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STUDIES ON THE INFLUENCE OF QUALITY ON BIOMETRIC AND PHYSIOLOGICAL INDICES IN APPLES (*MALUS DOMESTICA* L.)

Carmen BEINȘAN[1], Ștefania GÂDEA[2], Giancarla VELICEVICI[1], Daniela SCEDEI[1], Anamaria VÂTCĂ[2], Ancuța ROTARU[2], Valentina STOIAN[2], Melinda HORVAT[3], Sorin VÂTCĂ[2]

[1]Banat University of Agricultural Sciences and Veterinary Medicine "King Mihai I of Romania" from Timișoara, 119 Aradului Street, Timișoara, Romania
[2]University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, 3-5 Mănăștur Street, Cluj-Napoca, Romania
[3]University of Medicine and Pharmacy Iuliu Haţieganu Cluj-Napoca, 8 Babeş Street, Cluj-Napoca, Romania

Corresponding authors emails: anamaria.vatca@usamvcluj.ro; sorin.vatca@usamvcluj.ro

Abstract

The Apple is one of the basic components in modern human nutrition. They are almost the only food ready prepared in nature, which can be eaten without other additives, either fresh or processed. Apple ranks first among fruit species grown in the temperate zone. The fruits are resistant to handling and transport. In this experiment we studied the biometric and physiological indices of twogapple varieties with different origins from western Romania zone. Compared to the imposed standards on diameter, both imported and domestic varieties fall into the Extra category, except for the Golden Varciorova variety which falls into category I. In order to observe the starch/glucose content following the AI test, it was found that all the samples show indicator 9, which reveals the increased amount of glucose, so that all varieties fall into the category of overripe fruits. Compared to the standard values regarding the maturity degree for apple varieties, it is observed that all the local varieties, both Golden and Idared, Arad and Varciorova fall into the Excellent category, according to the Brix index.

Key words*: diameter; weight; firmness; glucyds; pH; dry matter.*

INTRODUCTION

The importance of the apple lies in its biological peculiarities. The existence of a large number of varieties, with staggered ripening in various seasons and the ability to keep fresh winter varieties for a long time, ensures the consumption of fresh fruit almost all year round, about 10 months out of 12 of a year (Thompson, 2008). With a high storage capacity and good handling resistance, fruits can be easily transported over long distances. Due to their technological properties, apples are a raw material with a high share in the food industry (Barreira et al., 2019). Thus, from a chemical point of view, apples contain on average: 84.5% water, 14.1% sugars, 0.2% pectic substances, 0.6% fatty substances, 90 IU vitamin A, 0.02 mg% vitamin B2, 0.1 mg% vitamin B1, 7 mg% vitamin C, 7 mg% calcium, 10 mg% potassium as well as small amounts of aluminum, manganese, sulfur, cobalt and others (Belding, 2008). Fruit quality depend on the species, variety, technological factors and climate (Vâtcă et al., 2020). In everyday life, the term "ripe" fruit refers to changes in the fruit, which makes it good to eat (Nyasordzi et al., 2013). Such changes normally include "softening" due to enzymatic breakdown of the cell wall (Puia et al. 2017), starch hydrolysis, accumulation of sugars, and the disappearance of organic acids and phenolic compounds, including tannins (Farneti et al, 2015). The main physiological change that indicates the level of maturity of the fruit is the internal production of the phyto-hormone Ethylene (C_2H_4) a naturally generated hormone, which causes a cascade of biochemical reactions (Stoian et al., 2019) involved in the ripening process (Thompson, 2008). Ethylene produced at the time of fruit ripening causes the fruit to ripen, ie it makes it softer, produces volatile

