Europ.J.Hort.Sci., **68** (4). S. 169–175, 2003, ISSN 1611-4426. © Verlag Eugen Ulmer GmbH & Co. Stuttgart

Fruit Quality of Different 'Gala' Clones

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Summary

The parameters of external fruit quality (colour, firmness, weight, diameter and height of fruits, length and thickness of fruit stalk) and internal fruit quality (content of individual sugars and organic acids) of the 5 apple 'Gala' clones ('Red Gala 95', 'Royal Gala', 'Mondial Gala', 'Schniga Gala', 'Galaxy') and the parental cultivar 'Gala' were evaluated in two cropping years. The proportion of the fruit surface colouring of the clones during both years was 80 %, while the parental cultivar exhibited from 60 to 80 % coloration. In the first years of cropping the fruits of the 'Schniga Gala' already regressed to yellow in higher proportion which is probably due to the instability of stronger red coloration. The clones differed in their stem lengths, but the differences in dimensions and firmness of the clones were not significant.

The contents of fructose and sorbitol in the 'Gala' clones differed significantly during both years, while the contents of glucose and sucrose showed differences only in the first year. The contents of total soluble solids, malic and citric acids among the 'Gala' cultivar and its clones were also different in both years, but there were no differences in the contents of shikimic and fumaric acids.

The comparisons between the clones and the parental cultivar in their external and internal qualities proved that favourable pedoclimatic conditions and application of suitable technologies enable the clones and the parental cultivar to develop fruits of good quality, with attractive appearance and sweet flavour. Among the studied clones, an excellent internal and external quality of fruits was reached at 'Royal Gala' and 'Galaxy'.

Zusammenfassung

Fruchtqualität von 'Gala'-Klonen. Verschiedene Parameter der äusseren (Fruchtfarbe, -festigkeit, -gewicht und -höhe sowie Stiellänge und -dicke) und inneren Fruchtqualität (Gehalt an verschiedenen Zuckern und organischen Säuren) von Äpfeln der Ausgangssorte 'Gala' sowie fünf davon abstammender Klone ('Red Gala 95', 'Royal Gala', 'Mondial Gala', 'Schniga Gala', 'Galaxy') wurden über zwei Erntejahre erfasst. Der Anteil der Deckfarbe lag in beiden Jahren bei allen Klonfrüchten über 80 %, bei der Ausgangssorte zwischen 60 und 80 %. Die Fruchtfarbe des Klons 'Schniga Gala' tendierte schon im ersten Jahren zu Gelbtönen, was ein Zeichen für die Instabilität der roten Deckfarbe sein könnte. Signifikante Unterschied zwischen den Klonen konnten bei der Stiellänge nachgewiesen werden, die Unterschiede bei den Fruchtgrößeparametern und der Fruchtfestigkeit waren nicht signifikant.

Die Fructose- und Sorbitolgehalte der 'Gala'-Klone wiesen in beiden Jahren signifikante Unterschiede auf, während diese Unterschiede im Glucose- und Saccharosegehalte nur im ersten Jahr signifikant waren. Auch die Gehalte an löslichen Kohlenhydraten sowie an Äpfel- und Zitronensäure zeigten in beiden Jahren Unterschiede zwischen der Standardsorte und ihren Klonen, diese Unterschiede waren bei der Shikimi- und Fumarsäure nicht nachweisbar.

Die durchgeführten Vergleichsanalysen zwischen mehreren äußeren und inneren Fruchteigenschaften zeigten, dass unter günstigen Boden- und Klimaverhältnissen sowohl die Ausgangssorte als auch ihre Klone, Früchte mit attraktivem Aussehen und harmonischem Geschmack produzieren kann.

Von den untersuchten Klonen wiesen 'Royal Gala' und 'Galaxy' besonders gute äußere und innere Fruchteigenschaften auf.

Key words. Apple – clones – fruit quality – fruit colour

Introduction

The quality of fruits, being a subjective and complex parameter, is very difficult to define, since it depends on a combination of several factors. The nutritional and commercial value of consumed fruits certainly depends on the internal fruit quality (contents of sugars, organic acids, vitamins, minerals, pectins) and the pomological characteristics (shape, size, fruit colour) (HUDINA and ŠTAMPAR 2000). The consumers tend to demand high quality fruits, which, of course, are provided also by the optimal picking time (ZUDE-SASSE et al. 2000; ZUDE and HEROLD 2002) and the right choice of the cultivar and its clones in present ecological conditions. The pomological characteristics as well as the content of sugars and organic acids in fruits are very important for the popularity of an individual variety and its clones among the consumers (DOLENC–ŠTURM et al. 1999).

