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Ljubica Karakasova

Ss. Cyril and Methodius University, karakasoval@yahoo.com

Jovanka Ampova

Ss. Cyril and Methodius University

Frosina Babanovska-Milenkovska

Ss. Cyril and Methodius University

Namik Durmishi

University of Tetova

Viktorija Stamatovska

St. Kliment Ohridski University

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Comparison of quality characteristics of fresh and dried strawberries

Ljubica Karakasova¹, Jovanka Ampova¹, Frosina Babanovska-Milenkovska¹, Namik Durmishi², Viktorija Stamatovska³

¹ University of Ss. Cyril and Methodius, Faculty of Agricultural Sciences and Food, Department of Food Processing, R. Macedonia,

² Faculty of Food Technology and Nutrition, State University of Tetovo, in Gostivar, Republic of Macedonia

³ Faculty of Technology and Technical Sciences, University St. Kliment Ohridski - Bitola, in Veles, R. Macedonia
karakasoval@yahoo.com

Abstract. The strawberries have a significant place among the berries family. It can be used fresh or for production of different products, available for consumption during the whole year. The aim of this research is to compare the quality changes of fresh and dried strawberries. The strawberries of variety: *elsanta*, *humi grande* and *mesecharka*, from Skopje region were used for drying. Before drying, the following treatments were applied: V₀ – not treated, V₁ - with vitamin C, V₂ - with sugar solution. The drying was performed in Armenian solar dryer. During research the chemical components of fresh and dried strawberries: the total dry matter, the sugars, the total acids, the proteins, the vitamin C and the mineral matter were examined. On the solar dried strawberry was performed microbiological analysis according to appropriate regulations. Based on the results of this research, the Armenian Solar Dryer showed very good characteristics from the economical and ecological aspect, as well as good quality properties.

Keywords: strawberries, quality, solar dryer, treatments.

INTRODUCTION

Strawberry (*Fragaria vesca*) is economically important crop, a type of berry fruit. The richness of species and varieties, as well as the diversity in biochemical composition make this fruit very important in the human nutrition [1]. The great interest in this valued culture is not only due to the nutritional value and the excellent taste, but also to the fact that it appears on the market seasonally, during the period when other types of fruit are less present.

As the basic elements of the quality of fruit, that is used in the processing, from a technological point of view are: the pomological properties, the mechanical and the chemical composition. The pomological characteristics such as dimensions, size, shape, color and pericarp of fruits are used not only for assessment of quality, but also are of great importance for the outward appearance, attractiveness and the market value. The mechanical composition is regarding to the weight ratio of the separate parts of the fruit. There are two different parts of the fruit: the useful part and the waste. The basic rule for processing of the fruits is that the amount of waste needs to be as small as possible. The ratio between the useful part and the waste is known as yield. The yield varies depending on the conditions of cultivation, but not on a large scale, because each variety has specific properties and characteristics. Knowledge of the variety and the right choice have a decisive role to play in order to get a quality product [2].

According to the research that was done in R. Macedonia from 2002 – 2004 on the mechanical properties of different varieties of strawberries, based on the average weight of the fruit, the examined strawberry varieties were classified into five groups: very large (fruit weight > 14 g), large (weight from 9 to 14 g), medium (7 to 9 g), small (5 to 7 g) and very small (weight <5 g). In this research it was estimated the mechanical composition of the *elsanta* variety, with the average values for: weight of the fruit (11.1 g), the height (30.2 mm), width (31.6 mm) and thickness (28.8 mm) [4]. The fruit of the variety *humi grande* are very large and their weight ranges from 30 to 40 g [3]. For the variety *mesecharka*, in 100 g of fruit, with approximately the same size, there are 95 pieces of fruit. The variety *mesecharka* bears fruit every month until November.

The chemical composition of the fruit is important both, from the point of view of the diet and from the technological aspect. The chemical composition is regarding to the content of all the ingredients in the product including the water. The components of the chemical composition with their quantity, as well as their interrelations are responsible for formation of the organoleptic, nutritional and biological properties of the product [2]. The quality varieties are considered ones with the highest content of the dry matter, which indicates a higher level of nutrients. The term “dry matter” includes all the nutritional ingredients of the fruit, with the exception of the water [1].