compounds (aroma and flavor), converts starch into glucose, develops skin color and breaks down green chlorophyll (Pineiro and Rios, 2007). The basic physiological processes in fruits are respiration, perspiration and circulation of substances (Dobrei et al, 2006). In apples, pears, peaches and partially in other fruits, respiration decreases continuously as it ripens to a minimum that coincides with the stage of maximum cell stretching (Alexa et al. 2018). After this stage, the respiratory intensity increases to a maximum and then decreases again until cell death (FAO, 2006). During storage, the fruit is released through respiration, heat and CO_2. The decrease of the temperature and of the O_2 concentration up to 3% makes the physiological functions of the fruits to be carried out with minimum intensity (Denver and Jensen, 2014; Camen et al., 2016). By breathing and perspiration the fruits lose weight during storage (Palmer et al., 2002). Dry matter content had been shown to influence directly the post-storage atributes and represents an important assessment of apple fruits characteristics (Zhang et al., 2019). Firmness is a primary measure of apple fruit texture, the key determinant of apples quality (Saei et al., 2011). Despite the well-developed understanding of the process of firmness loss in storage, there is very limited information concerning the causes of fruit quality variation in the market-place. Nowadays few trials are made to characterize the biometric parameters of apples after ripening. This experiment sets out to examine quality indices of two apples cultivars.

MATERIALS AND METHODS

The biological material was represented by two cultivars of apples, taken from the agricultural market in the west of the country, namely 'Golden', and 'Idared' from different areas of culture (Italy, Hungary, Romania: Arad and Vârciorova). We took into study a number of 5 apples from each cultivar in 5 replicates for each area and analysis. During the experiment the following quality parameters were studied: fruit's dimensions respectively thediameter, and weight following Table 1, starch-iodine test following Figure 1, firmness, pH of vegetable juice, total sugar content, dry matter.

Table 1. The minimum diameter and weight values for apples determination

	Extra	Category I	Category II
DIAMETER			
Large fruited varieties	≥ 65 mm	≥ 60 mm	≤ 60 mm
Other varieties	60 mm	55 mm	50 mm
WEIGHT			
Large fruited varieties	110 g	≤ 90 g	≥ 90g
Other varieties	90 g	80 g	70 g

In order to determine maturity, the samples were subjected to the AI test (Chu, 2000), the interpretation of the results being based on the comparison of the results with the standard starch-iodine (AI) diagram.

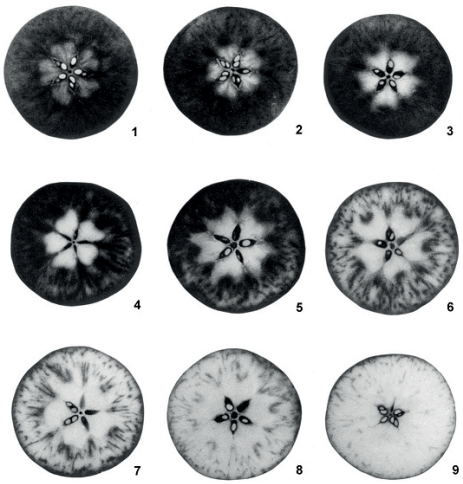

Figure 1. The degree of maturity of the apples according to the AI test (Chu, 2000); Dark areas indicate starch, open areas indicate glucose

To determine fruit firmness we used a digital penetrometer, removing the two small disks of peeled fruit in the middle of the dry flower stems and opposite sides of the apple. Total sugar content was achieved with digital refractometer, Brix degrees (Table 2) was equate to the percentage depending on the temperature determination (for each 10°C we increase the percentage of total soluble percentage with 0.5%) (Camen et al., 2011).

Table 2. Maturity varieties of apple based on Brix index (soluble glucose)

Brix guide	Low	Weak	Good	Excellent
All varieties	< 11	11	12	13
Honeycrisp	< 12	12	13	> 14

The percentage of dry fruit pulp was determined using Kern thermobalance. Prior to analysis, all the fruits were kept at 4°C to avoid their accentuated degradation until the moment of analysis. The analysis were made at room temperature. Statistical analysis was perforemed for each parameter values together, Anova and LSD with Rstudio program, agricolae package.