The apple cultivar 'Gala' has enraptured the world with its crisp, juicy flesh and pleasant refreshing fla-

vour. The standard cultivar proved to be highly prone to colour mutations and many clones of it has been discovered (WHITE 1991). Numerous clones of the standard cultivar can be found differing in proportions of coloration, quality of fruits, bearing time and height of yield. The coloured clones enable the growers to cultivate apples of good quality in less favourable areas. However, a bad feature of the mutants is their high resemblance, and regression in mutation traits, especially in the desired colouration, and this can lead to a lower yield (SANSAVINI et al. 1999). Preliminary comparisons suggested that the quality of fruits of 'Gala' and 'Royal Gala' were similar, while 'Regal Gala' fruits appeared to be softer and to have lower soluble solids at the same level of maturity (WALSH and VOLZ 1990). The fruits of the 'Gala' mutants tend to ripen earlier than those of standard cultivar, with the red colour appearing about 3 weeks earlier on the mutants (KRUCZYNSKA et al. 2001). In comparative trial of apple variety 'Gala' and four of its mutants, 'Imperial Gala', 'Royal Gala', 'Regal Gala' and 'Galaxy', no significant difference was noted between the mutants regarding firmness, sugar content and acidity of the fruits (RAPILLARD and DESSIMOZ 2000).

In this research the colour and size of fruits, the length and thickness of stalk as well as the contents of individual and total sugars and organic acids in fruits of various clones of 'Gala' grown in Slovenia are presented. Based on the results, the different clones can be evaluated according to their external and internal quality and producers can get guidelines for selecting the best planting material in their pedoclimatic conditions. In addition, it can be find out, whether the new and better-coloured clones of the 'Gala' cultivar show also other improvements in their properties.

Materials and Methods

Fruit samples

Fruit samples of the five apple 'Gala' clones ('Red Gala 95', 'Royal Gala', 'Mondial Gala', 'Schniga Gala', 'Galaxy') and standard 'Gala' grown in Slovenia were analysed in the seasons of 2000 and 2001. All trees were grafted on M9 rootstock, planted in the spring 1998 and trained in the spindle shape. Fruit samples of all clones were picked on the same day (20 August 2000 and 27 August 2001) in the stage of commercial maturity based on the measures of fruit firmness, starch iodine test, the content of total soluble solids and calculated Streif index.

Preparation of fruit samples for macroscopic analysis

For the standard cultivar and each 'Gala' clone, 20 fruits from each of 5 trees per trial were estimated. Fruits were weighted and with the use of a beak-shape measuring instrument the diameter and length of fruits were measured. The same fruits were also used for stripe red or blush area analyses. The shares of blush areas were visually categorised into four groups: first group with 0–40 %, second group with 40–60 %, third group with 60–80 % and fourth group with more than 80 % of blush area. Fruit firmness was measured after removing the skin by four punctures per fruit using fruit pressure tester (TR, Italy). Soluble solids were determined in the juice of each fruit with a refractometer (Kübler, Germany) at 20 °C. At the picking time the external qualities of fruits (colour, the area of waxy and russet coating) and general impression of internal qualities (juiciness, firmness and colour of flesh, flavour, taste) were evaluated.

HPLC analysis of apple sugar and organic acid contents

On previously measured apples chemical analyses were performed. HPLC (High Performance Liquid Chromatography) method was used for separation, identification and quantification of individual compounds in apple puree. The HPLC system consisted of Thermo Separation Products (TSP, USA) equipment with pump (model P2000), autosampler (model AS1000), column heater (Spark, Holland) and work station (OS/2 Warp, IBM Operating system, 1994).

Samples for HPLC analysis were prepared firstly by homogenisation with manual blender (Braun), then with Ultra-Turrax T-25 (Ika-Labortechnik, Germany). 10 g of mashed fruit were dissolved in bidistillated water up to 60 ml and centrifuged at 4200 rotation/min for 15 min. The extract was filtered through 0.45 μm Minisart filters (RC-25, Sartorious). For each HPLC analysis of sugars and organic acids 20 μl of sample was used.