The strawberry has good nutritional value, which depends primarily on the variety, degree of maturity, birthing and applied agro-technological measures [5]. Depending on the variety and growing conditions of the strawberries, the percentage of water is 92 %. Besides the water, that is present in high percentage, the strawberries contain sugars, minerals, vitamins, organic acids and antioxidants, which are necessary for the normal functioning of the human body [6]. The percentage of water in the strawberries is from 82 to 88 %, total dry matter from 9 to 12 %, total sugars from 4 to 13 %, reductive sugars from 4 to 10 %, sucrose from 0.2 to 2 %, total acids from 0.6 to 1.5 %, mineral matter from 0.3 to 1 %, pectic matter from 0.5 to 1.5 %, tannins in trace and vitamin C from 20 to 28 mg/100 g [3]. According to the other research, the strawberries contain: 3.8 % invert sugar, 1.7 % sucrose, 4.5 % to 7.8 % total sugars, total acidity 0.50 % and pH 3.5. [2]. Some authors indicated that in the chemical composition of the strawberries there are: 8.3 % carbohydrate, 0.8 % protein, fat 0.5 %, ash 0.5 % and water 89.9 % [7]. The strawberry is considered to be a rich source of minerals, which gives it a special value.

Drying is one of the oldest methods of preserving fruits and is an excellent method for preserving the flavor and the nutrients. Fruit preservation by drying allows the fruit to be used throughout the year, which is crucial and necessary for good human health, especially in those months of the year when the fruit supply is reduced or not present at all on our markets [8]. The fruit can be dried in different ways, depending on the possibilities, ie the equipment, as well as the chemical and physical properties of the fresh product [2]. Which technological procedure will be applied, which reactions can be expected during the processing, what product and how much quantities will be obtained depends on the chemical composition and the technological properties of the raw material. Through the development of technology and finding different techniques, the use of solar energy in the solar dryer has found an increasingly greater application and utilization. The technology of drying fruits in solar dryers is the cheapest way of drying, since it uses the free solar energy [1]. It has been established that the main factors affecting the efficiency of drying are the air, the temperature, the humidity and the fast movement of the air [9]. There are three types of solar dryers present in Macedonia: the Armenian type, the German type - Hohenheim and the Macedonian type, which are point to the great benefit and effect of the application of the solar energy and the solar dryers [10].

Dried fruit is a product obtained by drying the fresh and technologically mature fruit – whole or cut in pieces, following an appropriate procedure in order to become suitable for longer storage. The dried fruit should meet the following conditions: to have flavor and color inherent in the variety; by immersing in boiling water for 10 minutes, to show good ability for rehydration; after the rehydration to get the smell and taste of the fruit from which it is produced; not to have stains

that occurred as a result of physiological damage of the fruit, from burning, etc.; not to have a smell and a taste of overdried (burned) fruit, nor any other foreign smell and taste; not to be polluted by mechanical or biological impurities and not to contain insects in any stage of their evolution [11].

MATERIALS AND METHODS

For performing the examinations in this research, were used fruit berries of the strawberry varieties: *elsanta*, *hummi grande* and *mesecharka*. The fruit was grown in a hanging system in greenhouses. The fruits were harvested in technological maturity. After a visual assessment on the field, for estimating the moment of harvesting, the samples were taken for the analysis of the mechanical and chemical composition of the fruit.

The variety *elsanta* (*Elsanta*) is of Dutch origin, created by hybridization of the strawberry varieties *gorella* and *holiday*. The fruit is flattened, elongated to round, quite large, with a red and shiny surface. The mesocarp of the fruit is reddish orange, with excellent organoleptic properties, good hardness consistency, juicy and tasty. The fruit is suitable for fresh usage, but also for processing [12].

The variety *hummi grande* (*Hummi Grande*) originates from West Germany and is characterized by a large berries fruit. The fruit, on the sun-exposed side is bright red, while on the bottom side has pink to pale red color. The mesocarp is characterized by medium hardness and juiciness, with a sweet-sour taste and moderate aroma [13].

The variety *mesecharka* (*Fragola Quatro Stagioni*) originates from Italy, obtained by selection of remnant types of wild strawberry (*F. Vesca* var. *semperflorens*) from the Alps. The fruit of the varieties *mesecharka* is reddish, on the intersection the mesocarp of the fruit is with a cream-white color, with a sour taste and a strong aroma.

From each variety of strawberries were measured 20 berries fruits. Thereby were measured the weight of the useful part and the waste of the strawberry fruit. The weight of the fruit was determined by measuring on the "Mettler" analytical balance, with an accuracy of ± 0.01 g. The yield was calculated mathematically, expressed in percentage. The height, the width and the thickness of the fruit were measured by vernier caliper (subler) with an accuracy of ± 0.1 mm.

