AVALIAÇÃO DE NOVAS LINHAGENS DE MORANGO PARA TRAÇOS CARACTERÍSTICOS DA QUALIDADE DOS FRUTOS

EVALUATION OF NEW STRAWBERRY LINES FOR FRUIT QUALITY TRAITS

СЕЛЕКЦИОННАЯ ОЦЕНКА ОТБОРНЫХ ФОРМ ЗЕМЛЯНИКИ САДОВОЙ ПО КОМПЛЕКСУ ПРИЗНАКОВ ПИЩЕВОЙ ЦЕННОСТИ

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RESUMO

Nos últimos anos, a atenção para a obtenção das variedades de fruteiras com alta qualidade nutricional e de sabor dos frutos tem sido aumentado cada vez mais. O objetivo deste estudo foi avaliar um número de formas híbridas de *Fragaria ananassa Duch*., obtidas utilizando a variedade *Callionymidae* – o doador de um teor aumentado de substâncias com atividade antioxidante e sabor de sobremesa. Os estudos mostraram que nas condições da região de Moscou, os genótipos obtidos de acordo com sua produtividade estão ao nível da variedade padrão de alta produtividade *Zenga Zengana*. As melhores linhas continham até 103,3 mg/100 g de vitamina C, até 228,9 mg/100 g de polifenóis totais e até 96,5 mg/100 g de antocianinas totais, que foi um terço acima dos valores de controle. O estudo da palatabilidade na degustação dos frutos dos híbridos de morango do jardim revelou três linhas com uma classificação de 4,9-5 pontos. Para mais trabalhos de reprodução nas condições da Rússia central, três linhas são recomendadas - ELS 2-04, ELS 8-04 e ELS 20-04.

Palavras-chave: *Fragaria ananassa, qualidade nutricional, qualidade sensorial, vitamina C, antocianinas totais, fenólicos totais*

ABSTRACT

In recent years, inbreeding has been increasing the attention to obtaining new varieties of fruit crops with high nutritional and tasting quality of fruits. The purpose of this study was to evaluate a number of selected forms of *Fragaria ananassa Duch*., obtained using the cultivar “Lirovidnaya” – a donor with an increased content of compounds with antioxidant activity and dessert taste. Studies have shown that in the conditions of the Moscow region, the productivity of obtained genotypes was at the level of the standard high-yielding cultivar

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"Senga Sengana". The best lines contained up to 103.3 mg/100 g of vitamin C, up to 228.9 mg/100 g of total polyphenols and up to 96.5 mg / 100 g of total anthocyanins, which was one third higher compared to control. The tasting evaluation of the fruits of strawberry revealed three lines with an assessment of 4.9-5 scores. Three lines, ELS 2-04, ELS 8-04, and ELS 20-04, were recommended for further breeding under Central Russia conditions.

Keywords: *Fragaria ananassa, nutritional quality, sensory quality, vitamin C, total anthocyanins.*

АННОТАЦИЯ

В последние годы в селекции усиливается внимание к получению новых сортов плодовых культур с повышенным питательным и дегустационным качеством плодов. Целью данного исследования была оценка ряда гибридных форм *Fragaria ananassa Duch.*, полученных с использованием сорта Лировидная – донора повышенного содержания веществ с антиоксидантной активностью и десертного вкуса. Исследования показали, что в условиях Московской области полученные генотипы по продуктивности находятся на уровне стандартного высокоурожайного сорта Зенга Зенгана. Лучшие линии содержали до 103,3 мг/100 г витамина С, до 228,9 мг/100 г общих полифенолов и до 96,5 мг/100 г общих антоцианов, что на треть превышало показатели контроля. Исследование вкусовых качеств при дегустационной оценке плодов гибридов земляники садовой выявило три линии с оценкой 4.9-5 баллов. Для дальнейшей селекционной работы в условиях центральной России рекомендуются три линии - ЭЛС 2-04, ЭЛС 8-04 и ЭЛС 20-04.

