Ilona Gałązka-Czarnecka[1], Ewa KORZENIEWSKA[2], Andrzej Czarnecki[1], Jacek Stańdo[3]

Institute of Food Technology and Analysis, Faculty of Food Sciences and Biotechnology, Lodz University of Technology, Poland (1)
Institute of Electrical Engineering Systems, Faculty of Electrical, Electronic, Computer and Control Engineering, Lodz University of Technology, Lodz, Poland. (2)
Centre of Mathematics and Physics, Lodz University of Technology, Poland (3)

doi:10.15199/48.2023.06.24

Modification of color in turmeric rhizomes (*Curcuma longa L.)* with pulsed electric field

Streszczenie: *W artykule przedstawiono wyniki badań wpływu impulsowego pola elektrycznego na barwę korzeni kurkumy Curcuma longa L. Badane korzenie poddano krótkotrwałemu oddziaływaniu PEF o natężeniu 2,5 kV/cm i 5 kV/cm. Zmianę koloru rośliny oceniano w systemie laboratoryjnym CIE. Wyniki badań wskazują na korzystny wpływ pola elektrycznego na intensywność barwy badanych kłączy kurkumy, ze szczególnym uwzględnieniem natężenia pola 2,5 kV/cm. W tym przypadku uzyskano zwiększony udział barwy czerwonej i żółtej odpowiednio o 21,6% i 9,2%. (**Modyfikacja koloru kłączy kurkumy (Curcuma longa L.) z wykorzystaniem impulsowego pola elektrycznego**)*

Abstract. *The article presents the results of research on the influence of the pulsed electric field on the color of Curcuma longa L roots. The examined roots were subjected to a short-term PEF impact of 2.5 kV/cm and 5 kV/cm intensity. The color change of the plant was assessed in the CIE lab system. The results of the research indicate a beneficial effect of the electric field on the color intensity of the tested turmeric rhizomes, with particular emphasis on the field strength of 2.5 kV/cm and in that case an increased obtained share of red and yellow colors was respectively 21.6% and 9.2%.*

Keywords: impulsowe pole elektryczne, kurkuma, (*Curcuma longa L.*), modyfikacja barwy roślin
Słowa kluczowe: pulsed electric field, turmeric, (*Curcuma longa L.),* plant color modification

Introduction

Curcuma longa L. (turmeric, Indian saffron, home saffron) is a plant belonging to the ginger family. It is cultivated in the equatorial zone, it is commonly found on the Malay Peninsula and in India. It was brought to Europe in the 13th century [1, 2]. Turmeric is most often found in the form of fresh rhizomes and as a dried yellow spice.

The color of plant products is a property that proves both the quality and content of bioactive ingredients. The color of fruit, vegetables, rhizomes and spices also reflects the type and amount of color compounds. In plant products, these may be compounds with a beneficial bioactive effect on human health. In the case of turmeric rhizomes, it proves their attractiveness, and consumers often look for products with a characteristic, natural, but also intense color.

The curcumin is the color substance which is mainly found in turmeric. It is responsible for the intense yellow color of these rhizomes/roots. Curcumin is one of the basic curcuminoids. It is a bioactive compound with strong healing and health-promoting properties. In Far East medicine, its beneficial effect on health was noticed centuries ago [3]. Many years of scientific research have shown that it has antioxidant, anti-cancer, anti-inflammatory and antifungal properties [4]. In the food industry, it acts as a dye and it is sometimes added during production, for example, to margarines, pasta, and as a spice to many Asian dishes, meats and vegetables. It is also a component of curry spices [5]. The turmeric rhizome also contains many nutrients, including carbohydrates, protein and fats. There are also essential oils, minerals such as sodium, calcium, potassium, iron and vitamins: C, B1, B2, B3 [6].