Sugars (glucose, fructose, sucrose and sorbitol) were analysed isocratically on the Aminex-HPX 87C (300 x 7.8 mm) cartridge (Bio-Rad, USA) with an eluent flow rate of 0.6 ml min^{-1} and at 85 °C with bidistilled and on-line degassed water used as eluent. Solute elution was monitored using differential refractive index RI (model Shodex-71RI, Japan). Sugars present in each sample were identified by comparison of the retention time of each peak with those of standard sugars and the concentration was calculated using an external standard. The reproducibility of the chromatographic separation of the components was determined by making six injections of the standard solutions and apple sample. The results expressed as relative standard deviation (RSD%) are as follows: 0.27 for glucose, 0.28 for fructose, 0.29 for sucrose and 0.26 for sorbitol.

Organic acids (malic, citric, shikimic and fumaric) were analysed on the Aminex-HPX 87H (300 x 7.8 mm) cartridge (Bio-Rad, USA) with the flow of 0.6 ml min^{-1} and at 65 °C using the variable wavelength UV detector. For mobile phase 4 mM sulphuric acid was used. Organic acids were identified and quantified by using UV detector with wavelength set at 210 nm (Knauer, Germany) and by comparison of retention times and peak areas with standard solution of known organic acids. Results of reproducibility study of chromatographic separation for organic acids expressed as relative standard deviation (RSD%) are as follows: 0.30 for malic acid, 0.31 for citric acid 0.15 for shikimic acid and 0.13 for fumaric acid.

For analyses of sugars (glucose, fructose, sucrose and sorbitol) and organic acids (citric, shikimic and fumaric) we used chemicals that are products of Fluka (New York, USA), except for malic acid (Merck, Darmstadt, Germany).

Statistical analysis

Results were statistically analysed with the program Statgraphics plus 4.0 using the One-Way ANOVA. Differences between treatments were estimated with multiple range test using Tukey's test (HSD) at $P<0.05$.

Results and Discussion

External fruit quality

Fruit colouration. The colouration of fruits in all clones during 2000 and 2001 was more than 80 % irrespective of the fruit striped red or blush surface colour type (data not shown). The fruits of the 'Galaxy' and clones exhibited the strongest red colour. However 'Schniga Gala' also exhibited obvious chiameric structures and tended to regress towards yellow easily. The lesser amount of the fruit surface colour was observed in the fruits of the standard 'Gala' cultivar, i.e. 60–80 %. This is still an excellent coloration as the surface colour is soft or bright red and thus attractive to consumers. RAPILLARD and DESSIMOZ (2000) reported that about 90 % of the fruits of all mutants presented a red colouring on more than one-third of their surface. MANTINGER and STAINER (1990) pointed out that the standard 'Gala' cultivar is only 40–45 % coloured. Somehow more colouring (30 % more than in the standard one) was exhibited by the red mutants 'Royal Gala' and 'Imperial Gala'. The achievement of the good colouration of fruits depends on not only a proper technology which provides perfect light to the tree crowns but also on the differences in temperatures between day and night during the time of ripening (SAURE 1990). According to the weather data it can be concluded that the conditions for achieving good surface colouring of fruits were optimal during our studies.

Dimensions of fruits. Table 1 displays mean values of fruit's height, diameter, and weight of the parental 'Gala' cultivar and its clones. In 2000, the differences among the individual clones were not significant. In 2001, the fruits of 'Gala' clones significantly differed in all the parameters (Table 2). Their fruits differed significantly in the stem lengths, and in 2001 also in the diameter of fruits. The longest stems were measured in the 'Gala' cultivar; the widest ones were in the 'Schniga Gala' clones. KRUEZYNSKA et al. (2001) state that among the observed 'Gala' clones the fruits of the 'Royal Gala' clones were the lightest and the smallest. In our trial fruits of all clones had satisfying weight, though it has been suggested that size can be a problem when growing 'Gala' apples. An observable increase in fruit growth rate can occur even during maturation and harvest. WALSH et al. (1990) reported that, while little or no significant change in fruit firmness and soluble solids were noted during the period maturation, fruit size increased significantly.

