Food Research 6 (5) : 108 - 115 (October 2022)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

FULL PAPER

Meteorological data, biometry and sensory evaluation of late season peach and nectarine varieties

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Article history:
Received: 5 September 2021
Received in revised form: 7 October 2021
Accepted: 10 December 2021
Available Online: 12 September 2022

Keywords:
Prunus persica L.,
Fruit Size,
Sensory attributes,
Peaches,
Meteorology

DOI:
https://doi.org/10.26656/fr.2017.6(5).680

Abstract

Peaches are some of the most preferred fruit worldwide. With the vast palette of varieties, they provide an excellent healthy dietary choice. Unfortunately, the peach tree is very dependent on the weather variations during its vegetation in the early spring period. Thus, it is important to link the simple meteorological data to the physical properties of the fruit (width, length, and thickness). Consumers are most likely drawn by-products that have outstanding physical properties. The present study provided information about the sensory attributes of three late-season peach varieties evaluated in five categories with a total of twenty-five attributes. The fruit attributes were evaluated by a 15-point ascending scale. The object of analysis were the "Flat Queen", "Evmolpiya", and "Morsiani 90" varieties. The panellists detected differences between varieties in each of the categories (aroma, texture, taste, internal and external appearance), and a relationship to the physical properties was made. The results emphasized the new data in terms of late-ripening peach variety properties.

1. Introduction

Worldwide, agricultural producers are requested to provide the markets with high-quality products for fresh consumption. This usually means fruits with excellent physical properties, i.e. shape, size, colour, firmness, and aroma. Furthermore, consumers expect to purchase products free of blemishes, damages, or pathogen attacks.

The peach tree, like many other fruit trees, is highly dependent on weather alterations during the early spring season. During active growth, seasonal factors like temperature, humidity, rainfall, and active orchard management are critical for future fruit quality (Jiang and He, 2021). Some authors point out that even the position of each individual tree can result in fruits with quality differences (Sakhidin *et al*., 2018). The global production of peaches and nectarines reaches an average of 22 million tons (FAOSTAT, 2021). Peaches are one of the most preferred seasonal fruits with distinct beneficial properties. They can be seen as excellent sources of vitamins, minerals and other bioactive substances (Mihaylova, Popova, Desseva, Manolov *et al*., 2021).

Consumers tend to look for products with outstanding physical properties. Imperfect produce is carefully considered before being purchased. The degree of abnormality strongly influences the perception of quality and overall appearance (Lombart *et al*., 2019). The Food and Agriculture Organization (FAO, 2014) accents the fact that billions of tons of edible agricultural products go to waste due to their imperfect appearance. The EU market standards label otherwise good products, as such of "wrong" size and shape, and thus appearance (de Hooge *et al*., 2017). Consumers also search for products marked as organic or locally produced (Verain *et al*., 2016). Products also pass an important evaluation of their nutritional data and freshness. Price is always an important factor, and usually higher prices indicate better quality in the consumers' personal perception (Moser *et al*., 2011).

The present study was designed to explore the performance of two local and one introduced peach varieties through quantitative characteristics (size, shape)

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eISSN: 2550-2166 / © 2022 The Authors.
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as well as to determine the variation of the weather conditions, and link them to their sensory attributes.

2. Materials and methods

2.1 Samples collection and harvest

Three late-ripening peach and nectarine varieties "Flat Queen" (flat peach, freestone), "Evmolpiya" (peach, freestone), and "Morsiani 90" (nectarine, freestone) participated in the study. "Laskava" and "Evmolpiya" are both local varieties, while "Morsiani 90" was introduced from Italy. Fruits were hand-harvested from trees at the Fruit-growing Research Institute (Plovdiv, Bulgaria), ranging from 5 to 8 years old, that were spaced 3 m apart, at full maturity in the period from the end of August until mid-September 2020. Peaches and nectarines were harvested in the morning between 6 am and 8 am on three harvest dates 3 ("Flat Queen"), 11 ("Evmolpiya") and 18 ("Morsiani 90") September 2020 at 164, 164, and 178 days after full bloom, respectively. No bactericides were applied to plantings during testing and no rain events within 24 h of harvesting have been registered. The fruits were free from major damages such as blemishes, flaws, and such. Forty peaches per variety were harvested and transported in pulp trays in an air-conditioned vehicle to the University of food technologies, where the fruit was randomly placed in new trays in order to minimize the differences in fruit quality. Extra fruit was harvested in case there was decay or damage during/after the harvest. The fruit was evaluated for physical and sensory attributes.