The turmeric rhizome is known as anti-allergy, anti-cancer, anti-fungal, anti-inflammatory, anti-viral plant. It heals wounds fast, helps control blood sugar. It is believed that it is immunity buster and improves digestion as well memory. According to the medical point of view it prevents tooth decay and Alzheimer's disease. The *Curcuma longa* reduces arthritis symptoms, risk of heart disease and symptoms of depression. It helps with aging, promotes a longer lifespan. The substances in this rhizome are natural pain killer and protect lungs.

Changes in the chemical composition of the mentioned curcuma as well as the other food can be influenced by various methods. The influence of pre-treatment and cooking on the vitamin content is unequivocal. The type of process, duration and temperature affect their reduction to a varying degree, especially vitamins C, A and folates. However, the decline in content does not apply to all compounds. The content of polyphenols, including some colored compounds, may increase or decrease depending on the type of product and the applied treatment. Currently, in the production of functional food, it is possible to modify the concentration of natural compounds, dyes to increase their share and enhance their beneficial effects [7-10], researchers use different methods of changing the properties of food or research the influence of different factors on biologic cells, e.g. pulsed electric field [11-13], electromagnetic field [14,15], microwaves [16-18].

In food processing where a pulsed electric field is applied, a series of very short electric current pulses with a high value of the electric field strength of the order of tens of kV/cm and duration from a few to several microseconds are used. Placing food products in the area of influence of the electric field leads to the phenomenon of electroporation inside the product. This phenomenon consists in the formation of pores in the cell membrane and perforation of the cell membrane, which can be used to preserve or change the properties of food.

The purpose of this research is to assess the possibility of modifying the color of turmeric with the use of the pulsed electric field (PEF) technique.

Materials and Methods

The turmeric rhizomes (*Curcuma longa L.),* originating from Thailand (Fig. 1) was the studied material. The roots were of high quality, dry, firm, evenly colored intensely orange.

Turmeric roots from Thailand were divided into three parts. The first part of turmeric rhizomes was not treated with PEF (reference test). Two subsequent parts were subjected to the PEF process with the use of electric pulses with a intensity of 5 kV/cm (the second test), and the third one with a intensity of 2.5 kV/cm. Roots from Peru were also split into two parts. In one test, electric pulses with a intensity of 5 kV/cm were used, while in the second test, pulses with a intensity of 2.5 kV/cm were used. To conduct research with the use of pulsed electric field, a laboratory stand was used.

It was built of a high voltage pulse generator (the range of voltage set is from 0 to 30 kV), a control system that allows to set the number of pulses and the time interval between them, a chamber, in which the discharge takes place and in which there are two flat electrodes, between which the sample was placed [9]. In order to determine the color, the Konica Minolta Chroma Meter CR-400 spectrophotometer (8 mm aperture) (Japan) was used, which defines the color parameters based on the standardized colorimetric calculation of CIE Lab in numerical form. The CIE Lab color model was developed by the International Commission on Lighting

Fig. 1. The turmeric rhizomes (*Curcuma longa L.)*

(CIE - Comission Internationale de l'Eclairage).

The standardized CIE system allows for a complete description of each color using three variables, color attributes. The CIE Lab system recommended by CIE consists of two axes, a* and b*, which are at right angles to each other and define the color tone. Their intersection point corresponds to the achromatic color. The a and b coordinates can take both positive and negative values. Positive values of the a coordinate indicate the share of red color, negative values corresponds to green.

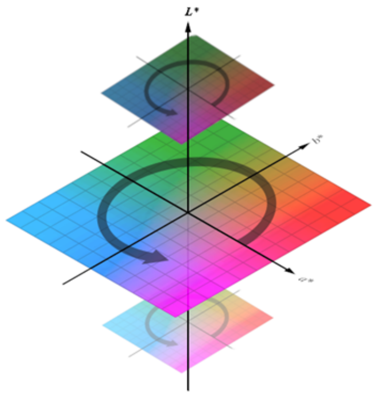

Fig. 2. The coordinates of the standardized CIE system

The a* parameter has a value on the red and green axis in the range a ± 120, b ± 120, the b * parameter has a value on the yellow and blue axis in the range a ± 120, b ± 120. The third axis (in the achromatic color point) means the brightness L*. It is perpendicular to the a* b* plane. The lightness axis of the L color is on a scale from 0 (black) to 100 (white). The tests showed the values of the components of the three-dimensional axis L* a* b*, L* brightness, the positive value a* determined the share of red and the positive value * b the amount of yellow (Fig. 2) [11].