Firmness of fruits. The clones of 'Gala' did not show significant differences in the firmness of fruits (Fig. 1) although all the fruits, which were analysed, were picked at the same time. Due to the earlier picking time, the fruits were firmer in 2000 than in 2001. In 2000, the firmness of the 'Mondial Gala' clone fruits was 89 N and the firmness of the 'Red Gala 95' clone fruits was 97 N, others were in between. In 2001, the firmness of fruits ranged from 61 N in 'Mondial Gala' and 'Schniga Gala' clones to 70 N in the parental 'Gala' cultivar. Un-

Table 1. The mean value of height and diameter of fruits (mm), weight of fruits (g), thickness and lenght of fruit stalk (mm) and yield/tree (kg) for standard cultivar 'Gala' and clones in the year 2000.

Clone	Fruit			Stalk		Yield
	height	diameter	weight	thickness	lenght	per tree
'Gala'	60.7	71.5	161.6	2.1	38.1 d	6.2
'Red Gala 95'	60.0	69.0	149.9	2.2	29.3 ab	3.9
'Royal Gala'	63.6	69.2	162.9	2.3	30.1 bc	5.9
'Mondial Gala'	65.5	69.0	160.4	2.2	26.5 a	7.4
'Schniga Gala'	62.2	70.5	157.3	2.1	34.5 cd	6.8
'Galaxy'	64.1	70.6	171.7	2.1	36.4 cd	7.1

[z] Means followed by the different letters are significantly different at P=0.05 level

Table 2. The mean value of height and diameter of fruits (mm), weight of fruits (g), thickness and lenght of fruit stalk (mm) and yield/tree (kg) for standard cultivar 'Gala' and clones in the year 2001.

Clone	Fruit			Stalk		Yield
	height	diameter	weight	thickness	lenght	per tree
'Gala'	64.5 c	72.2 c	194.5 b	2.4 ab	31.5 b	1.8
'Red Gala 95'	58.7 ab[z]	66.8 ab	139.9 a	2.2 a	30.0 ab	3.0
'Royal Gala'	57.9 ab	64.5 a	132.0 a	2.2 a	24.1 a	4.2
'Mondial Gala'	58.7 ab	67.4 ab	142.6 a	2.1 a	30.2 b	3.4
'Schniga Gala'	61.9 bc	69.4 bc	157.7 a	2.7 b	27.0 ab	2.0
'Galaxy'	55.0 a	65.7 ab	132.3 a	2.1 a	28.3 ab	2.0

[z] Means followed by the different letters are significantly different at P=0.05 level

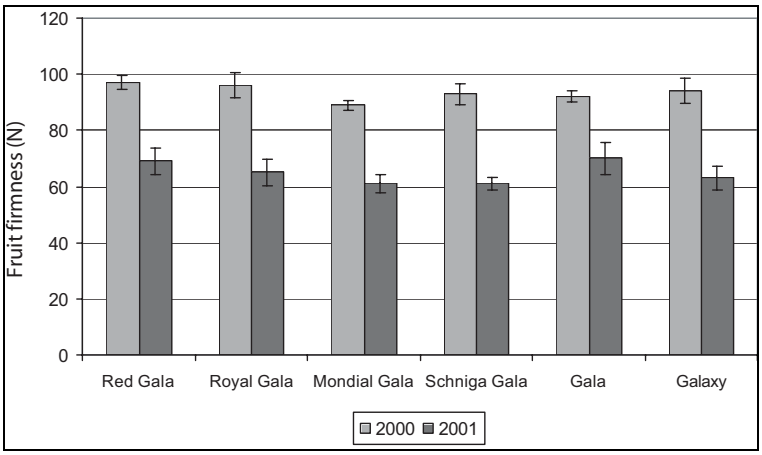


Fig. 1 The average firmness (N) and standard error estimations of fruits for different 'Gala' clones in the years 2000 and 2001 (no significant differences beetwen clones.)

der current conditions all the clones together with the parental cultivar matured simultaneously irrespective of the earlier coloration of the clone fruits. RAPILLARD and DESSIMOZ (2000) achieved similar results. Also WALSH and VOLZ (1990) suggested that harvesting on surface colour alone is not a good predictor of maturity. Growers should estimate the fruit maturity on qualitative components, rather than on blush colour.

Yield. In 2001, due to the frost during the time of full blooming, the yield was lower than in the previous year. The yield per tree was not statistically evaluated, as we were interested in the mean yield per individual clone (Table 1 and 2). SANSAVINI et al. (1999) reported that trees of clones that are chimeric mutations, induced adverse effects on yield, which were lower as for standard cultivars. However, this statement cannot be confirmed by our experiments, because the trees were not fully fruitful and the bearing volume was not yet completely developed. But the starting time of fruitfulness was the same in both the standard cultivar and its clones.