Ключевые слова: *Fragaria ananassa, питательное качество, сенсорное качество, витамин С, общий антоцианин.*

INTRODUCTION

The strawberry *Fragaria ananassa Duch.*, due to its taste, aroma and visual appeal, it is the most common berry culture in the world. It is cultivated in Europe, Asia, America, Africa, Australia, and the annual production are about 9 million tones (FAOSTAT, 2018; AOAC International, 1995), which is significantly higher than other berry crops. This culture combines high yield, fast fruiting and high adaptability to environmental conditions. In addition to taste and aroma, strawberries have a high content of bioactive compounds with high antioxidant activity (Meyers *et al.*, 2003; Tulipani *et al.*, 2008). These compounds have preventive and therapeutical properties against heart, oncology, inflammatory and other diseases (He and Giusti, 2010; Putta *et al.*, 2017). Among fruit crops, strawberries have a greater overall antioxidant capacity (TAC) (2-11 times) than apple, pear, peach, oranges, grapes, kiwi, or tomatoes (Scalzo *et al.*, 2005). This antioxidant capacity is associated with a high content of vitamin C, polyphenols, anthocyanins, and other flavonoid compounds (Capocasa *et al.*, 2008). Thus, an increase in the consumption of berries with beneficial properties will help to improve human health.

For a long time, the main directions in the fruit breeding were increasing yield and resistance to diseases, as well as improving the shelf-life. However, in recent years, for most breeding programs of fruit crops, the importance of improving the quality of fruits in new varieties is increasing and they are now being considered along with yield and resistance to pathogens (Mezzetti *et al.*, 2018). This also applies to strawberries and to improve the organoleptic and nutritional quality of fruits; not only traditional breeding but also marker-assisted selection (Zorrilla-Fontanesi *et al.*, 2011) and genetic engineering (Kadomura-Ishikawa *et al.*, 2015; Domínguez *et al.,* 2015) methods were used. The combination of a high content of nutritional components with high sensory characteristics will help to increase the consumption of berries and thus, improve health. The most important selection criterion for consumers is the taste of berries. A correlation has been shown between the sensory quality of berries of strawberries and the sugar / acid ratio (Wozniak *et al.*, 1997). Although the quality of the berries is influenced by external (latitude, soil, illumination) and agronomic (cultivation method, fertilizer, water regime) factors, the main effect is having a genotype (Di Vittori *et al.,* 2018). Various studies have shown the effect of genotype on sensory and nutritional quality of strawberries (Olsson *et*

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al., 2004; Olbricht et al., 2008; Schwieterman *et al.*, 2014), but the number of varieties studied is rather limited.

In Russia, strawberry is very popular and intensive breeding is being conducted with this culture. Studies have shown that the cultivar “Lirovidnaya” inbreeding can serve as a donor of such traits as winter hardiness, large fruits, dessert taste of berries and high content of biochemical components (Bryukhina, 2003). W Using this cultivar as a parent, a number of hybrids were obtained, some of which showed high nutritional value in the conditions of South-West Russia (Ivanova, 2016). The aim of the work was to study the behavior of these hybrids under soil and climatic conditions of Central Russia and to evaluate their organoleptic and nutritional traits.

MATERIALS AND METHODS

The objects of the study were 10 promising lines of the garden strawberry (*Fragaria x ananassa*), obtained by crossing the cultivar “Lirovidnaya” and the cultivar “Istochnik” (Ivanova, 2016). The German cultivar “Senga Sengana” was used as a standard. Plants were planted in 2017 infield in the Moscow region. All genotypes were located randomly, with 4 replications of 10 plants. Analysis of the yield, biochemical composition of berries and tasting evaluation was carried out in 2018.

