatly to human nutrition and health because of their richness in antioxidant compounds,

Zusammenfassung

Dieser Beitrag untersucht chemische (Feuchtigkeitsgehalt, lösliche Feststoffe, Gesamtzucker, titrierbare Säure, pH-Saft, das Verhältnis lösliche Feststoffe/titrierbare Säure und das Verhältnis Gesamtzucker/titrierbare Säure) und physikalische Eigenschaften (Fruchtmaße, mittlerer arithmetischer und geometrischer Durchmesser, Frucht-Steingewicht, Fleisch/Stein-Verhältnis, Sphärizität, Seitenverhältnis und Oberfläche) von früh- (Senetate), mittel- (Ungarische Beste) und spätreifenden (Kecskemét Rose) Aprikosensorten. Die Anwendung bewerteter Eigenschaften wird ebenfalls diskutiert. Die Unterschiede im Feuchtigkeitsgehalt, löslicher Trockensubstanz, Gesamtzucker, pH-Saft, Verhältnis lösliche Feststoffe/titrierbare Säure und das Verhältnis Gesamtzucker/titrierbare Säure von drei Aprikosensorten erwiesen sich als statistisch signifikant, während Unterschiede in der titrierbaren Säure nicht beobachtet wurden. Die Aprikosensorte beeinflusst wesentlich die untersuchten physikalischen Eigenschaften. Auf der Grundlage der chemischen und physikalischen Eigenschaften kann gesagt werden, dass Senetate in erster Linie für den Frischverzehr geeignet sind, während Ungarische Beste und Kecskemét Rose für die Verarbeitung, zum Trocknen und zum Frischverzehr empfohlen werden kann.

Schlagworte: *Prunus armeniaca* L., Qualitätsmerkmale, lösliche Feststoffe, Gesamtzucker.

Summary

This article presents chemical (moisture, soluble solids and total sugars contents, titratable acidity, pH juice, soluble solids/titratable acidity ratio and total sugars/titratable acidity ratio) and physical (fruit dimensions, arithmetic and geometric mean diameter, fruit and stone mass, flesh/stone ratio, sphericity, aspect ratio and surface area) properties of early (Senetate), mid-time (Hungarian Best) and late ripening (Kecskemét Rosè) apricot cultivars. The application of properties evaluated is also discussed. The differences in moisture content, soluble solids, total sugars, juice pH, soluble solids/titratable acidity ratio and total sugars/titratable acidity ratio of three apricot cultivars were found to be statistically significant, whereas differences in titratable acidity were not observed. The cultivars of apricots affected significantly the physical properties evaluated. On the basis of the chemical and physical properties, it could be said that fruits of Senetate are primarily recommended for fresh consumption, whereas Hungarian Best and Kecskemét Rosè can be recommended for processing, drying and fresh consumption.

Key words: *Prunus armeniaca* L., quality attributes, soluble solids content, sugars.

sugars, minerals etc. (PEKER, 2004; DROGOUDI et al., 2008). It is also widely used for traditional medicinal purposes. Therefore, apricot cultivars must be characterized by high fruit quality attributes which satisfy consumers (MOREAU-RIO & ROTY, 1998). However, fruit quality attributes are affected by a number of pomological traits and their correlations (RUIZ & EGEA, 2008; MRATINIĆ et al., 2011). In this context, fruit quality is a combination of physical and chemical characteristics accompanied by sensory properties (appearance, texture, taste and aroma), nutritional values, chemical compounds, mechanical and functional properties (KRAMER & TWIGG, 1966). Ripening time is the principal parameter affecting fruit quality attributes in the opinion of BADENES et al. (1998) and ŠTURM et al. (2003). Also, fruit quality is affected by a number of pomological traits that cannot be analyzed separately from the biological properties of the fruit tree and the yield obtained, agronomical and ecological factors and their correlations (LICZNAR-MAŁAŃCZUK & SOSNA, 2005). In addition, a great number of authors reported that the cultivar and rootstock, or interstock, play an important role in the physical and chemical traits of apricot fruit (HERNÁNDEZ et al., 2010; MILOŠEVIĆ et al., 2012).

Generally, agricultural crops and food products have several unique characteristics which set them apart from engineering materials. These properties determine the quality of the fruit and identification of correlations between changes in these properties makes quality control easier (JANNATIZADEH et al., 2008). Also, the determination of physical properties of agricultural materials is important to design machines and processes for harvesting, handling and storage of these materials and requires understanding for converting these materials into food and feed. Moreover, information with regard to some physical properties such as length, width, thickness, fruit and stone mass, arithmetic and geometric mean diameter, sphericity, aspect ratio, etc. of apricot fruit may have more importance for the proper design and constructing equipment and structures for handling, transporting, processing, storing and drying and also for assessing the product quality (MOHSENIN, 1986; JANNATIZADEH et al., 2008; DURMAZ et al., 2010). However, these properties have not been reported extensively for Senetate, Hungarian Best and Kecskemét Rosè apricot cultivars in literature.