RESULTS AND DISCUSSIONS

For all genotypes studied, a linear relationship existed between the maximum and minimum size of fruit. The large variation in fruit size (diameter as well as weight) indicates that apples should be sorted to improve quality. This standard governs apples of the *Malus domestica*. L. varieties intended for fresh delivery. Thus, a minimum diameter and weight are required.

Compared to the imposed standards on diameter, both imported and domestic varieties fall into the Extra category, except for the 'Golden' cultivar from Vârciorova which has a diameter of 62.63 mm, thus falling into category I. Regarding the weight, both studied varietes belong to the category of large fruits with values in the range between 128.66 ('Golden' from Vârciorova), framed as a value between minimum and average weight from other studies (Blazek and Hlusickova, 2007; Musacchi and Serra, 2017) and 204.05 grams ('Idared' from Italy) (Table 3) framed as a value between average and maximum weight from the study of Blazek and Hlusickova in 2007. In terms of fruit weight, all varieties are falls into the Extra category.

Table 3. Experimental results regarding biometric indices for the studied apple genotypes (mean ± S.E.)

Genotype/Place of origin	Genotype code	Diameter (mm)	Weight (g)
'Golden'/Italy	GI	72.00 ± 2.60	193.42 ± 9.47
'Golden'/Hungary	GH	71.75 ± 1.38	198.98 ± 9.21
'Golden'/Arad	GA	68.13 ± 0.88	160.24 ± 5.41
'Golden'/Vârciorova	GV	62.63 ± 1.50	128.66 ± 7.98
'Idared'/Italy	II	76.25 ± 1.44	204.05 ± 8.26
'Idared'/Hungary	IH	75.25 ± 3.89	193.80 ± 13.82
'Idared'/Arad	IA	70.25 ± 2.69	179.63 ± 26.26
'Idared'/Vârciorova	IV	65.75 ± 2.46	132.28 ± 14.93

The fruits 'Idared' from Italy and Hungary have ideal size for serving as desert apples as a study conducted in Canadian territories reported the range between 7.4 and 7.6 cm as being ideal (Hampson et al., 2002). Usually the lines of sorting machines determine these size classes and usually smaller apples size usually give a lower price of the fruit.

As a rule, fruits with an AI indicator of 3-4, compared to the AI diagram, are suitable for long-term storage in rooms with a controlled atmosphere, apples with an AI indicator of 4-6 are best suited for long-term storage short in rooms with a controlled atmosphere, and fruits with an indicator of 6, 7, 8, 9, should be placed in regular cold stores or sold immediately. In order to observe the starch/glucose content after performing the AI test, it was found that all samples show indicator 9, which reveals the increased amount of glucose, so that all varieties fall into the category of overripe fruits (Figure 2).

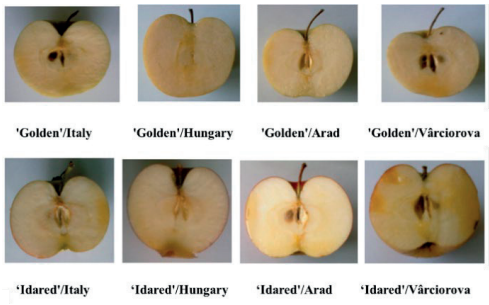

Figure 2. The results of the AI (starch-iodine) test in the studied apples

By ripening the fruit, the pulp is softer, and the best indicator is firmness. The cell walls of the apple pulp are bound to each other by pectin, which is activated by calcium, which forms a very important component of the cell walls of the fruit pulp (Asgharzade et al. 2012). Calcium levels in fruits contribute to both the integrity and durability of the fruit tissue, including its firmness (Saei et al., 2011). In addition to the variety/genetic characteristics, the level of calcium in the fruit is also one of the most important factors that determine the firmness of the fruit.