2.2 Meteorological data

Temperature (T, °C), rainfall (RF, mm) and humidity (H, %) were recorded automatically every day using the local weather station (Sencor SWS 9700, Sencor, Japan) at the orchard. The study focuses on the weather conditions between April and September, or the conditions during flowering, fruit growth and fruit development, according to Tromp and Wertheim (2005). Employees at the Fruit Growing Institute, Plovdiv, have recorded information about the number of rainy days (RD), sun days (SD), and sun hours (SH, hr).

2.3 Fruit and stone biometry

Thirty peaches/nectarines of each variety were divided into three groups and were positioned in three orientations and photographed with a Nikon D5600 digital SLR camera as described by Popova *et al*. (2021). The obtained coloured .tiff images were processed and analysed with ImageJ software to determine the length, width, and thickness of the selected peach/stone (Figure 1). The geometric mean diameter and sphericity were calculated following the equations of Mohsenin (1986). The surface area was calculated according to McCabe *et al*. (1986).

Figure 1. Determination of length, width, and thickness in peach fruit and stone

2.4 Sensory analysis

Sensory analysis was performed at the University of food technologies. The sensory panel of 10 specially selected evaluators (recruited following ISO 8586:2012) (ISO, 2012) who have passed the preliminary tests to assess the ability to recognize the main tastes, and sensitivity thresholds of the receptors, and are familiar with the methodology for conducting the sensory test, was used to conduct the sensory evaluation. The ten trained panellists (four male, six female) used a modified Sensory Spectrum method and objective method for describing the intensity of attributes to references. A lexicon of attributes was developed for the needs of the evaluation. The fruit attributes were evaluated by a 15-point ascending scale. Each panellist evaluated one fruit per variety in triplicates. The fruit was served at room temperature (24°C) on plates labelled with 3-digit codes in a randomized design. Panellists cleansed their palates between samples using water and crackers and evaluated the fruit for external appearance (n = 8), internal appearance (n = 6), basic taste (n = 3), texture (n = 4), and aroma (n = 4). The phase of the evaluation followed international standards ISO 6564:1985 (ISO, 1985) and ISO 4121:2015 (ISO, 2015) as well as techniques described by Lawless *et al*. (2010) and Meilgaard *et al*. (2016).

2.5 Statistical analysis

Data were analysed using MS Excel software. All assays were performed in at least three repetitions. Results were presented as mean±SD (standard deviation). Fisher's least significant difference test at a level of $p<0.05$ were used to determine the significance of differences between mean values.

3. Results and discussion

Climate information is very helpful for the agro sector as it can provide the necessary information to producers to better address unfavourable weather conditions, especially during the spring season. At the

times of flowering, drastic changes in the weather can lead to frost damage and consequently to poor fruit quality and yield (Wertheim and Schmidt, 2005). Having systematic documentation about the temperature, rainfall, and humidity can help producers and researchers to better address the challenges of climate change. Figure 2 provides information about the temperature in the peach orchard. Table 1 summarizes information about the rainfall, number of sunny days and rainy days, humidity, and sun hours.

Table 1. Climate information in peach orchard

Month	RF (mm)	RD	SH (hr)	SD	H (%)
April	133.6	19	248	10	73
May	134.9	25	297	6	71
June	158.3	23	283	7	68
July	75	15	317	17	58
August	41.9	15	335	16	52
September	4.7	4	360	26	47

Rainfall (RF), Rainy days (RD), Sun hours (SH), Sun days (SD), Humidity (H)

