

Application of the CIE L*a*b* method for the evaluation of the colour of fried products from potato tubers exposed to C band ultraviolet light

Piotr Nawara^{1*}, Tomasz Jakubowski¹, Zygmunt Sobol¹

¹ Institute of Machinery Management, Ergonomics and Production Processes, University of Agriculture in Krakow

Abstract. Colour evaluation, using its numerous parameters, is applied to assess qualitative changes of products resulting from the use of specific technological treatment. The study investigates the possibility of using the CIE L*a*b* method to determine selected colour coefficients of fried potato products. Statistical analysis of the results was performed at the assumed significance level of $\alpha = 0.05$. It was demonstrated that the method proposed (CIE L*a*b*) is effective in evaluating the colour of French fries modified with the use of raw material exposed to ultraviolet radiation in the C band.

1 Introduction

Colour in the food industry is an identifier used by producers, processing engineers as well as consumers. The colour analysis was carried out by Przybylski and Jaworska (2008) in order to select high quality pork meat. Zapotoczny and Zielińska (2005) investigated the change in the colour of heterogeneous material including carrot roots, Śmigielska et al. (2013) investigated the effect of using starch as a thickener on the colour change of ketchup. Tomaszewska and Neryng (2007) determined the colour of finished potato products, obtained with varying heat treatment parameters and storage time, and prepared with the aid of the rapid cooling technology. Used increasingly for the colour description, the CIE L*a*b* model is a tool which can be applied to analyse the quality of fruits, vegetables, dairy products and potatoes (Maskan 2001, Pedreschi et al. 2006, Rój, Przybyłowski 2012, Sansano et al. 2015). The CIE L*a*b* model has a significant advantage over other systems since it uses a separate brightness channel and chromatic components giving an indication of the content of one of the following colours: green, purple-red, blue and yellow (Pytko 2010, Kowalczyk et al. 2018, Cupiał et al. 2018). Ultraviolet radiation in the C-band (wavelength 253.7 nm) has bacteriostatic (also virostatic) properties and its applications include the food industry (Corrales et al. 2012) and plant protection (patent US 2009/0272029 A1). Destructive influence of ultraviolet in

* Corresponding author: Piotr.Nawara@urk.edu.pl

the C-band was found (Aiking et al. 2009) on the pathogens of cultivated plants including: *Botrytis cinerea* L. and *Phytophthora citricola*. L. Páez et al. (2011) used ultraviolet in the C-band as germicidal treatment for maize grains (*Zea mays* L.) of San Juan and H-159 hybrids. UV-C was also used to determine its effectiveness as a germination inhibitor of seed potatoes - Cools et al. (2014).

The objective of the study was to examine the possibility of using the CIE $L^*a^*b^*$ method to determine selected colour coefficients of fried potato products resulting from exposure of the raw material to ultraviolet radiation in the C band.

2 Material and methodology

The colour of the fried product was evaluated by applying the CIE $L^*a^*b^*$ method to fries. Instrumental colour measurement was applied at which the following component values were recorded: L^* – brightness, chromaticity, a^* – (from red to green), b^* – (from yellow to blue). Figure 1A shows the configuration of a colour test bed consisting of a Basler aca-4600-10uc camera connected to a computer by means of the U3-PCIE1XG205 card supported by the Pylon 5 software. Prior to the test, the camera had been calibrated with a control palette of white and black (Fig. 1, B) placed against the white background in order to reproduce the colour correctly. The Basler aca-4600-10uc camera features an Aptina MT9F002 CMOS sensor with a resolution of 4608 px x 3288 px and a pixel size of 1.4 μm x 1.4 μm . Then, using the LabView2015 graphic programming environment, the CIE $L^*a^*b^*$ colours were determined in 3 points of the examined objects. 12 colour measurements were taken on each object.

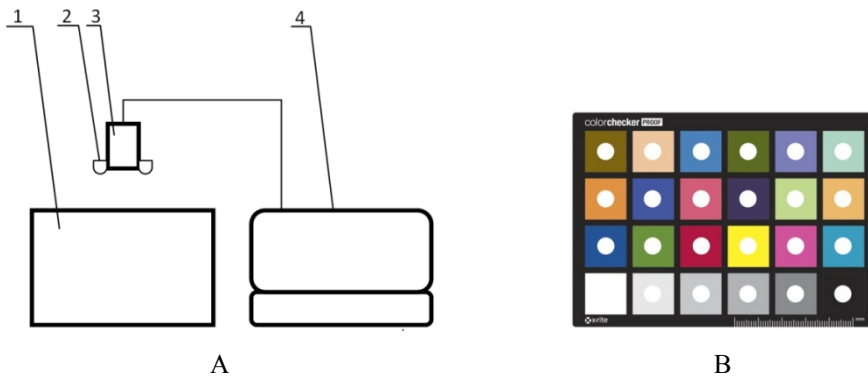


Fig. 1. A- test bed configuration: 1-chamber, 2-lighting, 3-camera, 4-computer, B - reference colour palette: X-Rite ColorChecker PRO

The tests were performed at the ambient temperature of 20°C. Each object of the study was analysed for colour against a white background. For each experiment combination, 10 fries were measured in two replications.

