IMPACT OF PARAMETERS OF IRRADIATION OF POTATO BULBS WITH UVC ON SELECTED COEFFICIENTS OF ASSESSMENT OF COLOUR OF FRIES DETERMINED WITH CIE L*A*B* METHOD

Zygmunt Sobol^{a*}, Tomasz Jakubowski^b, Piotr Nawara^c

^a Institute of Machinery Management, Ergonomics and Production Processes, University of Agriculture in Krakow, Poland, Zygmunt.Sobol@urk.edu.pl ORCID 0000-0002-0082-7935

^b Institute of Machinery Management, Ergonomics and Production Processes, University of Agriculture in Krakow, Poland, Tomasz.Jakubowski@urk.edu.pl ORCID 0000-0002-5141-2705

^c Institute of Machinery Management, Ergonomics and Production Processes, University of Agriculture in Krakow, Poland, Piotr.Nawara@urk.edu.pl ORCID 0000-0002-4497-8858

* Corresponding author: e-mail: Zygmunt.Sobol@urk.edu.pl

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ABSTRACT

Assessment of the colour with the use of many parameters is used with reference to evaluation of the quality changes of products resulting from application of specific technological treatments. The paper investigates the effect of relations between parameters of irradiation of potato bulbs with UVC on selected coefficients of assessment of the colour of fries determined with CIE L*a*b* method. It was statistically significantly proved that UV-C radiation affected brightness of fries, change in colour, recognition of the difference in colour and intensity of the colour reception. Statistical analysis of results was carried out at the assumed level of significance $\alpha=0.05$.

Introduction

Colour is one of the most important parameters that serves for assessment of quality of raw materials and food products. It is used by producers, processing technologists, and consumers. Assessing the colour with number of parameters refers, for example, to determination of quality changes in products that result from specific technological treatments. Przybylski (2008) analysed the colour to distinguish high quality pork. Zapotoczny and Zielińska (2005) investigated a change in colour of a non-uniform material, namely carrot roots, Śmigielska et al., (2013) traced the impact of use of starch as a thickener on the change of colour of ketchup. Tomaszewska and Neryng (2007) described the colour of ready products from potatoes obtained at variable parameters of thermal processing and the time of storing and prepared according to technologies of sudden cooling. Cendrowski et al., (2012) investigated the impact of production methods and long-term storing on the colour of beach rose petals preserves, and Rój and Przybyłowski (2012) determined the colour of natural yoghurt in re-

lation to the content of fat. Ciurzyńska et al., (2011) investigated the impact of osmotic dehydration on the colour of freeze-dried strawberries and Gościńska et al., (2014) determined the change of colour of beetroot juice in relation to the conditions of heating. Pasławska et al., (2010) considered a change of parameters of colour of berries resulting from drying, storing and rehydration. Sakowski and Janiszewska (2013) investigated a change of the carrot juice colour as a result of its treatment with ultraviolet and Mieszkalska and Piotrowski (2014) analysed application of colour models for assessment of dried plant raw material. For description of the colour even more often the model CIE $L^*a^*b^*$ is applied which may be used for analysis of the quality of fruit, vegetables, dairy and potato products (Maskan 2001; Pedreschi et al., 2006; Rój, Przybyłowski 2012; Sansano et al., 2015). CIE $L^*a^*b^*$ model has a significant predominance over the remaining systems since it has a separate channel of brightness and chromatic components informing (Pytko 2010) on the content of one of the colours: green, violet-red, blue and yellow (Pytko 2010). UV-C radiation (100-280 nm) with the length of waves of 253.7 nm has sterilizing properties and is used in food industry (Corrales et al., 2012) and in crop protection (patent US 2009/0272029 A1). According to the mentioned patent specification (US 2009/0272029 A1) there is a destructive impact of UV-C on some crop pathogens, such as: *Botrytis cinerea* L. and *Phytophthora citricola* L. (Aiking et al., 2009). UV-C radiation was also used as a sporicidal treatment with reference to corn seeds (*Zea mays* L.) hybrids San Juan and H-159 (Páez et al., 2011). Cools et al., (2014) used ultraviolet to determine the effectiveness of UV-C as a germination inhibitor of potato seedlings.

The aim of the paper was to determine the impact of radiation of potato bulbs with UVC on selected coefficients of assessment of the colour of fries determined with CIE $L^*a^*b^*$ method.