Using the laboratory standard methods, the following chemical parameters were determined in the strawberries: total dry matter, total sugars, sucrose, glucose, fructose, total acids as citric acid, vitamin C, proteins and mineral matters (total ash) [11].

-The total dry matter was determined by gravimetric method, in the oven dryer at 105 °C, up to constant mass;

-Determination of the sugars, sucrose, glucose and fructose by applying liquid chromatography, HPLC-method with RI-detector;

-The total acids were determined by a volumetric method, with a 0.1 M NaOH solution and an indicator of 1 % phenolphthalein solution, expressed as citric acid;

-The proteins were determined through the content of nitrogen, analyzed with the Kjeldahl method;

-The vitamin C was determined according to the Tillmans method;

-The mineral matter (total ash) was determined by a gravimetric method, by incineration and burning of samples in a Muffle oven, at a temperature of 525 ± 25 °C;

Technological procedure for production of dried strawberries

During the process of drying, by the evaporation of the free water, the weight and the volume of the fruits decreases, and the amount of dry matter increases, which increases the concentration of sugars, acids and other ingredients, and at the same time the development of microorganisms becomes disabled. For a good quality of the final product, it is necessary to use a quality raw material. The fruit should be healthy, harvested in a phase of uniform technological maturity,

without mechanical, physiological and phytopathological damages. The strawberries were harvested manually (one by one) and placed in clean, dry, wooden packaging. After receiving the raw material, the technological process of drying strawberries begins.

The technological procedure for drying strawberries was performed through the following operations: selecting, washing, removing the unsuitable part, re-controlling and pretreating, cutting the fruits in halves and placing the fruits for drying, drying, cooling, packaging and storage. Washing is a technological operation that is mandatory in every fruit processing. Although the strawberry fruit that was subject to this examination were grown on a substrate, in greenhouses and they did not have direct contact with the soil, before being set for drying, they were washed, under a tap with low jet of water, due to their sensitive consistency. The washed fruit is placed in a strainer, after which are removing the stalk. Then was performed the inspection and selection according to the required standards, and the fruits were exposed to a pretreatment, where it was placed in one of the three variants: V_0 variant - (control) without any treatment; V_1 variant - the treatment with a 2 % solution of ascorbic acid on each of the varieties of strawberries, *elsanta*, *hummi grande* and *mesecharka*, for a period of 5 min.; V_2 variant - the treatment with a sugar solution (2:1) on each of the varieties of strawberries, *elsanta*, *hummi grande* and *mesecharka*, for a period of 5 min. The treated fruits were cut into halves and then placed on wooden drying shelves, with plasticized grids, with an area of 1 m².

In our examination, for the drying was used the Armenian solar dryer, which is walled on the north side, and on the south side it is covered with glass set at an angle, through which the sun's rays penetrate (Figure 1). At the ground floor there are intake openings for fresh air, and in the upper part there are exhaust openings (ventilators) for the wet and hot air. On the bottom, there is a layer of gravel or stones from 2 cm to 3 cm, dark colored, naturally or artificial. They absorb the heat, which increases the air temperature, and the drying of the fruit is accelerated. In the evening the intake openings are closed, and the intake openings in the gravel zone are opened. The air that passes through the heated stones enters in the dryer enabling the drying process to continue at night, but with a lower intensity. The temperature in our conditions was reaching from 65 to 70 °C during the day, and from 30 to 40 °C during the night, which favorably reflected on the drying of strawberries, both during the day and in the night. Factors that significantly affect the evaporation of the water from the fruit are: the temperature, the humidity and the airflow [1].



Figure 1. The Armenian solar dryer

The prepared strawberry of the *mesecharka* variety were set for drying on May 10, 2012, and the drying process lasted for three days, at an average outdoor temperature of 17.9 °C during the period of the drying process, and the average humidity was 62.86 %. The solar drying of the varieties of *elsanta* and *hummi grande* lasted for five days, starting from 10. 05. 2012 to 15. 05. 2012, with an average outdoor air temperature of 15.6 °C and with an average humidity of 68.77 %. The average temperature during the month of May, when drying was performed for the strawberries: *elsanta*, *hummi grande* and *mesecharka*, was 16 °C, with the average air humidity

of 67.92 %. For uniform drying of whole or cut strawberries, they were flipped over for the duration of the drying process. The dried strawberries, in order to be successfully preserved for a longer period of time, need to be packaged in appropriate packaging and stored in suitable storage conditions, protected from moisture and direct sunlight.