Berries for determining the total yield (g/bush) were collected every 2-3 days. Soluble solids (total soluble solids (TSS), expressed in ° Brix, were determined using a refractometer calibrated against sucrose. Reducing sugars were determined by Luff-Schoorl method (AOAC…, 1995). Unreduced sugars were first transformed by acid hydrolysis into reduced monosaccharides, after that the procedure was continued by using Luff-Schoorl reagent. Titrable acidity determined by titration of 10 mL of juice against 0.1 N sodium hydroxide. The content of vitamin C was determined using Tillman's reagent (Santos *et al.*, 2016). The phenol content was measured by the Folin-Ciocalteau reagent (Slinkard and Singleton, 1977) using gallic acid as standard. The total phenolic content was expressed as gallic acid equivalents (the concentration of gallic acid was established from a calibration curve) in mg per 100 g fresh weight. Total anthocyanins were determined by Lee *et al.* (2005). Data presented as mg pelargonidin-3-glucoside per 100 g FW. UV-1800 spectrophotometer (Shimadzu, Japan) was used for all estimations of absorbance. Sensory analysis was carried out by non-trained researchers and employees. Assessors evaluated fresh fruits for various sensory parameters like color, flavor, and aroma. The samples were sorted from the less preferred (score 1) to the most preferred (score 5).

All statistical analyses were performed using STATISTICA software (Statsoft Inc., USA). All the data were analyzed using a one-way ANOVA test for mean comparisons, with standard errors and significant differences were calculated according to Duncan’s multiple range test. Differences at $p < 0.05$ were considered statistically significant.

RESULTS:

For the experiment, 10 strawberry hybrids were selected that are perspective in terms of yield, the content of bioactive components and taste. The data obtained showed that the highest yield was observed in ELS 13-04 and ELS 2-04 hybrids (603 and 568 g/plant, respectively), which hardly differed from the parameters of the control cultivar “Senga Sengana” (Figure 1). The remaining hybrids had a yield of 514 g/plant and lower, but significant differences from the control were confirmed only for the ELS lines 5-04 and ELS 7-04 (431 and 423 g/plant, respectively).

The results of biochemical analyzes of strawberries are presented in Table 1. The content of soluble solids in the berries of strawberry lines varied from 9.1 to 12.8%. Most of the lines contained more soluble solids than control (by 5.9-13.9%), but the differences were insignificant. Only one line, ELS 10-04, contained significantly less soluble solids than cultivar “Senga Sengana”. Means followed by the same letter within column were not significantly different by Duncan’s LSD test at a = 0.05 (n = 4).

The content of sugars in general correlated with the content of soluble solids, but there were significant differences. In five lines of strawberries – ELS 2-04, ELS 5-04, ELS 8-04, ELS 16-04 and ELS 20-04, the berries contained significantly more sugars than the control variety (by 16.2-22.2%). Only two lines contained significantly lower sugars than the cultivar “Senga Sengana” – ELS 10-04 and ELS 14-04 (18.1 and 15.3%, respectively). The other lines did not differ from the control.

The acidity of the analyzed genotypes varied from 0.75 to 1.14%. The acid content in the berries of most of the new lines was higher than that in control, but not significant. The line ELS 10-04 demonstrated the lowest acidity. The maximum ratio of sugar/acidity was observed in the lines ELS 8-04 and ELS 20-04. In these lines, this parameter significantly exceeded both the ratio of the control variety and in the other six lines.

The data obtained indicate that the strawberry lines contained vitamin C more than of cultivar “Senga Sengana”. In 8 lines out of 10, the content of vitamin C was 4.3-31.0% higher than in the control, moreover, in the lines ELS 8-04, ELS 14-04 and ELS 20-04, this excess was statistically significant. In the line ELS 8-04, the content of vitamin C exceeded 100 mg/100 g. Only in the lines ELS 6-04 and ELS 13-04, the vitamin C was slightly lower than in the control.

Similar results were obtained on the content of total phenolic compounds in the berries. Most of them were contained in the line ELS 8-04 – on 36.4% higher than in the control. All other lines were also more enriched with phenolic compounds compared to cultivar “Senga Sengana”, except for the line ELS 10-04 (lower by 2.5%).

The maximum content of anthocyanins – pigments with antioxidant activity, was found in the line ELS 5-04. In it and in the lines ELS 2-04, ELS 8-04 and ELS 18-04, this parameter exceeded 90 mg / 100 g, which significantly exceeded the content of anthocyanins in the control variety (by 22.5-29.8%). In another six lines, the content of anthocyanins was also higher than that of the cultivar “Senga Sengana” (80-90 mg/100 g) but statistically is insignificant.