Material and methods

Storage and laboratory experiments were performed in 2016-2017. Potato bulbs of Innovator cultivar were used as a material for research. Innovator cultivar is one of the most eagerly used cultivars in production of fries by European and Polish companies (Lisińska 2006). It is an early cultivar, culinary type B with bulbs of a regular shape, round and oval, of the average content of starch 14.6%. This cultivar is very resistant to darkening of the pulp of raw material and after cooking it is suitable for storing. Bulbs are kept in a refrigerator in single layers on the openwork substrate. Temperature of storing was 10°C and relative moisture of air 90-95%. Intermediate products for fries were potato columns 10x10 mm and length of 60 mm. Columns were cut off along the longest axis of bulbs, determined between a top and umbilical part. Tests were carried out after 3 months of storing. A stand for radiation of the biological material with UV-C is a chamber equipped with a radiator TUV UV-C NBV 15 W type (Jakubowski et al., 2012, 2013, 2015). A structure of the radiator enabled smooth regulation of the height over the bottom of the chamber within 0.4 and 1.0 and was equipped with a precise time switch (model AURATON 100). Potato bulbs during radiation were located on the flat, metal bottom with the area of 0.52 m². UV-C radiation of potato bulbs were differentiated assuming the following parameters: (1-3) - radiation 30 minutes on one side of the bulb (2-4) - radiation 15 minutes from two opposite sides of the bulb, 0- control sample (without radiation). Radiation was carried out two days before formation of intermediate

products (1,2) and before storage (3,4). Temperature of frying was 170°C and frying time was 15 minutes. Fries were fried at one stage to the moment of achieving proper sensory parameters for the ready product. The relation of the mass of a batch (intermediate product) to the mass of frying fat was 1:15. Frying time was determined in a separate initial experiment by analysis of a sensory input of a group of persons that assess them. Fried fries were dried of excess of oil in two stages: 1 - on a mesh shaken substrate, 2 - on a paper absorptive material. Colour of fries was assessed with the use of CIE $L^*a^*b^*$ method with instrumental measurement of colour during which element values were registered: L^* - brightness, chromaticity, a^* - (from red to green), b^* - (from yellow to blue). Figure 1A presents a structure of the stand for measurement of the colour consisting of Basler aca -4600-10uc camera connected to a computer with U3-PCIE1XG205 card served by Pylon 5 program. Before the study, the camera was calibrated on the colour palette of controlled white and black hues (fig. 1 B) placed on the white background to improve the correct mapping of the colour. Basler aca-4600-10uc camera is equipped with a sensor Aptina MT9F002 CMOS with resolution 4608 px x 3288 px and size of pixel 1.4 μm x 1.4 μm . Then, with a graphic environment of LabView2015 CIE $L^*a^*b^*$ colours were marked in 3 points for the investigated objects. In each object 12 measurements of colour were made.

Figure 1. A – structure of the stand: 1 – chamber, 2 – lighting, 3 – camera, 4 – computer, B – palette of control colours: X-Rite ColorChecker PROOF

Temperature of the investigated samples was equal to the temperature of surrounding and was 20°C. Each object of studies was analysed with regard to colour on the white background. For each combination of the experiment measurement on 10 fries was performed in two iteration.

Based on the values of parameters of colour L^* , a^* , b^* the following were calculated (Draft Standard CIE DS 014-4.3/E: 2007; Wrolstad, Smith 2010; Zielińska, Markowski 2012):

Difference in brightness ΔL^* :

$$\Delta L^* = L^*_1 - L^*_0 \quad (1)$$

Difference of chromaticity of Δa^* parameter:

$$\Delta a^* = a^*_{i1} - a^*_{i0} \quad (2)$$

Difference of chromaticity of Δb^* parameter:

$$\Delta b^* = b^*_{i1} - b^*_{i0} \quad (3)$$

Total difference of colour ΔE^* :

$$\Delta E^* = ((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)^{0.5} \quad (4)$$

Difference of colour (change in colour saturation) ΔC^* :

$$\Delta C^* = ((a^*_{i1})^2 + (b^*_{i1})^2)^{0.5} - ((a^*_{i0})^2 + (b^*_{i0})^2)^{0.5} \quad (5)$$

Difference in tone (shade) ΔH^* :

$$\Delta H^* = ((\Delta E^*)^2 - (\Delta L^*)^2 - (\Delta C^*)^2)^{0.5} \quad (6)$$

The obtained results of research were analysed with the use of STATISTICA 13.3 software on the assumed significance level of $\alpha=0.05$. Regularity of distribution (Shapiro-Wilk test) and uniformity of variance in samples (Levene test). Analysis of variance was applied with Duncan test.