Table 1. Color parameters in the CIE Lab system of fresh and PEF treated turmeric rhizomes

CIE Lab color parameters						Mean ± SD
Fresh turmeric rhizome						
L* brightness	67.72	66.76	67.91	66.66	67.1	67.23±0.39
a* proportion of red component	24.38	23.76	23.42	24.55	24.56	24.13±0.36
b* proportion of yellow component	54.31	53.39	52.08	53.47	53.15	53.28±0.44
Turmeric rhizome modified with PEF 2.5 kV/cm						
L* brightness	61.01	60.83	60.62	60.84	60.06	60.67±0.22
a* proportion of red component	29.56	29.88	29.47	29.03	28.77	29.34±0.29
b* proportion of yellow component	58.98	57.85	57.34	58.04	58.59	58.16±0.42
Turmeric rhizome modified with PEF 5 kV/cm						
L* brightness	63.73	63.16	62.55	62.82	62.83	63.02±0.28
a* proportion of red component	25.41	26.91	26.8	28.36	27.51	27.00±0.62
b* proportion of yellow component	55.96	56.38	56.32	56.76	55.71	56.23±0.26

Results and Discussion

It has been shown that application of PEF to turmeric rhizomes results in a modification of the color of rhizomes (Table 1, Fig. 3). It was observed that all the parameters describing the color in the CIE Lab system were changed using PEF as a pre-treatment. An increased share of red and yellow colors was obtained in turmeric rhizomes after PEF 2.5 kV/cm by 21.6% and 9.2%, respectively, in relation to untreated turmeric rhizomes. After applying PEF 5kV/cm, the increase in the red and yellow color was smaller and amounted to 11.9% and 5.4%, respectively. Based on the obtained results, it was found that the application of PEF to turmeric rhizomes has a positive effect on the modification of the color, intensifying it.

Table 1 and Fig. 2 show the results of the measurements of the brightness and the share of red and yellow components of the turmeric rhizomes subjected to a short-term impact of an pulsed electric field. The information presented shows that the rhizome had the brightest color when it was not subjected to additional treatment, but in this situation the smallest share of the yellow and red components was achieved compared to the samples treated with PEF.

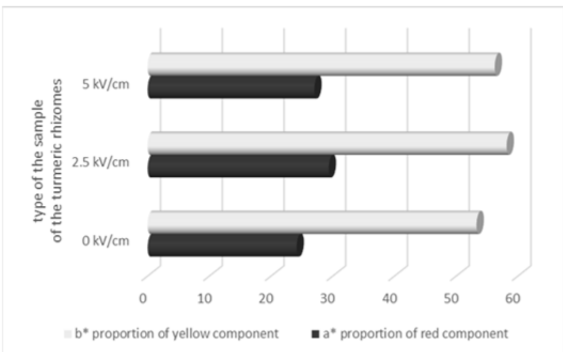

Fig. 3. The share of yellow and red color of fresh turmeric rhizomes fresh and applied to the PEF process

The highest value of the desired color component in this case had rhizomes exposed to an electric field of 2.5 kV/cm intensity and amounted to 29.34 for the red component and 58.16 for the yellow component. These are the highest

values in the conducted research. The use of the field with the intensity of 5 kV/cm resulted in smaller changes in the observed color components, although the brightness of the sample was higher than in the case of the samples subjected to the field of 2.5 kV/cm intensity. The reduction in the red and yellow components may be due to the destruction of more cells in the rhizome, which is not noticeable at the microscopic level even used the tomography research [19-22].
The absolute color difference DE