Zambrano-Vaca *et al.* (2020) report a high daily peach water demand between August and October. The peach tree demands a relatively high moisture availability because of its rich leaf area. The results from the year 2020 suggest that the later ripening varieties have been subjected to a low amount of rain days and actual rainfall during this period, which is a combination of the low temperatures in the event of their full bloom (Figure 3) can affect the physical characteristics of the fruits. The prolonged periods of missing rainy days leave the tree to retrieve the available accumulated drought depending on the soil. The precipitation and cloud cover can affect fruit quality, especially during the latter stages of fruit development (Kwon *et al.*, 2008). Research shows that the increase in air temperature though is more important than precipitation when it comes to tree well-being and development (Zupanc *et al.*, 2007). Higher temperatures at the early stages of development lead to a reduced fruit development period (Wert *et al.*, 2009). This can be observed for the "Flat Queen" and "Evmolpiya" varieties, which have a 7-day difference in the harvest date but the same period considering the days after full bloom. An average of above-average season precipitation can lower water requirements by up to 40% (Gibson *et al.*, 2019). Although the "Morsiani 90" variety has received the most sun hours and sunny days, this has not positively affected its external appearance (colour). Among all varieties, the "Morsiani 90" variety was the one with the least vivid colouring of the flesh.

The temperature in April and May did not anticipate any abnormal development of the trees. There were not any temperature events, which were too high to anticipate the earlier development of the trees. The peach tree develops well in summer temperatures above 24°C. Figure 2 shows that the summer temperature in the orchard provides favourable conditions for the trees. Certain temperatures are considered critical in the development of peach fruit. Spring frost damage is quite common and fruit growers have to find ways to adapt to the constant changes in the climate. Low temperatures can cause up to 90% damage in just 30 mins. Early ripening peach varieties are more prone to spring frost damage (Caramori *et al.*, 2008). Additionally, the development of the bud determines the level of susceptibility of the crop in the event of frost. Table 2 shows the temperature in spring 2020 and its impact on the studied late-ripening varieties.

Early in the development, there are no extremities in the temperatures. Temperature rise encourages dormancy to overcome and promotes flowering and budburst of plants (Simonetto *et al.*, 2004). Up until the first bloom of the varieties, no damage has been recorded. For the varieties, "Flat Queen" and "Morsiani 90" unfavourable

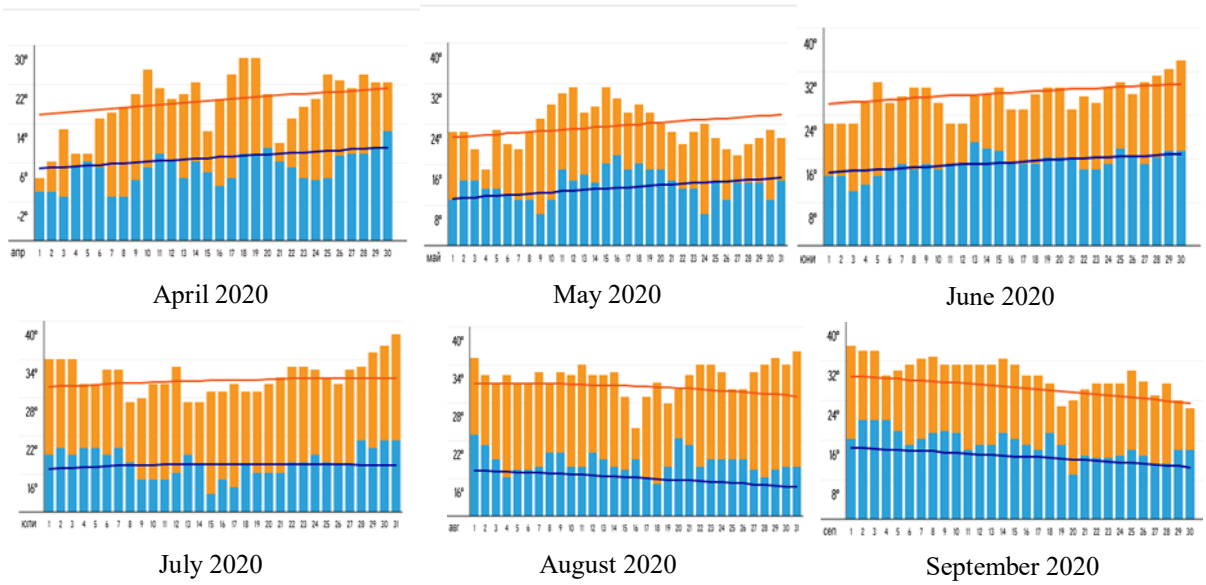

Figure 2. Temperature, peach orchard (°C)