Results and discussion

Table 1 shows that all analysed coefficients of assessment of the colour of fries determined with CIE $L^*a^*b^*$ (ΔL^* , Δa^* , Δb^* , ΔE^* , ΔC^* , ΔH^*) method were statistically significant with regard to relations between parameters of radiation of potato bulbs.

Table 1.

Analysis of variance in single classification. Impact of relations between parameters of radiation of potato bulbs on selected coefficients of assessment of the colour of fries determined with CIE $L^*a^*b^*$ (ΔL^* , Δa^* , Δb^* , ΔE^* , ΔC^* , ΔH^*) method

Parameters of analysis of variance	Difference in brightness $\Delta L^*(-)$	Difference $\Delta a^*(-)$	Difference $\Delta b^*(-)$	Total difference in colour $\Delta E^*(-)$	Difference in colour $\Delta C^*(-)$	Difference in tone (shade) $\Delta H^*(-)$
F Snedecor statistics	12.026	13.541	14.082	9.076	14.071	8.501
Test probability	0.000	0.000	0.000	0.000	0.000	0.000

Differences in brightness ΔL^* are within -5.012 and 1.208 (tab. 2), (fig. 2). Values of differences in brightness occurring in particular relations were divided into two homogenous groups: group (a) (0-3, 0-4, 1-3, 1-4, 2-3, 2-4) and group (b) (0-1, 0-2, 1-2, 3-4) tab. 2. All values of the homogeneous group (b) assume negative values and this indicates that in these relations between parameters of radiation fries darkened. While, values of difference in brightness of fries in relations 0-1 and 0-2 are positive, thus, they become slightly lighter.

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Values of difference in brightness of fries in the remaining relations assume low negative values, which results in slight differences in brightness.

Table 2.

Average values of selected coefficients of assessment of colour of fries determined with CIE $L^*a^*b^*$ (ΔL^* , Δa^* , Δb^* , ΔE^* , ΔC^* , ΔH^*) method

Relations between the parameters of radiation	Difference in brightness $\Delta L^*(-)$	Difference $\Delta a^*(-)$	Difference $\Delta b^*(-)$	Total difference in colour $\Delta E^*(-)$	Difference in colour $\Delta C^*(-)$	Difference in tone (shade) $\Delta H^*(-)$
0-1	1.208 _(b)	-5.031 _(c)	6.678 _(c)	14.110 _(b,d)	7.252 _(c)	4.586 _(a,b)
0-2	0.566 _(b)	-4.265 _(c)	2.662 _(b,c)	13.574 _(b,d)	3.180 _(b,c)	4.148 _(a,b)
0-3	-3.651 _(a)	3.689 _(a)	-16.217 _(a)	18.015 _(a,b)	-16.092 _(a)	5.585 _(b,c)
0-4	-3.804 _(a)	3.592 _(a)	-16.045 _(a)	17.650 _(a,b)	-15.926 _(a)	5.496 _(a,b,c)
1-2	-0.6429 _(b)	0.767 _(a)	-4.016 _(b)	8.304 _(d,e)	-4.071 _(b)	3.487 _(a,b)
1-3	-4.859 _(a)	8.720 _(b)	-22.895 _(a)	28.404 _(c)	-23.343 _(a)	9.583 _(e)
1-4	-5.012 _(a)	8.623 _(b)	-22.723 _(a)	25.029 _(a,c)	-23.178 _(a)	7.232 _(c,d)
2-3	-4.217 _(a)	7.954 _(b)	-18.879 _(a)	22.054 _(a,c)	-19.272 _(a)	7.577 _(c,d,e)
2-4	-4.370 _(a)	7.857 _(b)	-18.707 _(a)	24.169 _(a,c)	-19.106 _(a)	8.928 _(d,e)
3-4	-0.153 _(b)	-0.097 _(a)	0.172 _(b,c)	6.427 _(e)	0.166 _(b,c)	3.121 _(a)