Internal fruit quality

Total soluble solids, total sugars and individual sugars. The contents of total soluble solids (TSS) in 2000 were lower in all the clones than in 2001 (Fig. 2). The clones exhibited significant differences in the contents of soluble solids over the period of the two years. The mean contents of TSS in 2000 ranged from 11.6 % in the 'Red Gala 95' to 14.3 % in the 'Royal Gala' and in 2001 from 14.1 % in the 'Galaxy' to 16.1 % in the 'Mondial Gala'. KRUCZYNSKA et al. (2001) reported the mean contents of TSS in 'Gala' clones ranged from 11.5 % to 15.1 %, the fact that corresponds to our results. Also KRUCZYNSKA et al. (2001) stated that the content of soluble solids at harvest was significantly lower for 'Royal Gala' and 'Mondial Gala' than for other mutants. But the results of our experiment showed that the fruits of the 'Royal Gala' in the first year of the experiment contained the highest amount of TSS (14.3 %).

The contents of individual sugars (glucose, fructose, sucrose, and sorbitol) in all the clones differed significantly during both years, but the contents of glucose and sucrose did not differ in 2001 (Tables 3 and 4). No significant differences were noted in the contents of individual sugars for the clones 'Royal Gala' and 'Galaxy', the same result was found by RAPILLARD and DESSIMOZ (2000). The clone 'Galaxy' originates from the clone 'Royal Gala', therefore it does not differ in genetic profile, which was ascertained by PANCALDI et al. (1999), who performed molecular analyses of DNAs of the original clone and of the bulk of the various clones. The highest content of glucose (14.9 g kg^{-1}) and the highest content of fructose (66.2 g kg^{-1}) in 2000 had the clone 'Schniga Gala'. The highest content of sucrose (51.1 g kg^{-1}) and sorbitol (6.3 g kg^{-1}) as well as high contents of glucose and fructose exhibited the clone 'Royal Gala'. The content of total sugars (sum of individual sugars) in the same clone was the highest

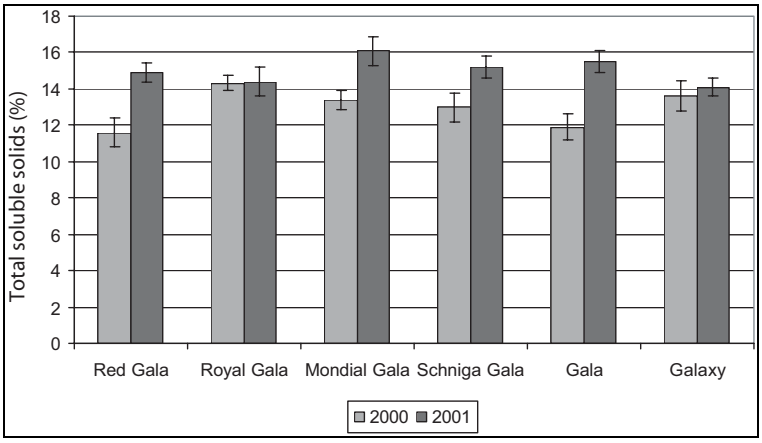


Fig. 2 The average content of total soluble solids (TSS) in % and standard error estimations for different 'Gala' clones in the years 2000 and 2001.

Table 3. The average content of sucrose, glucose, fructose, sorbitol and total sugars (in g kg^{-1}) of fresh fruits for different 'Gala' clones in the year 2000.

Clone	Sucrose	Glucose	Fructose	Sorbitol	Total sugars
'Gala'	39.1 a	10.5 a	62.7 ab	2.3 a	114.6
'Red Gala 95'	38.3 a^z	11.3 ab	61.2 ab	2.4 a	113.2
'Royal Gala'	51.1 c	14.7 b	61.8 ab	6.3 c	133.2
'Mondial Gala'	47.3 bc	13.7 ab	64.9 ab	3.8 ab	129.7
'Schniga Gala'	44.0 b	14.9 b	66.2 b	3.7 ab	128.8
'Galaxy'	48.2 bc	14.5 b	60.4 a	4.7 b	127.8

^{z} Means followed by the different letters are significantly different at P=0.05 level

Table 4. The average content of sucrose, glucose, fructose, sorbitol and total sugars (in g kg^{-1}) of fresh fruits for different 'Gala' clones in the year 2001.