Table 2. Temperature effect on peach stage development

Peaches							
Stage		Swollen bud	Calyx green	Calyx red	First pink	First bloom	Full bloom
Date, Flat Queen		16 Feb	4 Mar	6 Mar	12 Mar	14 Mar	25 Mar
Lowest daily Temperature, (°C)		0	-1	1	10	-1	2
Date, Evmolpiya		19 Feb	4 Mar	9 Mar	16 Mar	20 Mar	30 Mar
Lowest daily Temperature, (°C)		6	0	8	-1	2	5
Date, Morsiani 90		15 Feb	4 Mar	14 Mar	13 Mar	16 Mar	22 Mar
Lowest daily Temperature (°C)		0	0	10	4	-1	5
Critical Temperature (°C)	10% damage	-8	-6	-5	-4	-3	-2.7
	90% damage	-17	-15	-13	-9.5	-6	-4.5

temperatures have been recorded at first bloom. It has to be noted that near bloom, the likelihood of severe damage is more common. This is a prerequisite for future abnormalities of the fruit i.e. size, shape, and skin colour. That was particularly visible in the "Morsiani 90" variety, where an atypical skin colour decomposition appeared due to the impact of the low-temperature event (Figure 3). The "Evmolpiya" variety has been subjected to a low temperature at first pink but later no damages to the fruit were registered. This supports the thesis that the damage range is connected to the growth stage, species and variety in particular.

"Flat Queen" "Evmolpiya" "Morsiani 90"

Figure 3. Fruit samples

Biometric studies are important for the determination of plant patterns in breeding programs. This is especially useful for varieties that are being introduced to new conditions. The cultivation of native varieties lies mainly on technical knowledge, as well as varieties specifics and environmental factors (Gordin *et al.*, 2016). Biometric characterization can target the whole plant, or specific features like fruit or stones/seeds (Silva *et al.*, 2017). Values of the dimensions and shape of the three evaluated peach/nectarine varieties are presented in Table 3.

Table 3. Peach varieties biometry

Attribute/Variety	"Flat Queen"	"Evmolpiya"	"Morisani 90"
		Fruit	
Length (mm)	79.75±6.48[a]	74.33±5.14[a]	71.92±7.54[b]
Width (mm)	42.00±5.76[a]	74.17±4.80[a]	71.58±5.95[cd]
Thickness (mm)	80.75±6.10[ab]	74.25±2.86[a]	72.50±4.91[c]
Geometric mean diameter (mm)	64.67	74.25	71.99
Sphericity (%)	81.09	99.88	100.11
Surface area (cm^2)	131.32	173.1	162.77
		Stone	
Length (mm)	22.50±2.16[a]	39.50±1.22[ab]	38.67±3.20[a]
Width (mm)	14.66±2.33[bc]	21.00±1.79[c]	22.33±2.33[b]
Thickness (mm)	22.33±2.73[a]	27.00±1.41[a]	29.50±2.51[a]
Geometric mean diameter (mm)	19.46	28.19	29.42
Sphericity (%)	86.49	71.36	76.09
Surface area (cm^2)	11.89	24.94	27.18

*Means with different letter(s) for each attribute within effects are significantly different ($P<0.05$) using Fisher's least significant difference test.

Fruit biometrics showed an average length of 75.33 mm. The size parameters of the different varieties verify that the "Flat Queen" variety stands out presenting the longest fruit (79.75±6.48) and the one with the thickest fruits. It has to be noted that, this is also the variety with the smallest stones. This is to be expected because "Flat Queen" is a variety with a flat shape and the stones are usually very small. Among the studied varieties, the "Evmolpiya" variety produces fruits with the largest stones. As regards the size parameters, the three peach varieties are quite comparable, but considering the pulp/pit ratio, the "Evmolpiya" variety has the best proportion, which will probably be an important parameter in the consumer's acceptability. For fresh fruit consumption, it is important to note that the larger the fruit and smaller the stone, the greater the quality and value for the consumer.