Based on the values of colour parameters L^* , a^* , b^* , the following values were calculated (7):

ΔL^* brightness difference:

$$\Delta L^* = L^*I - L^*0 \quad (1)$$

Δa^* parameter chromaticity difference:

$$\Delta a^* = a^*I - a^*0 \quad (2)$$

Δb^* parameter chromaticity difference:

$$\Delta b^* = b^*1 - b^*0 \quad (3)$$

ΔE^* total colour difference:

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

ΔC^* colour difference (change in colour saturation):

$$\Delta C^* = [(a^*1)^2 + (b^*1)^2]^{0.5} - [(a^*0)^2 + (b^*0)^2]^{0.5} \quad (5)$$

ΔH^* difference in tone (shade):

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

Storage and laboratory experiments were carried out in the years 2016-2017. Potato tubers of the Innovator variety were used as the material for the test. The Innovator variety is one of the most popular species used for French fries by European and Polish companies (Lisińska 2006). It is an early, culinary B type variety with regular and oblong tubers, shallow eyes and average starch content of 14.6%. That variety is highly resistant to darkening of the raw flesh and, after cooking, it is good for storage. The tubers were stored in a cold store, in single layers on an openwork surface. The storage temperature was 10°C and the relative humidity was 90-95%. The semi-products for potato fries were potato sticks with a cross-section of 10x10 mm and a length of 60 mm. The sticks were cut along the longest axis of the tubers, determined between the apical and umbilicus part. The tests were carried out after 3 months of storage. The frying temperature was 170°C and the frying time was 15 minutes. The fries were fried in single stage to achieve the appropriate sensory qualities for the finished product. The charge (semi-finished products) to frying fat weight ratio was 1:15. The frying time was determined in a separate preliminary experiment, analysing the sensory feelings of a group of people evaluating them. Fried French fries were drained from excess oil in two stages: 1 - on a mesh shaking surface, 2 - on paper absorbent material.

The chamber for UV-C irradiating of the biological material is equipped with a TUV UV-C NBV 15 W radiator (Jakubowski et al. 2012, 2013, 2015). The radiator is able to smoothly adjust the height above the chamber bottom in the range from 0.4 to 1.0 m. The test bed is equipped with a precise timer (model AURATON 100). During irradiation, the potato tubers were located on a flat metal bottom with an area of 0.52 m². The UV-C irradiation of potato tubers was varied by adopting the following parameters: (1, 3) – 30 min. exposure on one side of the tuber, (2, 4) – 15 min. exposure at two opposite sides of the tuber, 0 – validation test (without irradiation). The irradiation was performed two days before preparing the semi-products (1, 2) and before storage (3, 4).

The results obtained were analysed using the STATISTICA 13.3 package at the assumed significance level of $\alpha=0.05$. Tested was the normality of distribution (Shapiro-Wilk test) and homogeneity of variance (Levene test). An analysis of variance with the Duncan test was used.

3 Results and discussion

According to Table 1, all the colour evaluation ratios of fries analysed, determined by the CIE $L^*a^*b^*$ method (ΔL^* , Δa^* , Δb^* , ΔE^* , ΔC^* , ΔH^*), were statistically significantly varied, depending on the relationships between exposure parameters of potato tubers.

Table 1. Analysis of variance in a single classification. The effects of the relationships between the parameters of potato tuber exposure on the selected colour evaluation ratios of the French fries determined by CIE L*a*b* method (ΔL^* , Δa^* , Δb^* , ΔE^* , ΔC^* , ΔH^*)

Parameters analysis of variance	Difference of brightness $\Delta L^*[-]$	Difference $\Delta a^*[-]$	Difference $\Delta b^*[-]$	Total colour difference $\Delta E^*[-]$	Colour difference $\Delta C^*[-]$	Difference in tone (shade) $\Delta H^*[-]$
Statistics F Snedecor	12,026	13,541	14,082	9,076	14,071	8,501
Probability of testing	0,000	0,000	0,000	0,000	0,000	0,000

The differences in brightness ΔL^* range from -5012 to 1 208 (Table 2). In the differences in the brightness of french fries in relationships 0-1 and 0-2 are positive, so to a small degree there is an increase in their brightness. Values of differences in brightness in relations with other brightness. The value of the tone difference (shade) ΔH^* according to ISO 12647-7 is tolerable in the base colours at 2.5. In each homogeneous group, there are differences in tone.