This research aimed to investigate the chemical and physical attributes of early, mid-time and late ripening apricot cultivars (*Prunus armeniaca* L.) grown in Skopje region, Macedonia.

2 Material and methods

Fruits of the well-known apricots Senetate (SE) (early ripening – mid June), Hungarian Best (HB) (mid-time ripening – beginning of July) and Kecskemét Rosè (KR) (late ripening – end of July) used in this study were harvested manually at commercial ripening according to fruit color and size (RUIZ & EGEA, 2008) from Skopje region (42°00' N latitude, 21°26' E longitude, 240 m altitude) in northern Macedonia during harvest season of 2003 and 2004. Cultivars were grafted on Myrobalan seedlings and grown under standard cultural practices, except for irrigation. The orchard was established in 1993 at a spacing of 6 m × 4 m. Fruit samples (50 fruits per cultivar) for chemical and/or physical analysis were randomly collected in plastic bags and immediately brought to the laboratory. Measurements were made immediately after harvest.

For moisture content (*M*), samples were prepared for analysis by grinding about 100 g of fruit to pass through a sieve with circular openings of 1 mm diameter and mixed thoroughly. Two grams of the comminuted material were dried in a hot-air ST-01/02 (Instrumentaria, Zagreb, Croatia) oven at 80 °C for 10 h, cooled in desiccators and weighed. Weight loss on drying to a final constant weight was recorded as moisture content of the material. Data are given in %.

Soluble solids contents (*SSC*) and juice pH (*pH*) were assessed by triplicate with a hand digital refractometer Milwaukee MR 200 (ATC, Rocky Mount, USA) and Cyber Scan 510 pHmeter (Nijkerk, Netherlands), respectively. Values are expressed as °Brix and *pH* units, respectively. Titratable acidity (*TA*), as malic acid (%) of fresh weight, was also determined by triplicate using titration device Metrohm 719S (Titrino, Herisau, Switzerland) with 0.1 N/10 NaOH up to pH 8.1. Once the *SSC* and *TA* were assessed, the SSC/TA rate or ripening index (*RI*) of the evaluated cultivars was determined.

Total sugars (*TS*) were analyzed isocratically according to the method of ŠTURM et al. (2003), as previously published by MRATINIĆ et al. (2011). Data are given in % of fresh weight. TS/TA ratio (index of sweetness, *IS*) was calculated as the relationship between *TS* and *TA*.

Fruit mass (*FM*) and stone mass (*SM*) were determined using a Tehnica ET-1111 technical scale (Iskra, Horjul, Slovenia) with 0.01 g sensitivity. Data are given in g. For determining flesh/stone ratio (*FSr*), fruits were cut in half horizontally with a stainless-steel knife and the stones were removed and weighed. The flesh content was calculated by subtracting the stone mass from the whole apricot fruit mass. Data are given as %.

For each apricot fruit, three linear dimensions, length (L), width (W), and thickness (T), were measured using a digital caliper gauge Starrett 727 Series (Athol, MA, USA) with a sensitivity of 0.01 cm. The measurement of L was made on the polar axis of fruit, i.e. between the apex and stem. The arithmetic mean diameter (D_a), geometric mean diameter (D_g), sphericity (φ) and surface area (S) was calculated by using the following relationships (MOHSENIN, 1986):

$$D_a = \frac{L+W+T}{3}, \tag{1}$$

where D_a – arithmetic mean diameter (mm), L – length of apricot fruit (mm), W – width of apricot fruit (mm), T – thickness of apricot fruit (mm),

$$D_g = (LWT)^{\frac{1}{3}}, \tag{2}$$

where D_g – geometric mean diameter (mm),

$$\varphi = \frac{D_g}{L}, \tag{3}$$

where φ – sphericity,

$$S = \pi D_g^2 \tag{4}$$

where S – surface area (mm^2).

The aspect ratio (R_a) was calculated (MADUAKO & FABORODE, 1990) as:

$$R_a = \frac{W}{L} \times 100 \tag{5}$$

where R_a – aspect ratio (%).

All data obtained were statistically analyzed using analysis of variance (ANOVA). The treatment means were compared by LSD test at $P \leq 0.05$, using the MSTAT-C statistical computer package (Michigan State University, East Lansing, MI, USA). All data in this study are mean ± SE for two successive years.

