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Modification of the colour of dessert strawberries subjected to pulse electric field

***Abstract**. The article presents the results of the impact of the pulsed electric field (PEF) on the modification of strawberry colour. The study concerned dessert strawberries. The electric field intensity of 5 kV/cm and 10 kV/cm was used. The CIELab system was used to assess the colour. It was shown that at the intensity of 5 kV/cm, the red component in the colour of the fruit increased by 19% in relation to the fruit not treated with PEF. This is important in the context of the content of the health-promoting anthocyanin pigments of pelargodnidin-3-glucosides, which give strawberries a red colour. The modification of strawberries with the use of an electric field also reduced the brightness of the color by 16.1%.*

***Streszczenie.** W artykule zaprezentowano wyniki wpływu działania impulsowego pola elektrycznego (PEF) na modyfikację barwy truskawek. Badanie dotyczyło truskawek deserowych. Zastosowano pole o natężeniu 5 kV/cm i 10 kV/cm. W celu oceny barwy wykorzystano system CIELab. Wykazano, że przy natężeniu 5 kV/cm zwiększyła się składowa czerwona w barwie owoców o 19% w stosunku do owoców nie poddawanych działaniu PEF. Ma to znaczenie w kontekście zawartości prozdrowotnych barwników antocyjanowych 3-glukozydów pelargodnidyny, które nadają czerwoną barwę truskawkom. Modyfikacja truskawek z wykorzystaniem pola elektrycznego spowodowała także zmniejszenie jasności koloru o 16,1%. **(Modyfikacja koloru truskawek deserowych z wykorzystaniem impulsowego pola elektrycznego**)*

Keywords: PEF, electric field, strawberries, colour, food preservation
Słowa kluczowe: PEF, pole elektryczne, truskawki, barwa, utrwalanie żywności

Introduction

Strawberry (Latin. *Fragaria x pineapple*) appeared in Europe as a hybrid of two imported American species. Little Scarlet is one of the oldest varieties of strawberries grown around the world to this day. Today, there are hundreds of strawberry varieties, and they are grown on all continents. From subarctic regions (Finland) to the tropics (Ecuador). Particularly suitable for cultivation are regions with temperate (Poland) and Mediterranean (Spain, Italy and California) climates. Strawberries can be divided depending on the fruiting of this fruit: one-time fruiting (at the turn of June and July), repeated fruiting (fruiting from August to autumn), alpine (they ripen from July to the first frost) [1].

Strawberries are one of the most popular berries grown in Poland. Poland is one of the leading strawberry producers in the EU. At the same time, in the European Union, Poland, after Spain, is the second largest producer of strawberries (in 2020 - with a 16% share in the total EU production). On a global scale, the country belongs to the top ten largest producers of this fruit. According to FAO data, in 2019 Poland was ninth in the production of this fruit (177 thousand tones), after China (3.2 million tones), the USA (1.0 million tones), Mexico (861 thousand tones), and Turkey (487 thousand tones), Egypt (460 thousand tonnes), Spain (352 thousand tones), the Russian Federation (209 thousand tones) and South Korea (193 thousand tones). From 2017 to 2019, Poland was a leader in the global export of frozen strawberries. In the years 2014 – 2020, 87–123 thousand tones of frozen strawberries were exported from Poland, which accounted for 45-60% of the domestic strawberry harvest (in terms of fresh fruit) [2].

Currently, Poland is the second, after Mexico, producer of frozen strawberries in the world. The harvest of Polish strawberries ranges from 175 to 205 thousand tones and most of them are exported. Mostly industrial fruits are exported. The majority of Polish dessert strawberries are sold to domestic consumers. According to GUS data, in 2020 the value of exports of fresh and frozen strawberries and their preserves amounted to EUR 174 million. Although Poland is an important world producer and exporter of strawberries, they are also imported. In the winter months, fresh dessert strawberries are imported to Poland (from Spain, Greece and Germany) [3]. Because there are so many varieties of these fruits, they are grown in many countries, and active packaging and rapid transportation techniques make strawberries available mostly all year round in most developed countries. Strawberry fruits are usually eaten raw, although the techniques of their preservation (cooling, freezing), processing into jams, juices, compotes, ice cream, etc. are widely used and constantly modernized. Strawberries, like other berries, are enjoying a growing interest in distribution markets around the world. This is due to the health benefits of berry fruits that are increasingly appreciated by consumers and also because of ensuring their continuity of supply in retail, in many regions of the world thanks to the globalization of trade. Strawberries belong to the so-called super fruit, food called smarfood, superfood, due to the content of bioactive compounds, including large amounts of vitamin C (60mg/100g), and other antioxidants. Vitamin C stimulates the immune system, facilitates the absorption of iron, is involved in the synthesis of certain hormones and neurotransmitters. The most important compounds with a broad spectrum of beneficial effects are flavonoids (anthocyanins and fisetin). In the plant world, these compounds have a protective function against ultraviolet radiation, and in the human body they play important health-promoting functions. Anthocyanins give strawberries red color, influencing their organoleptic characteristics. These compounds are also credited with antioxidant, anti-inflammatory, and prevention of chronic diseases, including diabetes, obesity, cancer and cardiovascular disease.