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$$

where: a* - parameter which describes the red and green, b* - parameter which describes yellow and blue ; L* - brightness

of fresh turmeric and after PEF treatment was calculated on the basis of the obtained results of color determination using the CIELab method. Values of ΔE<5 were obtained for turmeric without any treatment, for roots subjected to 2.5 kV/cm - ΔE = 9.69, and turmeric subjected to 5 kV/cm - ΔE = 5.88. The calculated total color difference indicates that the observer/consumer is able to perceive the clear color differences with fresh (untreated with PEF) turmeric. The characteristics of the product may be suggested by its color. The characteristic intense color of the turmeric root is one of the factors proving its attractiveness to the consumer, because it is strongly related to the taste and smell as well as the declared effect.

Conclusions

increase in the share of both the yellow and red components in the tested material was obtained. This confirms the legitimacy of using the pulsed electromagnetic field to modify the natural occurring compounds in the plants, including dyes, and thus for the extraction of health-promoting components also in the hard rhizomes of turmeric.

ACKNOWLEDGE:

The research was supported by funds from the project POWR.02.15.00-00-4008/19.

Authors: *PhD Ilona Gałązka-Czarnecka, Institute of Food Technology and Analysis, Faculty of Food Sciences and Biotechnology, Lodz University of Technology, Poland, ul. Wólczańska 171/173, 90 924 Łódź, e-mail: ilona.galazka-czarnecka@p.lodz.pl; PhD DSc Ewa Korzeniewska, associate proffesor, Institute of Electrical Engineering Systems, Faculty of Electrical, Electronic, Computer and Control Engineering, Lodz University of Technology, Lodz, Poland, ul. Stefanowskiego 18, 90-537 Łódź, e-mail: ewa.korzeniewska@p.lodz.pl; MSc Andrzej Czarnecki, Institute of Food Technology and Analysis, Faculty of Food Sciences and Biotechnology, Lodz University of Technology, Poland, ul. Wólczańska 171/173, 90-924 Łódź e-mail: andrzej.czarnecki@p.lodz.pl, DSc Jacek Stańdo, Centre of Mathematics and Physics, Lodz University of Technology, Poland, Al. Politechniki 11 90-924 Łódź, e-mail: jacek.stando@p.lodz.pl*