RESULTS AND DISCUSSION

In the research there were included the strawberry varieties: *elsantana*, *hummi grande* and *mesecharka*. The size and the weight of the fruit are of great importance not only for the outer appearance, but also for the yield and the quality of the fruit [1].

Pomological properties of the strawberry fruit

From the obtained results, it can be concluded that with the highest average values in terms of the height (35.7 ± 1.06 mm), the width (29.05 ± 0.67 mm) and the thickness (29.47 ± 1.39 mm) was characterized the fruit of the variety *elsanta*. Then follows the fruit from the variety *hummi grande*, with the height of 31.26 ± 1.19 mm, the width (26.11 ± 0.79 mm) and the thickness (28.35 ± 0.82 mm), and the lowest values were estimated in the strawberries of *mesecharka* with the height of 18.03 ± 0.44 mm, the width 12.83 ± 0.33 mm and the thickness of 13.76 ± 0.27 mm. According to the determined data on the average weight of the strawberry fruit in the examined varieties, *elsanta*, *hummi grande* and *mesecharka*, were classified in the following groups. The fruit of the variety *mesecharka*, with an average weight of 1.40 ± 0.07 g belongs to a group of very small fruit (weight < 5), the fruits of the *hummi grande*, with an average weight of 11.29 ± 0.94 g belongs to a group of large fruit (weight from 9 to 14 g) and the fruits of the *elsanta* variety, with an average weight of 14.38 ± 0.94 g belongs to the group of very large fruits (with a weight of > 14 g).

By analyzing the variance, in terms of the weight, the height, the width and the thickness of the strawberries, it was determined a statistically significant difference between the strawberries from the varieties *elsanta* and *mesecharka* and between the varieties *hummi grande* and *mesecharka*, with determined values of $LSD_{\text{weight}} = 11.48$, $LSD_{\text{height}} = 9.64$, $LSD_{\text{width}} = 8.25$, $LSD_{\text{thickness}} = 11.01$, at a probability level of $p = 0.01$.

The strawberries of the *mesecharka* varieties, were harvested without leaves, actually without waste, but 100% fruit utilization, which is not the case with the other two varieties of strawberries. For other two varieties of strawberries, it was estimated that the *elsanta* has a yield of 97.69 %, and the *hummi grande* 97.49 % yield. According to this, it was concluded that for the fruit of the strawberry varieties: *elsanta*, *hummi grande* and *mesecharka*, there was a high degree of utilization.

Chemical composition of the strawberry fruit

According to the obtained results of the research, for the content of the total dry matter in the varieties of strawberry *elsanta*, *hummi grande* and *mesecharka*, it was concluded that with the highest content of total dry matter 14.43 % were the strawberries of the variety *mesecharka*, and with the smallest value of 9.33 % were characterized the strawberries of the variety *hummi grande*. For the variety *elsanta*, the content of total dry matter was 10.77 %. The content of the total dry matter in the strawberries varieties, for *elsanta* (10.77 %) and for *hummi grande* (9.33 %) were within the limits of the previous examinations from other authors, from 9.08 % to 11.9 %, or from 9 % to 12 % [5], [14].

Sugars, together with acids, are the basic ingredient for the formation of the taste of the fruit. The content of the total sugars varies, depending on the variety, degree of maturity and cultivation conditions. The content of total sugars in the strawberries of the variety *elsanta* was with the highest values of 7.62 %, then in the variety *mesecharka* was 6.34 %, and in the variety *hummi grande* was 5.10 %. According to the previous studies, the content of the total sugars in the strawberries fruit was in the ranges of 4.5 % to 7.8 % [2]. The most common sugars in the strawberry are sucrose, glucose and fructose. According to the analyzes of the sugar content in

the fruits of the examined strawberry varieties, *elsanta*, *hummi grande* and *mesecharka*, the highest value for sucrose (1.87 %), glucose (2.87 %) and fructose (2.88 %) were determined in the strawberry variety *elsanta* and the lowest value were in the fruits of the variety *hummi grande*, 1.10 % for sucrose, 2.00 % glucose and 2.00 % fructose. In the strawberries of the variety *mesecharka*, the values were: for sucrose 1.34 %, fructose 2.5 % and glucose 2.5 %. According to the other research, in the strawberry of the variety *elsanta*, the content of sucrose was from 1.12 % to 1.29 % [15].