Peach and nectarines, being climacteric fruit and having dynamic changes in the ethylene and auxin biosynthesis after ripening, significantly change their textural and flavour properties (Ziosi *et al*., 2009). Attractive fruits with likeable physical features have been an important milestone in the peach breeding programs in the last decade (Iglesias and Echeverría, 2009). Prior to purchasing the consumer's satisfaction is directly linked to the physical appearance of the product. After being able to taste it, flavour stimulates the consumer to make a decision to repurchase the fruit (Gorny *et al*, 1999).

The sensory properties of foods are a principal reason for choice and consumption. The descriptive sensory analysis gives an excellent explanation of the product's characteristics by describing a wide array of carefully chosen attributes (Belisle *et al.*, 2017). The common quality characteristics of fruits for the consumer's acceptance are colour, size and shape, firmness, and flavour perceived by the combination of taste and smell. Thus, the sensory analysis conducted in this research focused on the peaches' external appearance, texture, taste, and aroma (Table 4).

The external appearance was first evaluated and it showed that not only variety differences existed but also fruit-to-fruit variations were established. This was to be expected, as the three varieties are quite different: a peach ("Evmolpiya"), a flat peach ("Flat Queen"), and a nectarine ("Morisiani 90"). Market specialists claim that consumers usually choose larger-sized fruits (Lopez *et al*., 2007). According to the panel, all three varieties can be considered large. When it comes to evaluating their shape (referenced with colour photographs), the panellists defined the "Evmolpiya" and "Morsiani 90" varieties as round-shaped, and "Flat Queen" as a flat peach. All three varieties are freestone, and this did not go unnoticed by the panellists. Before being able to cut the fruit in half in order to further evaluate and taste it, the panellists had to characterize the three varieties' external colour uniformity, fuzziness, aroma, and the presence of any deformities or blemishes (Figure 4).

"Evmolpiya" and "Flat Queen" had very tender and practically imperceptible fine fuzz. "Morsiani 90" is nectarine and it had a fizzles exterior. Many fruits are visually graded by their colour, and the three tested varieties were classified as rather colourful. The variety with the most redness was "Flat Queen", and the one with the most yellowness – "Evmolpiya". The fact the "Morsiani 90" had an atypical colouring was also observed by the panel, but this was a characteristic of rather minor importance in terms of sensory quality. According to the panel, none of the studied varieties had distinguishable deformities or blemishes. Vivid colours

Table 4. Reference substances and lexicon attributes used in the sensory evaluation

Attributes	Definition	Reference
Flavour		
- Sweet	Degree of sweetness, sourness, and respectively bitterness on chewing a piece of the fruit	sugar solution 1 g/10 mL
- Sour		citric acid solution 0.05 g/10 mL
- Bitter		caffeine solution 0.003/100 mL
Aroma		
- Peachy		fresh peach
- Unripe		fresh cut grass
- Overripe		fermented peach puree
- Earthy		wet soil
Texture		
- Flesh hardness	Force required to break with teeth	banana (low); carrot (high)
- Moisture release	Amount of liquid released on first three bites	banana (low); orange (high)
- Crispiness	Stringy texture on chewing	banana (low); carrot (high)
- Presence of fibres		mango (low); canned pineapple pieces (high)

eISSN: 2550-2166

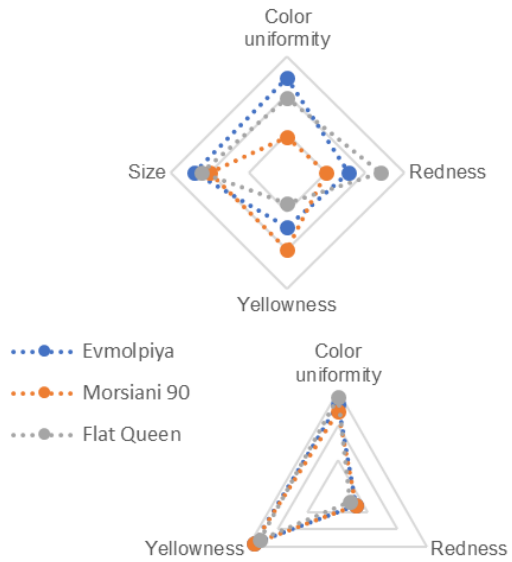

Figure 4. Spider plot of the sensory profile of the tested peach varieties

and the absence of blemishes are usually indicators of freshness in fruits.