The determinations regarding the firmness of the fruits highlighted the variety with the lowest value, namely 'Golden' from Arad, with 4.24 lbr, as well as the variety with the highest value of 'Idared' from Italia firmness, with 8.09 lbr (Figure 3). In the study of Blazek and

Hlusickova from 2007, both 'Golden' and 'Idared' cultivars complied their firmness values respectively in average of 8.1 and 8.2 kg/cm^3.

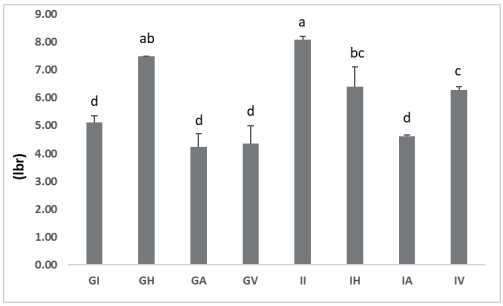

Figure 3. Experimental results on fruit firmness in studied apples; (LSD test, $p < 0.05$); GI–'Golden'/Italia; GH–'Golden'/Hungary; GA–'Golden'/Arad; GV–'Golden'/Vârciorova; II–'Idared'/Italy; IH–'Idared'/Hungary; IA–'Idared'/Arad; IV–'Idared'/Vârciorova

Foreign varieties, with a greater firmness, can be kept for a longer period of time, compared to domestic varieties. The LSD test indicate a superior significance of 'Idared' Italy variety firmness compared to all other varietes except 'Golden' Hungary variety. 'Idared' Hungary has good firmness with significant values compared to GI, GA, GV and IA. For 'Golden' variety, the highest firmness is achieved in the plants orginated from Hungary, with signifficant differences to the other 3 ones. 'Idared' originated from Italy have a signifficant higher firmness than all the other 3 varities, but there is no signifficant difference between the cultivars from Hungary and Vârciorova. Compared to the standard values regarding the degree of maturity for apple varieties, it is observed that all local varieties, both 'Golden' and 'Idared', Arad and Vârciorova fall into the Excellent category, according to the Brix index. Almost all varieties from Italy and Hungary fell into the Good category, with a percentage of over 12% (Table 3) except 'Golden' weak variety from Italy with 11.63%.

Regarding the content of soluble carbohydrates, the 'Golden' Vârciorova variety had the best percentage of glucose for about 14.20%, compared to 'Golden' Hungary with 12.35% (Figure 4). Another comprehensive study found low soluble solids to 'Idared' 11.9% BRIX (Blazek and Hlusickova, 2007) and also aur resuls are according to remarcable contents of solible solids found to 'Golden' cultivar respectively 13.8 % BRIX indicating a high fruit quality (Blazek and Hlusickova, 2007).

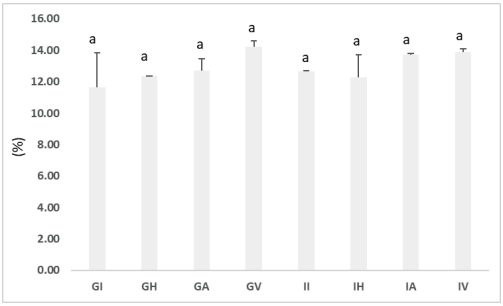

Figure 4. Experimental results on the content of soluble glucose in the studied apple varieties (% BRIX); (LSD test, $p < 0.05$); GI-'Golden'/Italia; GH-'Golden'/Hungary; GA-'Golden'/Arad; GV-'Golden'/Vârciorova; II-'Idared'/Italy; IH-'Idared'/Hungary; IA-'Idared'/Arad; IV-'Idared'/Vârciorova

These parameters were tasted with ANOVA to explore their significance level (Table 4).

Table 4. Parameters significance level analized with ANOVA

Parameter	Variety	*p* value
Weight	6.22	$p < 0.001$
Diameter	3.67	$p < 0.001$
Soluble glucose	0.84	ns.
Acidity	12.47	$p < 0.001$
Firmness	14.26	$p < 0.001$
Dry matter	3.04	$p < 0.05$
Residuals	NA	NA

Soluble glucose parameter did not differ significantly between varieties; a low level of significance was observed to dry matter parameter.