Along with the study of the content of the complex of biologically active compounds in the fruits of hybrids of strawberries its tasting assessment was carried out in scores (Figure 2). The maximum marks were obtained for the berries of the lines ELS 2-04, ELS 7-04 and ELS 10-04 (4.9-5.0). This is significantly higher than that of the control cultivar “Senga Sengana” (4.5). The berries of the other lines, with the exception of ELS 13-04 and ELS 18-04, which received 4.3 scores each, were also rated higher than the control.

On the basis of the conducted research on the complex of the signs (prolificness, nutritional value, taste qualities), the lines ELS 2-04, ELS 8-04 and ELS 20-04 are of greatest interest, surpassing the control cultivar “Senga Sengana” in most parameters, first of all, in content biologically active compounds and taste. The ELS 6-04, ELS 10-04 and ELS 14-04 lines on the content of vitamin C, phenols and anthocyanins are at the level of control, but inferior to it in terms of yield. The other lines correspond to the control or exceed it by single parameters.

DISCUSSION:

Increasing the level of biologically active compounds, in particular, antioxidants, in fruits by the methods of classical breeding and/or biotechnology is an important way to increase their consumption. Strawberry breeding programs have long focused on agronomic properties and relatively recently switched to the sensorial and nutritional quality of berries (Lerceteau-Kohler *et al.,* 2012). Studies of offspring from various crosses have shown that the quality of the berries is an inherited trait and can be improved by selection using certain genotypes (Capocasa *et al*., 2008; Diamanti *et al*., 2012). For example, in Europe, where there are currently 23 classic strawberry breeding programs and 8-biotech programs, much attention is paid to this issue (Mezzetti *et al*., 2018).

To improve the quality of the strawberry berries, we have evaluated 10 hybrid lines and a standard cultivar as a control for productivity, biochemical composition (soluble solids, sugar, acidity, vitamin C, phenols, anthocyanins) and sensorial parameters (taste, aroma). The reason for choosing the lines was the fact that they were obtained using the cultivar “Lirovidnaya”, a genotype that had already demonstrated a high quality of berries compared to other varieties (Bryuhina, 2003). Later, a high content of vitamin C and phenolic compounds in the berries of this variety was confirmed when grown in another region of Russia (Makarkina, 2015). This approach is also used in other countries, for example, in Italy, the variety Maletto has been identified as a good source of nutrients and bioactive components, especially phenols (Panico *et al*., 2009). We assumed that the content of bioactive compounds in the offspring would be at least not lower than that in the original form. For example, up to 30% of hybrids exceeded the parental forms of strawberries in productivity (Galvao *et al*., 2017). In our work, we used lines obtained by crossing local varieties. It is known that imported varieties do not fully correspond to local soil and climatic conditions, which reduces productivity and are susceptible to biotic and abiotic stresses (Galvao-2017). As a control, As a control, cultivar "Senga Sengana" was used – one of the most widely used in Russia and often used as a standard when evaluating new varieties.

Studies have shown that the productivity of the best lines is at the level of the control variety. This can be considered a good parameter since the cultivar "Senga Sengana" belongs to the late fruiting varieties and is distinguished by high yield. The content of soluble solids in 5 lines exceeded 12%, which is considered a good parameter and in the two lines was significantly higher than the control. At the mature berries of strawberries, the taste correlates to the ratio between the sugars and acids (De Resende *et al.*, 2008; Bryukhina, 2003). The berries of the five lines contained 8.5% sugar and more and significantly exceeded in this parameter the cultivar "Senga Sengana". The acidity of almost all lines was not statistically different from the control (Ivanova, 2016; Makarkin, 2015). As a result, the sugar-acid balance in most lines was higher than in the control variety.

Biochemical analyzes showed that the content of bioactive compounds in new lines is significantly higher than that in the standard variety. Several lines were significantly exceeding the cultivar "Senga Sengana" berries by the content of vitamin C (up to 31.0%), total phenols (up to 36.8%) and anthocyanins (up to 29.8%). The content of vitamin C in hybrid lines was higher than that of the new Italian varieties Romina and Cristina (Capocasa *et al.*, 2016) or the standard Spanish varieties (Dominguez *et al.*, 2015). According to the content of total phenols, the tested lines correspond to industrial Italian varieties (Tulipani, 2008). Sensory strawberry quality is the result of a complex balance between sweetness, aroma, texture, and appearance (Jouquand *et al.*, 2008; Marangon *et al.*, 2016). The sensory assessment revealed a very good taste of berries in three lines. This confirmed the previously expressed possibility of using the cultivar "Lirovidnaya" as a donor of the dessert taste of the berries of strawberries (Bryukhina, 2003).