REFERENCES

[1] Sztaba D. Barwa szafranu. aromat cynamonu. smak kaparów - właściwości lecznicze biblijnych przypraw. Rozmaitości 2009. 65 (1). 29-40
[2] Wierońska J.M. Kurkuma - roślinne panaceum. Wszechświat 2017. 118 (4-6). 117-124
[3] Deptuła T., Gruber B., Krówczyński A. Kurkumina i jej pochodne - zastosowanie w terapii przeciwnowotworowej i chemoochronnej. Postępy Fitoterapii 2014. (3). 155-165
[4] Kubina R. Przeciwnowotworowy efekt kurkuminy. oraz jej pochodnych w stosunku do komórek raka języka linii SCC-25**. Postępy Fitoterapii 2017. 18(2). 105-112
[5] Sikorska - Polaczek M., Bielak - Żmijewska A., Sikorska E. Molekularne i komórkowe mechanizmy działania kurkuminy - dobroczynny wpływ na organizm. Postępy biochemii 2011. 57(1). 74-84
[6] Przybylska S. Kurkumina - prozdrowotny barwnik kurkumy. Problemy Higieny i Epidemiologii 2015.96(2). 414-420
[7] Różańska D., Regulska - ILow B., ILow R. Wpływ wybranych procesów kulinarnych na potencjał antyoksydacyjny i zawartość polifenoli w żywności. Problemy Higieny i Epidemiologii 2014. 95(2). 215-222
[8] Gałązka-Czarnecka I., Korzeniewska E., Czarnecki A., Politowski K., Modyfikacja zawartości polifenoli w winach z wykorzystaniem impulsowego pola elektrycznego. Przegląd Elektrotechniczny. 95 (1), 2019. 89-92
[9] Gałązka - Czarnecka I., Korzeniewska E., Czarnecki A. Influence of pulsed electric field on the content of polyphenolic compounds in wine. IEEE Xplore 2018. 37-40
[10] Gałązka -Czarnecka I., Korzeniewska E., Czarnecki A: Impact of pulsed electric field on the color of wine made from grapes Marechal Foch variety. IEEE Xplore, 2018, Strony: 33-36
[11] Korzeniewska E., Gałązka-Czarnecka I., Czarnecki A., Piekarska A., Krawczyk A., *Wpływ Impulsowego Pola Elektrycznego na zawartość antocyjanów w winie*, 2018 Przegląd Elektrotechniczny, 94, doi:10.15199/48.2018.01.15
[12] Oziembłowski M., Dróżdż T., Wrona P.: Pulsed Electric Fields (PEF) treatment on microorganisms in the context of food technology 2013 Przegląd Elektrotechniczny 89, 12, 222-225
[13] Oziembłowski M., Dróżdż M., Kiełbasa P., Dróżdż T., Gliniak M., Nawara P., Ostafin M.: *Impact of pulsed electric field on the quality of unpasteurized beer*, Progress in Applied Electrical Engineering (PAEE), Koscielisko 2017, 1-4. doi: 10.1109/PAEE.2017.8009011
[14] Drozdz T., Bienkowski P., Kielbasa P., Nawara P., Popardowski, E.: *The research stand to stimulation of biological materials by the various electromagnetic field*, 2019 Przeglad Elektrotechniczny 95, 3, 66-69
[15] Sztafrowski D., Jazwiec B.. Gumiela J., Kuliczkowski K.: *Influence of north and south poles of static magnetic field (SMF) on apoptosis of Hl60 cell line*, 2018 Przeglad Elektrotechniczny 94, 12, 182-185
[16] Jakubowski T.: *Wpływ mikrofal 2,45 GHz na wzrost rzeżuchy siewnej (Lepidium sativum L.)* 2018 Przegląd Elektrotechniczny 94, 12, 254-257, doi:10.15199/48.2018.12.58
[17] Jakubowski T.: *The reaction of garden cress (Lepidium sativum L. to microwave radiation*, in: 2018 Applications of Electromagnetics in Modern Techniques and Medicine (PTZE), IEEE Xplore digital library, 2018, ss. 81-84, doi:10.1109/PTZE.2018.8503170
[18] Lapczynska-Kordon B., Lis S., Tomasik M.: *Control of the microwave drying process of selected fruits and vegetables* 2019 Przeglad Elektrotechniczny 95, 3, 74-77
[19] Rymarczyk T., Oleszek M., Szumowski J., Tchorzewski, P., Adamkiewicz P., Sikora J.: *A hybrid tomography for assessing the moisture level of walls and building condition*, 2019 Przeglad Elektrotechniczny 95, 2, 100-103
[20] Rymarczyk T., Szumowski J., Adamkiewicz P., Tchorzewski P., Sikora J: *Moisture Wall Inspection Using Electrical Tomography Measurements*, 2018 Przeglad Elektrotechniczny 94, 1, 97-100
[21] Sekulska-Nalewajko J., Kornas A., Goclawski J., Miszalski Z., Kuzniak E: Spatial referencing of chlorophyll fluorescence images for quantitative assessment of infection propagation in leaves demonstrated on the ice plant: Botrytis cinerea pathosystem 2019 Plant Methods 15
[22] Sekulska-Nalewajko J., Goclawski J., Kuzniak E.: *Computer-Assisted Image Analysis of the Distribution and Intensity of Reactive Oxygen Species Accumulation in Plant Leaves,* 2019 Reactive Oxygen, Nitrogen And Sulfur Species In Plants: Production, Metabolism, Signaling And Defense Mechanisms, 1-2, 489-513