Clone	Sucrose	Glucose	Fructose	Sorbitol	Total sugars
'Gala'	57.7	22.7	92.8 b	4.8 a	178.0
'Red Gala 95'	55.7	23.2	91.5 ab^z	5.4 ab	175.8
'Royal Gala'	47.7	23.7	82.4 a	4.2 a	158.0
'Mondial Gala'	51.8	26.5	84.3 ab	7.9 b	170.5
'Schniga Gala'	54.2	21.8	83.4 ab	4.8 a	164.2
'Galaxy'	48.4	24.8	84.4 ab	4.9 a	162.5

^{z} Means followed by the different letters are significantly different at P=0.05 level

during the first year (133.9 g kg^{-1}) and the lowest during the second year (158.0 g kg^{-1}). The lowest contents of glucose (10.5 g kg^{-1}), sorbitol (2.3 g kg^{-1}) and consequently the lowest content of total sugars (114.6 g kg^{-1}) had the fruits of the 'Gala' standard in the first year, but the highest contents were measured in the second year. Thus, we can conclude that juvenile trees with high fruitfulness and high contents of total soluble solids in one year, tend to exhibit deficiencies in assimilates supply in the following year, which effects the internal fruit quality. To ascertain the assumption the trees and fruits would have to be observed and evaluated at least for five more years in succession.

Organic acids. During both years, there were statistically significant differences in the contents of malic acid, whose amounts ranged from 4.7 g kg^{-1} in 'Red Gala 95' to 6.0 g kg^{-1} in 'Galaxy' in 2000, and in 2001 from 4.2 g kg^{-1} in 'Galaxy' to 5.1 g kg^{-1} in 'Red Gala 95' (Fig. 3). The clones 'Royal Gala' and 'Galaxy' do not differ significantly according to the malic acid contents, found by RAPILLARD and DESSIMOZ (2000) as well.

The content of citric acid was higher in 2001 than in 2000 (Fig. 4). As mentioned above, the content of malic acid was lower in the second year. The reason could be in the later time of picking. This is confirmed also by the fact that the firmness of fruits was lower in the first year (Fig. 1) as well as by the measured starch tests (data not shown). The differences in the contents of citric acid were not significant, but the range was quite wide. Attention should be drown to the clone 'Galaxy' which exhibited higher amounts of sugars, malic acid

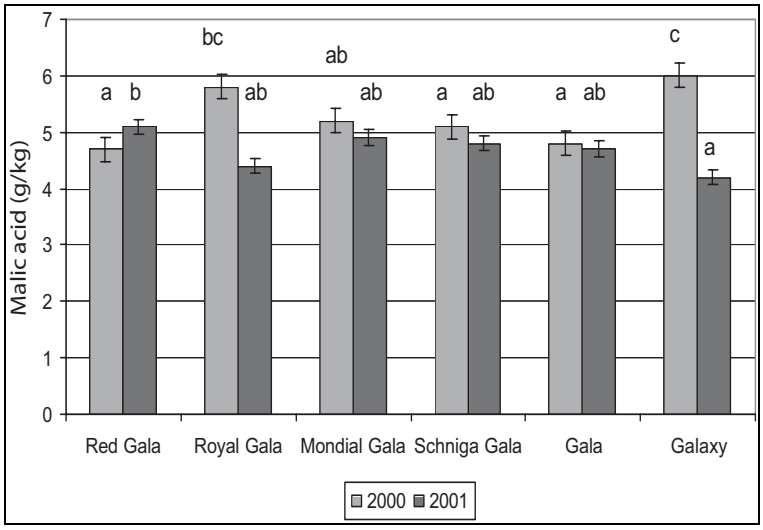


Fig. 3 The average content of malic acid (in g kg^{-1}) and standard error estimatons of fresh fruits for different 'Gala' clones in the years 2000 and 2001.