CONCLUSIONS:

As a result of the research conducted in the Moscow region, three hybrid lines were identified – ELS 2-04, ELS 8-04 and ELS 20-04, which have a high content of bioactive components and high taste qualities and are promising for further breeding work. This list partially coincides with the list of lines selected according to the results of the research in the Belgorod region. Differences can be explained by too short research time in compared with previous work (one and three years, respectively).

It is also known that although the genotype strongly influences the aroma and taste, the harvest time is also an important factor influencing the composition of the berries. Thus, it is necessary to continue research to clarify the results and assess the degree of influence of environmental factors on the quality of berries. In the future, we intend to carry out molecular labeling of promising strawberry lines in order to detect allele variants of the genes that determine nutritional properties, which will speed up the breeding of new varieties using marker-assisted selection. Genetic markers can also be used to identify valuable varieties in order to prevent illegal commercial use.

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***Table 1**. The chemical composition of the fruits of strawberry hybrids*

Genotype	SS, %	Sugar, %	Acid., %	Sug: Acid.	vitamine C, mg/100 g	phenols, mg/100 g	anthots, mg/100 g
Zeng Zengan	11.3 abc	7.2 b	0.98 abc	7.4 bc	78.9 cd	167.8 cd	74.4 cd
ELS 2-04	12.6 a	8.8 a	1.03 a	8.7 ab	92.9 abc	215.8 ab	94.0 ab
ELS 5-04	12.1 ab	8.5 a	1.14 a	7.6 bc	87.3 bcd	209.4 abc	96.5 a
ELS 6-04	10.8 bc	7.6 ab	1.13 a	6.8 bc	73.5 d	174.2 bcd	79.1 bcd
ELS 7-04	12.0 ab	8.3 ab	0.94 abcd	8.9 ab	91.9 abc	186.2 abcd	82.2 abcd
ELS 8-04	12.5 ab	8.6 a	0.82 bcd	10.6 a	103.3 a	228.9 a	95.0 ab
ELS 10-04	9.1 d	5.9 c	0.75 d	7.9 bc	82.3 bcd	163.7 d	72.2 d
ELS 13-04	12.8 a	8.7 a	1.07 a	8.2 bc	74.4 d	177.8 bcd	82.1 abcd
ELS 14-04	10.0 cd	6.1 c	1.02 ab	6.1 c	96.4 ab	182.7 bcd	89.1 abc
ELS 18-04	12.3 ab	8.4 ab	1.08 a	8.1 bc	86.2 bcd	201.2 abcd	91.2 ab
ELS 20-04	11.9 ab	8.5 a	0.79 cd	10.8 a	94.6 ab	198.5 abcd	82.7 abcd