The most common acids in the fruit are citric, malic and tartaric acid, which are known as "fruit acids". In the last phase of the fruit maturation, the content of acids decreases, while the content of sugars increases. According to the research, the highest value for total organic acids of 1.26 % was determined in the strawberries of the variety *mesecharka*, and the lowest value of 0.90 % was determined in the variety *elsanta*. In the strawberries of the variety *hummi grande*, the content of total organic acids was 0.92 %. In the research done by another author, the content of total acids in strawberries amounted to 1.00% [11]. For the variety *elsanta*, according to a previous research, it was determined a content of total acid of 0.84 %, while according to others, this values were within the range from 0.98 % to 1.20 % [4], [15].

Strawberries are a good source of vitamin C, which is a strong natural antioxidant, soluble in water, but very sensitive, quickly degradable under the exposure of light, air and high temperature (thermolabile). Because of these features, the strawberries need to be processed as soon as possible after their harvest. From the obtained results, the highest value of the vitamin C (106.57 mg/100 g) was determined in the strawberries of the variety *hummi grande*, the vitamin C content in the strawberry *elsanta* was 69.33 mg/100 g and the lowest value of the vitamin C was obtained in the fruits of the variety *mesecharka* (44.96 mg/100 g). Some prior findings suggest that the content of vitamin C in the strawberries, was 50,00 mg/100g or 83.6 mg/100 g for the *elsanta* variety [11], [16]. In the previous research in R. Macedonia, were made examination on 17 varieties of strawberries, and it has been established that the content of vitamin C in average was 87.90 mg/100 g. For the *elsanta* variety, which was also the subject of analysis and in our research, the content of vitamin C was 98.81 mg/100 g [4].

The results of the performed analyzes for protein show that the highest value was determined in the variety *mesecharka* (7.09 %), in the variety *elsanta* the value was 3.68 % and the lowest value for protein was determined in the fruits of the variety *hummi grande* (2.10 %). The protein content in strawberries, according to other analysis was 0.40 % [11].

The mineral matters, compared to the other matters in the fruit, are stable and do not change during the preservation technology and storage. According to the analysis of the content of mineral matter (total ash) in the examined strawberries varieties, with the highest value of 0.51 % were the strawberries of the variety *mesecharka* and with the lowest value of 0.20 % was the variety *hummi grande*. In other research it was found that the total ash content in the strawberry fruit was 0.5 % or the total ash content was in the range of 0.3 % to 1.0 % [11], [3].

Chemical composition of dried strawberry fruit

After the drying was completed, the analysis was made of the dried fruit for determining the contents of the following parameters: total dry matter; total sugars, sucrose; glucose; fructose; total acids expressed as citric acid; vitamin C; proteins and total ash.

According to the obtained results for the content of total dry matter in the dried strawberries of the varieties: *elsanta*, *hummi grande* and *mesecharka*, it was estimated that with the highest average value was the dried fruit of the *mesecharka* (83.30 %), and with the lowest value was the dried fruit of the *elsanta* variety (80.72 %). For the *elsanta* variety, the highest value (82.35 %) of total dry matter was determined in the control variant V₀, and the lowest value (79.06 %) was in variant V₂. The variety *hummi grande* was characterized by the highest value of total dry matter (81.41 %) in variant V₁, and the lowest value of 80.78 % was determined for the variant V₂. In the strawberries of the variety *mesecharka*, the value of the total dry matter was highest (84.05 %), in the variant V₁, and the lowest (82.71 %) in the control V₀ variant.

In terms of the total sugars content, the highest average value of 28.45 % (with 0.30 % sucrose, 13.77 % glucose and 14.38 % fructose) was determined in the *elsanta* variety, while the lowest average value of 21.78 % (with 0.88 % sucrose, 10.32 % glucose and 10.58 % fructose) had the fruit of *mesecharka* variety. Based of the obtained results, it was estimated that the lowest content of total sugars, 15.08 % (with 0.69 % sucrose, 6.76 % glucose and 7.63 % fructose) was in the strawberries of the variety *mesecharka*, in the variant V₁, while the highest content of total sugars was 34.61 % (with 0.64 % sucrose, 16.16 % glucose and 17.81 % fructose) was determined in the variety *hummi grande*, in the variant V₁.