(a),...(e) -Homogeneous groups

Figure 2. Impact of radiation parameters of UV-C rays on difference in brightness ΔL^* of fries

Values of differences in chromaticity of Δa^* parameter: are within -5.031 to 8.720 (tab. 2, fig. 3). Values of difference of chromaticity of Δa^* parameter that occur in particular relations between radiation parameters were divided into three homogeneous groups: group (a) (0-3, 0-4, 1-2, 3-4), group (b) (1-3, 1-4, 2-3, 2-4) and group (c) (0-1, 0-2) (tab. 2). Small values of difference of chromaticity of Δa^* parameter, homogeneous groups (a) prove a slight change of this parameter and cause a slight increase of intensity of the colour of fries towards a red colour. Values of differences in chromaticity of Δa^* parameter: distinguished in a group (b) show a clear increase of the colour of fries towards a red colour (increase in browning). Negative values of difference of chromaticity of Δa^* parameter in group (c) justify a difference in the colour of fries towards a green colour.

Figure 3. Impact of radiation parameters of UV-C rays on difference in brightness Δa^* of fries

Values of differences of chromaticity of Δb^* parameter are from -22.895 to 6.678 (tab. 2, fig. 4). Values of difference of chromaticity of Δb^* parameter that occur in particular relations between radiation parameters were divided into three homogeneous groups: group (a) (0-3, 0-4, 1-3, 1-4, 2-3, 2-4), group (b) (0-2, 1-2, 3-4) and group (c) (0-1, 0-2) (tab. 2). Considerable negative values of chromaticity of Δb^* parameter in the homogeneous group (a) prove that the colour of fries in relations between radiation parameters aims at the change in colour towards blue. Relating a direction of the change of difference in chromaticity of Δa^* parameter of the homogeneous group (b) and a change of difference in chromaticity of Δb^*

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parameter of a homogenous group (a) (relations: 1-3, 1-4, 2-3, 2-4) and a difference in brightness of fries ΔL , for these relations, maintains changes of the colour of fries towards a lesser brightness and the increase of browning. Values of difference in chromaticity of Δb^* parameter in the homogeneous group (b) prove slight changes of the colour (rather towards yellow) while from group (c) a considerable change of the colour towards yellow.

Figure 4. Impact of radiation parameters of UV-C rays on difference of chromaticity of parameter Δb^* of fries

Values of the total difference in colour ΔE^* change from 6.427 to 28.404 (tab. 2) (fig. 5) and they are included in the considerable colour deviation (above 5) recognised even by a non-experienced person (Wrolstad, Smith 2010). Value of the total difference in colour ΔE^* were divided into five homogeneous groups: group (a) (0-4, 0-3, 2-4, 1-4), group (b) (0-2, 0-1, 0-4, 0-3), group (c) (2-3, 2-4, 1-4, 1-3), group (d) (1-2, 0-2, 0-1), group (e) (3-4, 1-3). Values of the total difference of colour ΔE^* : of homogeneous groups (a, b, c) indicate that recognisability of a difference in colour of fries with sight for those relations between parameters of radiation of bulbs is noticeably clear and easy to determine.

Values of difference in colour (changes of colour intensity) ΔC^* are within -23.343 and 7.252 (tab. 2, fig. 6). Values of difference in colour ΔC^* parameter were divided into three homogeneous groups: group (a) (1-3, 1-4, 2-3, 2-4, 0-3, 0-4), group (b) (1-2, 3-4, 0-2) and group (c) (3-4, 0-2, 0-1). In the homogeneous group (c) differences of colour assumes positive values, thus it may be said that it results in the increase of intensity of reception of the colour of fries. The remaining values ΔC^* were negative and this proves a decrease of intensity of the reception of the colour.

Figure 5. Impact of radiation parameters of UV-C rays on the total difference in brightness ΔE^* of fries

Figure 6. Impact of radiation parameters of UV-C rays on the difference in brightness (change of intensity of colour) ΔC^* of fries

Values of difference in tone (shade) ΔH^* of the colour of fries were within 3.121 and 9.583 (table 2, fig. 7). Values of ΔH^* due to relations between parameter of bulbs were divided into five homogeneous groups: group (a) (3-4, 1-2, 0-2, 0-1, 0-4), group (b) (1-2, 0-2, 0-1, 0-4, 0-3), group (c) (0-4, 0-3, 1-4, 2-3), group (d) (1-4, 2-3, 2-4), group (e) (2-3, 2-4, 1-3). Values of a difference in shade ΔH^* acc. to the standard ISO 12647-7 assumes a maximum tolerance in basic colours at the level of 2.5. In particular homogeneous groups, visible differences in shade appear.