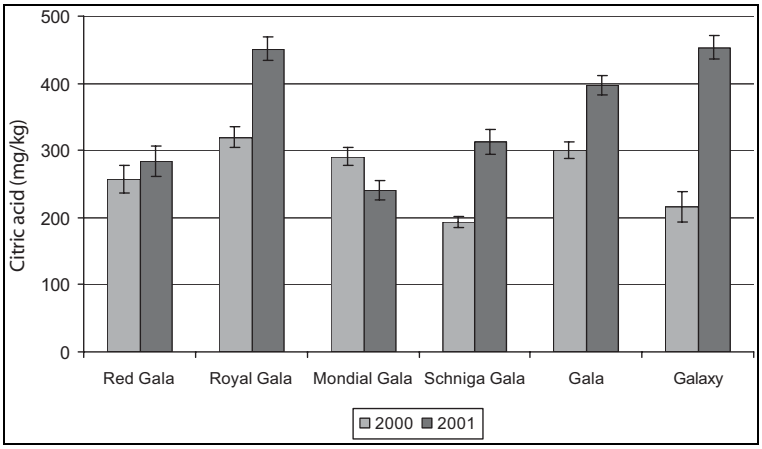


Fig. 4 The average content of citric acid (in mg kg^{-1}) of fresh fruits and standard error estimations for different 'Gala' clones in the years 2000 and 2001 (no significant differences beetwen clones).

(6.0 g kg^{-1}) in first year or citric acid (453.3 mg kg^{-1}) in the second year. At harvest time clone 'Galaxy' was the best evaluated on testing panels, because of its harmonic and sour-sweet taste. Appropriate maturity at picking time and good storage conditions give the guaranty for fresh taste of 'Gala' fruits, because of higher acid content. During respiration of fruits, in the process of oxidative decarboxylation malic acid is metabolised, while during gluconeogenesis, synthesis of sugars from malic acid takes place (BLANCO et al. 1992).

The content of shikimic and fumaric acids was not significantly different between the 'Gala' clones (Table 5). In 2000, the contents of shikimic acid were from 13.6 mg kg^{-1} in 'Royal Gala' to 16.4 mg kg^{-1} in 'Red Gala 95', and in 2001 from 15.3 mg kg^{-1} in 'Mondial Gala' to 18.6 mg kg^{-1} in 'Royal Gala'. The contents of fumaric acid ranged from 0.6 mg kg^{-1} to 2.0 mg kg^{-1} in 2000, and in 2001 from 0.3 mg kg^{-1} to 0.8 mg kg^{-1} fresh weight of fruit. The shikimic and fumaric acids do not influence the internal quality of fruits significantly, as they appear in very small amounts in the 'Gala' cultivar and its clones.

Conclusions

Relatively consistent weather during harvest contributed to good fruit colouring throughout the harvest period. It should be emphasized that in our experiment the parental cultivar exhibited a good colouration as well. The light conditions were perfect and the temperature ranges between day and night during the time of maturation were favourable. The lively red fruit colour, appropriate size and firmness of the 'Gala' fruit make the apple attractive for consumers, who want to be satisfied with internal quality of the fruit as well. Harmonized flavour of the fruits distinguish the standard cultivar 'Gala' and its numerous clones, among which special attention deserve the clones 'Galaxy' and 'Royal Gala' with their perfect internal qualities. Some consumers refuse the 'Gala' fruits because of their sweetness. Therefore, it would be wise, to plant the clones, which exhibit higher contents of citric and malic acids. The clone 'Schniga Gala' has the fruits of intense red colour. But already during the first years of fruitfulness the chimeric structures appear due to the clone's proneness towards regression to yellow colour. The mutant is instable, therefore, it cannot be recommended for wider use. The standard cultivar should be cultivated in the areas where the light intensity is high. In addition, good technology measures are necessary to achieve proper relationship between growth and fruitfulness, to avoid the shadowing of the fruits in the crown, and to develop fruits of good size and diameter.

Acknowledgment

The authors wish to thank Mr. Boštjan Godec for plant material and Mrs. Anita Bele for technical assistance, as well as Dr. Gregor Osterc for reviewing the manuscript.

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Table 5. The average content of shikimic and fumaric acids (in mg kg^{-1}) of fresh fruits for different 'Gala' clones in the years 2000 and 2001.

Clone	Shikimic acid		Fumaric acid	
	2000	2001	2000	2001
'Gala'	15.5	15.7	0.6	0.3
'Red Gala 95'	16.4	15.7	0.9	0.5
'Royal Gala'	13.6	18.6	1.2	0.7
'Mondial Gala'	16.1	15.3	2.0	0.8
'Schniga Gala'	16.1	15.5	0.8	0.6
'Galaxy'	15.0	15.5	0.8	0.8

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Received February 21, 2003 / Accepted May 23, 2003

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