3 Results and discussion

3.1 Evaluation of fruit chemical properties

The determined fruit chemical properties of SE, HB and KR apricot cultivars are shown in Table 1. Regarding M, the SE had significantly higher content than the other two cultivars, while differences among HB and KR were insignificant. Our values were similar to the findings obtained by JANNATIZADEH et al. (2008) for Iranian cultivars, but generally lower than those for a group of Turkish cultivars (HACISEFROĞULLARI et al., 2007). The differences between the present results and those of the above authors were likely due to the different eco-geographical groups of apricot cultivars studied. Some authors reported that knowledge of fruit moisture content and water activity is very useful to forecast the stability conditions in apricot fruits in order to select formulations and storage conditions in new products and to improve drying processes and equipments (VULLIOD et al., 2004). In addition, the cultivars with low moisture content have a desired good fruit property for dried apricot, as previously reported (RUIZ & EGEA, 2008).

According to the results given in the Table 1, HB had significantly higher SSC, TS, RI and IS, whereas SE had lower those values. In KR, above values were intermediate. All cultivars in this work showed SSC higher than 12 °Brix. Some authors reported that apricot genotypes which have a $SSC > 12$ °Brix are characterized by an excellent gustative quality (MOREAU-RIO & ROTY, 1998; RUIZ & EGEA, 2008). Above authors also found that SS content is a very important quality attribute, influencing notably the fruit taste and consumer acceptance. Moreover, HACISEFROĞULLARI et al. (2007) stated that cultivar significantly influences SSC, which was confirmed our results. Previous studies on apricots belong to European eco-geographical group indicated that SSC of ripe fruit in 37 cultivars varied between 10.4 and 17.0 % (RUIZ et al., 2005) or 16.01 and 18.88 % in a study obtained by MILOŠEVIĆ et al. (2010). Sugars are basic parameters in evaluating fruit market quality attributes. In general, our values for TS are in agreement with previous work in apricot (AUDERGON et al., 1990). To some researchers, the divergence noticed on sugar contents might be due to diverse agro-climatic conditions (HACISEFROĞULLARI et al., 2007). In contrast to others, the cultivar factor per se (genotype) influences most apricot sugar profiles (DROGOUDI et al., 2010; MRATINIĆ et al., 2011). In the present study, cultivars produced similar TA content, while pH was higher in HB and lower in KR. The SE had similar *pH* with both cultivars. Fruit maturity stage at the harvest date is the principal factor affecting fruit acidity and also the *SSC* (RUIZ & EGEA, 2008). The range of *TA* and *pH* values obtained in this study is in agreement with previous work on apricot (MILOŠEVIĆ et al., 2010; DURMAZ et al., 2010).

Sweet taste is an important quality parameter for fruits. It is usually associated with sucrose, glucose and fructose content, which are often used as an index of ripening (GOMEZ et al., 2002; CRISOSTO et al., 2004). In addition, the sugar/acid rate is also an important indicator of a fruit's taste and aroma (ISHAG et al., 2009). On the basis of our data, mid-time ripening HB had better *RI* and *IS* values than the other two cultivars. Thus, it could be said that apricot *RI* and *IS* were basically conditioned by the cultivar factor, as previously reported (BADENES et al., 1998).

3.2 Evaluation of fruit physical properties

The physical properties of apricot cultivars are summarized in Table 2. According to the results, most of the above properties of different apricot cultivars were found to be statistically significant. The greatest dimensional characteristics were found for HB, related to *L*, *W* and *T*, respectively. KR had the lowest values of *L*, *W* and *T* among the studied cultivars, as previously described by MATIĆ-KEKIĆ et al. (2007) and MRATINIĆ et al. (2011). The importance of dimensions is in their influence on aperture size of machines, particularly in separation of materials, as discussed by MOHSENIN (1986). These dimensions can be used in designing machine components and parameters. For example, to design a mechanism for mechanical harvesting of apricot cv. Hacthaliloglu, ERDOGAN et al. (2003) reported *L*, *W*, and *T* of the fruit as 38.94, 40.92, and 35.21 mm, respectively. However, in our study, only KR had similar values when compared with cv. Hacthaliloglu, whereas other cultivars had greatly higher dimensions.

As is shown in Table 2, D_a and D_g values were very similar. The highest values were found in HB and the lowest in KR, while SE was intermediate. Knowledge related to D_g would be valuable in designing the grading process (JANNATIZADEH et al., 2008). In addition, our values were higher than those of the above authors probably due to the dif-

Table 1: Chemical properties of three apricot cultivars
Tabelle 1: Chemische Eigenschaften von drei Aprikosensorten

Properties	Senetate	Hungarian Best	Kecskemét Rosé
Moisture content (%)	87.75 ± 0.21 a	85.95 ± 0.17 b	85.60 ± 0.15 b
Soluble solids content (°Brix)	12.25 ± 0.66 c	14.36 ± 0.79 a	13.59 ± 0.67 b
Total sugars content (%)	9.64 ± 0.24 c	10.88 ± 0.51 a	10.54 ± 0.33 b
Titratable acidity (%)	1.15 ± 0.01 a	1.18 ± 0.03 a	1.16 ± 0.01 a
pH juice	4.35 ± 0.04 ab	4.45 ± 0.08 a	4.25 ± 0.05 b
SS/TA ratio (RI)	10.65 ± 0.57 c	12.17 ± 0.81 a	11.71 ± 0.62 b
TS/TA ratio (IS)	8.38 ± 0.34 c	9.22 ± 0.44 a	9.09 ± 0.59 b