The average value for the total acid content expressed as citric acid, ranged from 1.03 % in the variety *mesecharka*, as the lowest value, up to 1.14 % as the highest average value in the *elsanta* variety. It was estimated that the control variant V₀ of the variety *hummi grande* had the highest value of 1.23 % for the content of total acids, while for the same variety the lowest value was 0.98 % in the variant V₁.

The highest average value of 115.25 mg/100 g of vitamin C was determined in the variety *hummi grande*, while the lowest average value of 65.68 mg/100 g was estimated for the variety *mesecharka*. The control variant V₀ for the strawberries of the variety *mesecharka*, was characterized by the lowest value of 32.79 mg/100 g of vitamin C content, and the highest value of 132.74 mg/100 g, was determined in the variant V₁, of the variety *hummi grande*.

The highest average value of 8.46 % for protein content was determined in the fruits of the variety *mesecharka*, while the lowest average value of 2.63 % was found in the fruit of the variety *hummi grande*. Regarding the treatments, the lowest protein content of 1.92 % was determined in the control variant V₀ of the *hummi grande* variety, and the highest content of protein (8.84 %) had the strawberries of the *mesecharka* variety, in the variant V₂.

The highest average value of 5.19 % for total ash content was estimated in the variety *mesecharka*, while the lowest value (4.34 %), was determined in the fruits of the variety *elsanta*. In the variety *elsanta*, the variant V₂, was determined the lowest value (3.80 %) for the total ash content, and the highest value of 5.54 % was determined in the control variant V₀ of the variety *hummi grande*.

The yield in production varies by varieties and has a great economic and technological significance in the processing of all agricultural products. From the obtained results, it was estimated that in order to obtain a 1 kg of dried strawberries, it takes in average 9.07 kg fresh fruit of the variety *elsanta*, 10.08 kg of the variety *hummi grande*, and 7.24 kg of the *mesecharka* variety.

CONCLUSION

According to the results of the analysis of fresh and dried strawberries, we can conclude the following:

-With the highest average values in terms of the height, the width and the thickness were characterized the fruits of the variety *elsanta*, and the lowest values for these parameters were estimated in the variety *mesecharka*.

-The fruit of the variety *mesecharka*, belongs to the group of very small fruit, the variety *hummi grande*, belongs to the group of large fruit and the *elsanta* variety belongs to the group of very large fruit.

-In terms of the weight, the height, the width and the thickness of the strawberries, it was determined a statistically significant difference between the varieties *elsanta* and *mesecharka* and between the varieties *hummi grande* and *mesecharka*.

-Regarding the yield, all varieties of strawberries have a high degree of utilization.

-For the chemical composition of the fresh strawberries, the *elsanta* variety has the highest value for: total sugars; the *hummi grande* variety was characterized by the highest value of vitamin C,

and the highest values for the variety *mesecharka* were determined for: total dry matter, total acids, total ash and protein.

-For the chemical composition of the dried strawberries, the highest average values were determined in the variety *elsanta* for total sugars and total acids; in the variety of *hummi grande* for vitamin C; and in the variety *mesecharka* for the total dry matter, protein and total ash.

-For the variety *elsanta*, the control variant V₀ was characterized by the highest values of the total dry matter; for the variant V₁ the highest values were determined for the proteins, total acid, total ash and the vitamin C; in the variant V₂, the highest value was determined for total sugars.

-For the variety *hummi grande*, the control variant V₀ was characterized by the highest values for the total acids and total ash; in the variant V₁ was determined the highest values for the total dry matter, total sugars, proteins and vitamin C.

-For the variety *mesecharka*, for the variant V₁, were determined the highest values of the total dry matter, total acids, total ash and the vitamin C; in the variant V₂ the highest values were estimated for total sugars and proteins.

-According to the yield in production was estimated, that to obtain 1 kg of dried strawberries, required: 9.07 kg fresh fruit of the variety *elsanta*, 10.08 kg of the variety *hummi grande*, and 7.24 kg of the *mesecharka* variety.

-With the best mechanical and pomological properties was characterized the strawberry from the *elsanta* variety, and the variety *mesecharka* was with the best chemical properties.

-With the applied treatment of the strawberries for the three varieties, in the variant V₁ and the variant V₂ was noted that some of the soluble constituents were lost in the water, especially in the varieties *elsanta* and *hummi grande*.

-In the solar drying of strawberries, consideration should be given to the choice of the raw material, the variety, the degree of maturity of the fruits and the weather conditions during the drying period. The drying in the Armenian dryer was shown to be evenly and uniform.

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