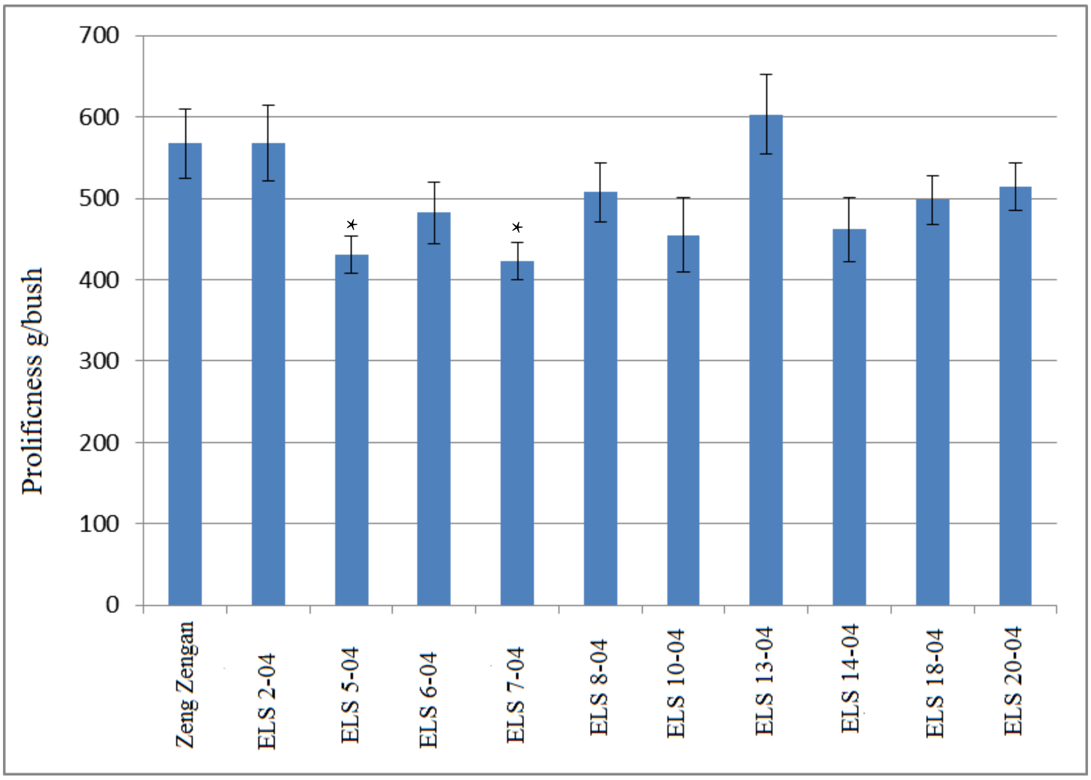

***Figure 1**. Yield of strawberry hybrids.*
Values are an average of four estimations and SE is indicated as vertical bars.
Asterisks indicate statistically significant differences between standard and tested genotypes (p<0.05).

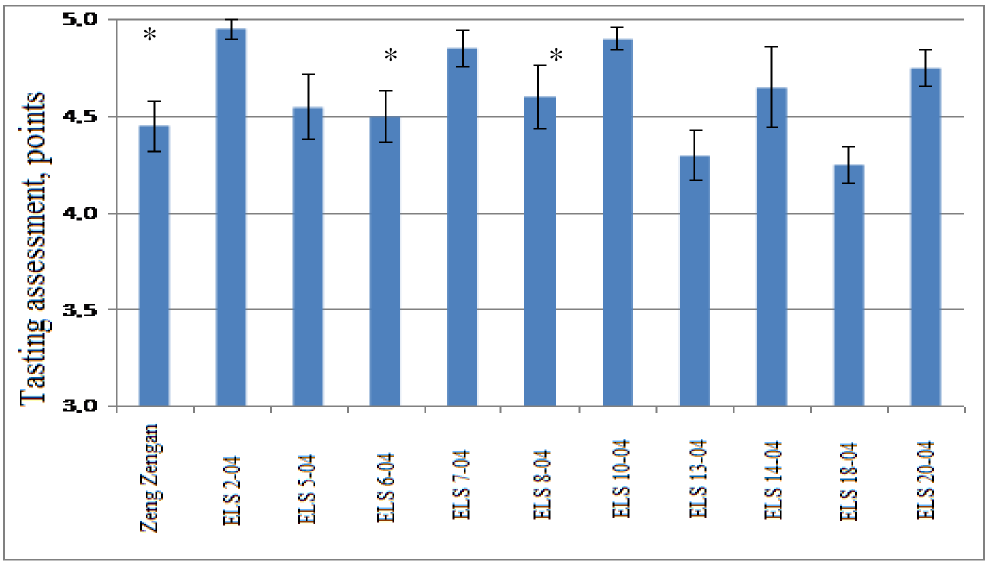

***Figure 2.** Tasting evaluation of strawberry fruits (score)*
Values are an average of four estimations and SE is indicated as vertical bars.
Asterisks indicate statistically significant differences between standard and tested genotypes (p<0.05).