Figure 7. Impact of radiation parameters of UV-C rays on difference in tone (shade) ΔH^* of fries

Ultraviolet in the band C - one of the most active physical factors that induces mutations permeate the potato bulb to the depth of periderm of about 2 mm and directly adjusting pulp (Jakubowski et al., 2015). Thus, significant changes in the course of biochemical processes caused by UV-C radiation should be searched for around periderm Reddivari et al., (2007) emphasise that activity of ultraviolet on biological material causes its photochemical reaction in the form of photoisomeration which may cause a transformation of flavonoids into its another isomer as a result of photons activity. Permission of UV-C into tissue and its dispersion causes the state of particle induction which leads to the phenomenon of ejection of electrons from external orbits to the levels of higher energy. This results in formation of pyrimid dimers which dislocate DNA structure disabling thus a correct course of replication. According to information provided by Slimestad et al., (2008) flavonoids (polyphenols, $C_6C_3C_6$) play a protective function against UV radiation and have antioxidant properties. This ability may thus stop or delay the oxidation process of some substances in a plant (Xiuhong et al., 2012). If an assumption is made that UV-C influences a plant not only mutagenically but also

causes an abiotic stress, then, because of such activity, metabolism may change into increase of production of secondary metabolites - as the mentioned flavonoids. Contents of polyphenols in potato bulbs is within 5.21 and 6.69 mg·100 g⁻¹ of fresh mass of flavonoids (mainly kaempferol, myricetin, luteolin). (Xiuhong et al., 2012, Ezekiel et al., 2013, Albishi 2013, Rytel et al., 2014 Wierzbicka et al., 2015). UV-C may, thus influence not only formation of flavonoids but also processes of transformations of simple sugars related therewith. This radiation may directly influence the reduction of simple sugars or its activity triggers mechanisms supporting sugars flushing by immersion in water. The effect of such a described permissible mechanism would be a change of the colour of fries after its thermal processing.

Conclusions

1. Relations between a control sample and parameters of radiation of bulbs 1, 2 carried out two days before formation of intermediate products indicate the increase of the brightness of fries, change of colour of fries towards green and yellow with a clear recognizability of a difference in colour, increasing intensity of colour reception and the slightest visible difference in shade.
2. Relations between the control sample and parameters of radiation of bulbs 3, 4 carried out two days before the period of storing indicate the increase of the brightness of fries, change of colour of fries towards red and blue with a clear recognizability of a difference in colour, decreased intensity of colour reception and a visible difference in shade.
3. The biggest changes (in absolute values) of the investigated coefficients of the assessment of the fries colour determined with CIE L*a*b* (ΔL^* , Δa^* , Δb^* , ΔE^* , ΔC^* , ΔH^*) method occurred in relations between parameters of radiation of bulbs (1-3, 1-4, 2-3, 2-4).

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WPŁYW PARAMETRÓW NAŚWIETLANIA BULW ZIEMNIAKA ULTRAFIOLETEM W PAŚMIE C NA WYBRANE WSPÓŁCZYNNIKI OCENY BARWY FRYTEK WYZNACZONE METODĄ CIE L*a*b*

Streszczenie. Ocena barwy, z wykorzystaniem jej wielu parametrów, wykorzystywana jest w odniesieniu do oceny zmian jakościowych produktów, wynikających z zastosowania określonych zabiegów technologicznych. W pracy badano efekty relacji pomiędzy parametrami naświetlania bulw ziemniaka ultrafioletem w paśmie C na wybrane współczynniki oceny barwy frytek wyznaczone metodą CIE L*a*b*. Wykazano statystycznie istotny wpływ naświetlania UV-C na jasność frytek, zmianę barwy, rozpoznawalność różnicy barwy oraz intensywność odbioru barwy. Analizę statystyczną wyników wykonano na założonym poziomie istotności $\varepsilon = 0,05$.

Słowa kluczowe: ziemniak, ultrafiolet, barwa, frytki, CIE L*a*b*