From the point of view of acidity, the 'Golden' Arad and 'Golden' Vârciorova varieties have the highest acidity with a value of 4.33 and 4.37, respectively, while at the opposite pole belongs the 'Idared' Italia variety, with a pH of 3.68 (Figure 5).

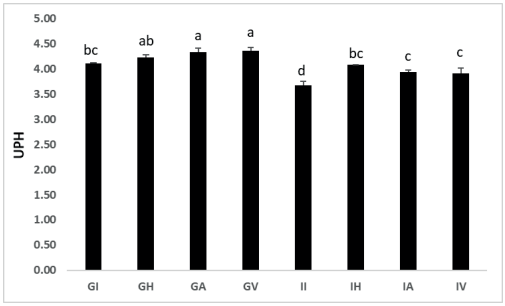

Figure 5. Experimental results on juice acidity (pH) in the studied apple varieties); (LSD test, $p < 0.05$); GI-'Golden'/Italia; GH-'Golden'/Hungary; GA-'Golden'/Arad; GV-'Golden'/Vârciorova; II-'Idared'/Italy; IH-'Idared'/Hungary; IA-'Idared'/Arad; IV-'Idared'/Vârciorova

The lowest value regarding the amount of dry matter was registered for the 'Golden' Italy variety with 13.69%, and the highest value, 'Idared' Vârciorova with 18.63% (Figure 6).

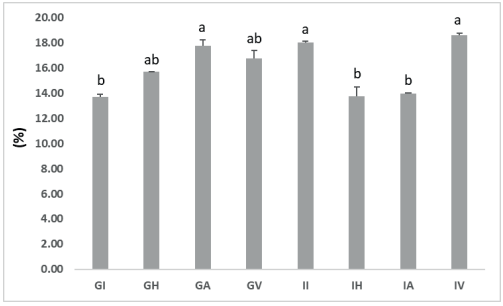

Figure 6. Experimental results on the percentage of dry matter in the studied apple varieties (%); (LSD test, $p < 0.05$); GI-'Golden'/Italia; GH-'Golden'/Hungary; GA-'Golden'/Arad; GV-'Golden'/Vârciorova; II-'Idared'/Italy; IH-'Idared'/Hungary; IA-'Idared'/Arad; IV-'Idared'/Vârciorova

Significant dry matter values were registered for GA, II and IV in comparison with GI, IH and IA. The cultivar 'Golden' usually suffer mutation and generally it has a decreased dry matter content, less acidity, also produces less russet fruits (Musacchi and Serra, 2017). We observed some contradictory results and the only explanation could be that in Arad, 'Golden' cultivar is best fitted to the environmental conditions and accumulates a significantly high dry matter. Our studies are also in the compliance with other results that present several improvements of the standard cultivars as 'Golden' and 'Idared' are (Blazek and Hlusickova, 2007; Faby, 1987; Stehr, 1996; Meyer, 2001)

CONCLUSIONS

Both cultivars fall into the Extra category, except for 'Golden' from Vârciorova which falls into category I in terms of diameter.
In terms of fruit weight, all varieties fall into the Extra category.
All varieties fall into the category of overripe fruits following the AI test.
According to the Brix index, both cultivars 'Golden' and 'Idared' degree of maturity from Arad and Vârciorova fall into the Excellent category. Cultivars from Italy and Hungary fell into the Good category, with over 12% BRIX.
Regarding the biometric and physiological indices, from the two cultivars, it can be seen that 'Idared' from Italia, 'Idared' from Hungary and 'Golden' from Hungary had high values in diameter, weight and firmness, while 'Golden' from Arad and 'Golden' and 'Idared' from Vârciorova had the highest content of soluble carbohydrates, pH and dry matter.

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