Aroma is particularly important when defining the consumer's preference. All three varieties had an intense, pleasant, peachy aroma. Odour intensity increased when the panellists were able to cut the peach. None of the panellists stated that an earthy, unripe, or overripe aroma was present. The fruit texture, but not saliva, is the leading factor in the volatile compounds' release during fruit consumption (Bonneau *et al*., 2016). Internal colour, deformities, and pit size and shape (references with colour pictures) were characterized immediately thereafter. "Flat Queen" had a small, round stone, while "Morsiani 90" and "Evmolpiya" had a medium, elliptic one. "Flat Queen" was the variety with predominantly one colour of its pulp. "Evmolpiya" and "Morsiani 90" had a predominant yellowish colour with red sections near their stones.

When it comes to consumers' acceptance and preference of food, texture and taste perception are the two main aspects, although many uncontrollable factors in food oral processing exist, especially eating patterns, chewing force and saliva secretion (Liu *et al*., 2017). Sweet, sour and bitter are the main flavour components evaluated by the panel. All three peach varieties were characterized as sweet (Figure 5). None of the panellists could distinguish a bitter taste, and the sour taste was in the range from 1.0 to 2.5. The intensive sweet taste is in agreement with previously published TSS values (13.54-14.50%) of the tested varieties in the paper of Mihaylova, Popova, Desseva, Petkova *et al*. (2021).

The juiciness perception is a complex mouth sensation linked to the cell wall strength of the fruit, cell dimensions, intercellular water distribution, firmness, and ripeness in general (Iwanami *et al*., 2017). The nectarine variety "Morsiani 90" was considered crispier than "Evmolpiya" and "Flat Queen". "Flat Queen" was a rather moisture release variety. The highest scores of all texture attribute corresponded to the "Evmolpiya" variety.

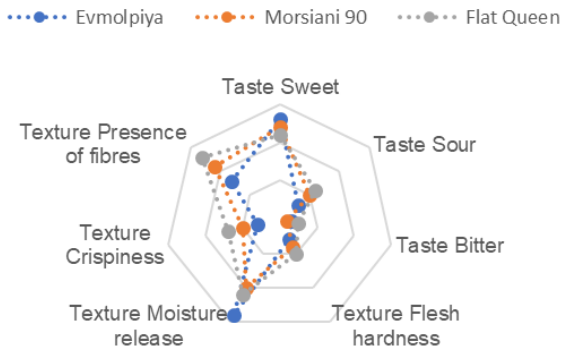

Figure 5. Spider plot of texture and taste attributes of peach varieties

4. Conclusion

The currently established results support the thesis that chilling requirements may be an important adaptation factor, but temperature, precipitation and other climatic factors can have a direct linkage to fruit biometrics and variety performance. It is important to clear all these factors before recommending certain varieties for planting. Fruit's physical attributes are the principal reason for choice and consumption. The sensory evaluation of the three tested varieties confirms that only fruits with excellent characteristics make them attractive for purchase in order to later determine their taste and draw the consumer's overall preference.

The perception of only the visual attributes will lead the consumer to choose the "Evmolpiya" variety over the other two, especially when it is not possible to taste the fruit prior to purchasing it. This was also the variety being least affected by some unfavourable climatic conditions. Considering that the physical characteristics of the fruits are deeply influenced by the environment, it is important to continue to enlarge the available climatic database and the possible correlations arising from the data available.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The authors gratefully acknowledge the financial support of the Ministry of Education and Science Scientific Research Fund, Bulgaria, project КП-06-Н37/23 – 2019. The authors would like to thank the team

of prof. Zhivondov for providing the fruit for research.

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