Strawberries are rich in significant amounts of fisetin (160µg/g), which activates longevity genes, including Sirt1. In addition, in meta-analysis provided in 2013, it is noted that fisetin exhibits anti-cancer properties (inhibits multiplication and induces cell apoptosis in tumors). An interesting direction of research is the protective effect of fisetin on neurons, thus fisetin may protect against dementia, memory loss and ischemia [4] Most likely, fisetin has a preventive effect on Alzheimer's disease, as it has been shown in animal models to reduce the levels of tau and betaamyloid.

Strawberries, despite many advantages and pro-health features, have disadvantages, the most important of which are their instability, susceptibility to mold development, and viral diseases during cultivation. During the processing and storage of strawberries, various changes can take place, leading to reactions causing colour changes.

The colour of plant products is a factor influencing its quality. The colour of fruit and vegetables is also a reflection of the type and amount of color compounds, including those of a health-promoting nature. In the case of strawberries, their colour proves their attractiveness and freshness, and consumers often look for products with a red and intense colour.

The content of anthocyanins, including some coloured compounds, depending on the type of product and the treatment applied, can change favourably. Currently, in the production of functional food, it is possible to modify the concentration of natural compounds and dyes in order to increase their share and enhance their beneficial effects [5, 7-9].

One of the methods of non-thermal processing of food is subjection it to a pulsed electric field (PEF). This method is now more and more widely used in the food industry [10-15].

The use of PEF for food drying and preservation preserves the nutritional value, natural quality, colour, flavor and vitamin components of food products. The interaction of the electric field with plant tissues is an interdisciplinary problem, combining the issues of electrical engineering and food technology. Basic issues concerning the electroporation process as applied to plant tissues, optimal energy consumption during the process and the influence of the process parameters are discussed in the literature [16-19].

The influence of electromagnetic fields on living organisms and food is the subject of research by many specialists [20,21]. In this study, the aim of the research is to assess the possibility of a favorable modification of the colour of dessert strawberries using the PEF technique. It was assumed that the use of the PEF technique can improve the colour of fruit intended, among others, for further thermal processing (preparing juices, heating, freezing).

Material and methods

Polish dessert strawberries were the tested material. The fruit was of the high quality, firm, with no signs of deterioration, evenly coloured, intensely red in colour. Strawberries were divided into three groups. The first part of the strawberries was not treated with PEF and it was the reference test group. Two other groups were subjected to PEF treatment using electric pulses of electric field intensity of 5 kV/cm (second part), of 10 kV/cm (third part).

The research on the effect of the electric field on the fruit was carried out with the use of a high voltage pulse generator with the possibility of regulating the output voltage in the range of 0-30kV and the possibility of regulating the duration and number of pulses. The tested material was placed in cells made of Teflon and ended on both sides with metal electrodes closing the electric circuit. The distance between the electrodes made it possible to obtain the desired electric field intensity of 5 kV/cm and 10 kV/cm. For 10 s the fruit was exposed to the electric field with a frequency of 20 Hz [17,18].

In order to determine the colour, the Konica Minolta Chroma Meter CR-400 spectrophotometer (8 mm aperture) (Japan) was used, which in numerical form defines the colour parameters based on standardized colorimetric calculus. The CIE Lab colour model was developed by the International Commission on Lighting (CIE - Comission Internationale de l'Eclairage) [5,6].

Fig. 1. Schematic laboratory stand for PEF treatment

The CIE Lab system is a three-dimensional colour space consisting of the L*, a* and b* values. The L value means brightness and ranges from 0 to 100 (the brightest colour). A positive a* value means the share of red, negative the share of green. A positive b* value indicates the proportion of yellow, while a negative proportion of blue. For each sample of analyzed strawberries, five replications ($n = 5$) were performed. In order to determine the significance of differences between the results of the quality assessment of the compared samples, the NIR significance test was performed at the significance level $p \leq 0.05$ using the licensed STATISTICA 10 software. The assessment of changes in the yellow and red components is not possible with the use of optical methods, even in tomographic examinations [22-25].

Results

It was observed that all parameters describing the colour of strawberries in the CIE Lab system changed when using PEF as a pre-treatment. It has been shown that the use of the PEF technique on strawberries results in the modification of the colour (Fig. 3), especially in the red and yellow. It was found that the share of red color (parameter a*) in dessert strawberries without any pretreatment and strawberries treated with PEF of 5 kV/cm and 10 kV/cm electric field intensity was 23.04 ± 0.15, 27.44 ± 0.27, 21.94 ± 0.24 respectively. The share of the yellow color (parameter b*) in dessert strawberries treated with PEF of 0 kV/cm, 5 kV/cm and 10 kV/cm, amounts to 12.74 ± 0.18, 13.14 ± 0.34 and 9.95 ± 0.27 respectively.