The different letters in same rows shows the significant difference at P ≤ 0.01 by LSD test

Table 2: Physical properties of three apricot cultivars
Tabelle 2: Physikalische Eigenschaften von drei Aprikosensorten

Properties	Senetate	Hungarian Best	Kecskemét Rosé
Length (mm)	40.79 ± 1.32 b	49.10 ± 2.23 a	41.84 ± 1.98 ab
Width (mm)	41.48 ± 2.01 b	49.19 ± 3.01 a	41.65 ± 1.89 b
Thickness (mm)	42.85 ± 2.76 b	46.36 ± 2.88 a	36.03 ± 1.01 c
Arithmetic mean diameter (mm)	41.71 ± 2.43 b	48.22 ± 4.15 a	39.84 ± 1.93 c
Geometric mean diameter (mm)	41.70 ± 2.44 b	48.20 ± 4.13 a	39.74 ± 1.91 c
Fruit mass (g)	39.11 ± 2.09 b	61.11 ± 3.78 a	36.51 ± 1.79 c
Stone mass (g)	3.25 ± 0.14 b	4.13 ± 0.17 a	3.37 ± 0.15 b
Flesh/stone ratio	91.69 ± 2.03 b	93.24 ± 1.88 a	90.77 ± 1.31 b
Sphericity	1.02 ± 0.01 a	0.98 ± 0.01 b	0.95 ± 0.00 b
Aspect ratio (%)	101.69 ± 3.45 a	100.18 ± 3.11 b	99.54 ± 4.39 b
Surface area (mm^2)	5460.11 ± 129.33 b	7294.97 ± 359.67 a	4958.90 ± 199.39 c

The different letters in same rows shows the significant difference at P ≤ 0.01 by LSD test ferent eco-geographical groups of apricot cultivars studied.

Regarding *FM*, *SM* and *FSr*, the highest values were registered in HB, whereas the lowest values were found in KR and SE, respectively. Previous studies on apricot also suggested a high variability among cultivars regarding these properties, especially *FM* (Ruiz & Egea, 2008; Milošević et al., 2010; Mratinić et al., 2011). *FM* may be useful in the separation and transportation of the fruit by hydrodynamic means in water canals (Jannatizadeh et al., 2008), and other processes related to apricot fruits (Matić-Kekić et al., 2007), whereas apricot stones are used in genotype identification and had a high utilization value (Mandal et al., 2007). Higher *FSr* is a desired fruit property in apricot, as previously reported by Mratinić et al. (2011).

The φ values and R_a differed significantly among the tested cultivars (Table 2), as previously described by Jannatizadeh et al. (2008). The highest values were obtained in SE and the lowest in HB and KR, respectively. Sphericity is an expression of the shape of a solid in relation to that of a sphere of the same volume, while the aspect ratio relates the width to the length of the fruit which is indicative of its tendency to be oblong in shape (Omobuwajo et al., 1999). In addition, shape is not only a physical property of the body, but also an engineering parameter. For instance, heat energy is widely used for cooling, heating or drying in food and processing industry (Matić-Kekić et al., 2007). According to the results, *S* significantly differed among cultivars (Table 2). The highest value was observed in HB and the lowest in KR, while SE had intermediate *S* value. Matić-Kekić et al. (2007) reported lower *S* value for Novosadska Rodna apricot cultivar than our results did. Some authors found that fruit surface area is an important physical property (Mohsenin, 1986; Matiić-Kekić et al., 2007) and may be essential for apricot drying because of their possible benefit in proper prediction of apricot drying rates and hence drying times in the dryer, especially in the drying equipment simulation models for apricot (Jannatizadeh et al., 2008).

4 Conclusion

Statistically significant differences were observed among the evaluated apricot cultivars. The cultivar per se (genotype) behaved as the most influencing factor conditioning apricot fruit physical and chemical attributes, except for titratable acidity contents. Furthermore, mid-time and late ripening cultivars had better potential to accumulate soluble solids and sugars than the early ripening cultivar. The assessment of apricot chemical composition implies great potential of cultivars for both fresh market and fruit processing. Hungarian Best and Kecskemét Rosé apricots were determined to have high soluble solids and total sugars content that naturally contributes to the production of dry apricot. In fact, the Senetate cultivar seems particularly suitable for fresh consumption because of its early ripening time, good fruit size and respectable chemical composition.

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Submitted: March 3, 2012
Accepted: February 5, 2013