The increased share of red colour was statistically significant in the fruit of strawberries treated with PEF with the electric field intensity of 5 kV/cm, by 19% and the yellow changed by 3%, in relation to the untreated dessert strawberries. After the application of PEF with an intensity of 10kV/cm, the share of red and yellow was lower and amounted to less than 4.8% and 21.9%, respectively.

The anthocyanin dyes imparting colour to strawberries are represented by pelargonidin-3-glucoside (85-95%) and cyanidin-3-glucoside (3.9% -10.6%), of which pelargonidine is responsible for the characteristic red colour of these fruits. The durability of these dyes is relatively low and significantly depends on the applied thermal treatment and packaging conditions. [26, 27]. The process of extracting these compounds is presented in [28].

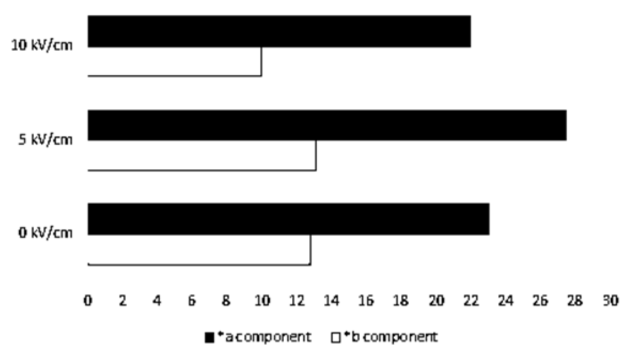

Fig. 2. Share of the yellow and red components in dessert strawberries untreated and treated with PEF

The colour of strawberries can also be modified with the use of PEF treatment, however, it is important to select the appropriate conditions, e.g. field intensity.

Fig. 3 shows the modification of the L parameter (brightness) of dessert strawberries treated with PEF and without treatment. It was noticed that using a pulsed electric field, the brightness parameter changes in the strawberries colour. In the case of strawberries, which were subjected to an electric field with the intensity of 5 kV/cm, the L parameter decreased by 16.1% (they became darker), and in the case of the intensity of 10 kV/cm by 22%. In both cases, these changes are statistically significant and visibly intensify the colour of strawberries.

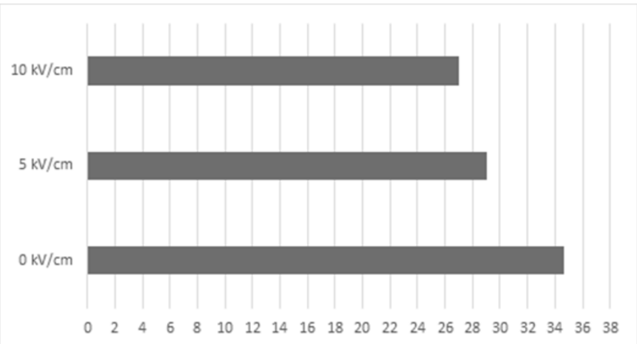

Fig. 3. Brightness (L parameter) of PEF-treated and untreated dessert strawberries

Studies by other authors have shown that the colour of strawberries during production and storage can be stabilized and strengthened by adding dyes or stabilizing anthocyanins contained in strawberries. Among others, addition of natural polyphenol stabilizers that preserve the red colour and counteract the adverse changes taking place under the influence of enzymes, temperature, oxygen and light in processed strawberries into jams and compotes [26].

The results obtained in this study indicate that the PEF treatment can be used to modify the colour of strawberries, e.g. before using a freezing or other processing operation for the fruit. The natural red and intense colour of strawberry preserves encourages consumption and increases their palatability. It is very important to adjust the field intensity values for processing depending on the fruit type.

Conclusion

Processing food with the use of pulsed electric field is a task not only for scientists in the field of food technology but also for specialists in the field of electrical engineering. By selecting the parameters of electrical impulses, we can influence the chemical composition of the processed products. PEF technology can be successfully used as a non-thermal pretreatment of strawberries, thanks to which it is possible to model colour parameters, e.g. favourably intensifying it. The intensification of the red color is associated with an increase in pro-health anthocyanins, and in the case of strawberries - pelargonidin-3-glucoside and cyanidin-3-glucoside. On the basis of the obtained results, it was found in the experiment that the application of PEF to dessert strawberries may have a positive effect on the modification of the colour, especially increasing the share of the a* parameter, i.e. the share of red colour. However, by applying the pulsed electric field to the fruit, structural changes and the permeability of the cell membrane are influenced, which depends on the used parameters. In order to modify the colour of strawberries, it is more advantageous to apply PEF treatment conditions with an intensity of 5kV/cm. It should be noticed that the red color corresponds to the content of pro-health anthocyanins and the higher value of the a* component, the better the fruit and preserves made of them are better.

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