Table 2. Average values of the selected colour evaluation ratios for French fries determined by the CIE L*a*b* method (ΔL^* , Δa^* , Δb^* , ΔE^* , ΔC^* , ΔH^*)

Relations between exposure parameters	Difference of brightness $\Delta L^*[-]$	Difference $\Delta a^*[-]$	Difference $\Delta b^*[-]$	Total colour difference $\Delta E^*[-]$	Colour difference $\Delta C^*[-]$	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

Conclusions

1. The CIE L*a*b* method is effective in evaluating the colour of French fries modified with the use of raw material exposed to ultraviolet radiation in the C band.
2. The smallest changes (in absolute values) of the fries colour evaluation ratios determined by the CIE L*a*b* method (ΔL^* , Δa^* , Δb^* , ΔE^* , ΔC^* , ΔH^*) occurred in the relationships between the parameters of tuber exposure (0-1, 0-2, 1-2, 3-4), while the greatest changes were found in the relationships (1-3, 1-4, 2-3, 2-4).

References

1. A. Aiking, F. Verheijen, Methods for treating live plants or live plant parts or mushrooms with UV-C light. Clean Light Wageningen, US 2009/0272029 A1, 5 November 2009, Numer zgłoszenia: 12/083,994
2. T. Albishi, J. A. John, A. S. Al-Khalifa, F. Shahidi, J. Funct. Foods **5**, 590–600 (2013).
3. K. Cools, M. Alamar, L. Terry, Postharvest Biology and Technology **98**, 106-114, (2014).
4. M. Corrales, P. Souza, M. Stahl, A. Fernández, Innovative Food Science and Emerging Technologies, **13**, 163-168 (2012).
5. Draft Standard CIE DS 014-4.3/E: 2007- CIE Publication No. 15.2, Colorimetry.
6. R. Ezekiel, N. Singh, S. Sharma, A. Kaur, Food Res. Int. **50**, 487–496 (2013).
7. ISO 12647-7:2016 Graphic technology - Process control for the production of halftone colour separations, proof and production prints -- Part 7: Proofing processes working directly from digital data
8. T. Jakubowski, P. Wrona, Acta Scientiarum Polonorum - Technica Agraria, **11** 1-2, 33–41 (2012).

9. T. Jakubowski, T. Pytlowski, *Agricultural Engineering*, **3** 145, 99-107 (2013).
10. T. Jakubowski, T. Pytlowski, *Agricultural Engineering*, **2** 154, 35-43 (2015).
11. Keutgen, A. J. Pobereżny, J. Wszelaczyńska, E. Murawska, B. Sychaj-Fabisiak, *Inżynieria i Aparatura Chemiczna*, **2**, 86-88 (2014).
12. G. Lisińska, *Zesz. Probl. Post. Nauk Roln.* **511** część I, 81-94 (2006).
13. M. Maskan, *J. Food Eng.*, **48**, 169-175 (2001).
14. C. Páez, M. Reyes, C. Aguilar, F. Pacheco, E. Martíne, A. Orea, J. Bonilla, *Acta Agrophysica*, **18** 2, 375-388 (2011).
15. F. Pedreschi, J. Leo'n, D. Mery, P. Moyano, *Food Research International* **39** 1092–1098 (2006).
16. W. Przybylski, D. Jaworska, E. Czarniecka-Skubina, K. Kajak-Siemaszko, *ŻYWNOŚĆ. Nauka. Technologia. Jakość*, **4**, 59, 43 – 51 (2008).
17. K. Pytka, *Archiwum Fotogrametrii, Kartografii i Teledetekcji*, **21**, 341–351 (2010).
18. L. Reddivari, J. Vanamala, S. Chintharlapalli, S. H. Safe, J. C. Jr. Miller, *Carcinogenesis. Anthocyanin fraction from potato extracts is cytotoxic to prostate cancer cells through activation of caspase-dependent and caspase-independent pathways* (2007).
19. E. Rytel, A. Tajner-Czopek, A. Kita, M. Aniołowska, A. Z. Kucharska, A. Sokół-Łętowska, K. Hamouz, *Food Chem.* **161**, 224–229, (2014).
20. M. Sansano, M. Juan-Borr'as, I. Escriche, A. Andr'es, A. Heredia, *Journal of Food Science*, **80** 5, 1120-1128 (2015).
21. R. Slimestad, T. Fossen, M. J. Verheul, *J. Agric. Food Chem.* **56**, (2008).
22. H. Śmigielska, J. Lewandowicz, J. Le Thanh-Blicharz, *ŻYWNOŚĆ. Nauka. Technologia. Jakość*, **2** 87, 137 – 149 (2013).
23. M. Tomaszewska, A. Neryng, *ŻYWNOŚĆ. Nauka. Technologia. Jakość*, **3** 52, 173 – 183 (2007).
24. A. Wierzbička, E. Hallmann, M. Grudzińska, *Fragm. Agron.* **32** 4, 81–88 (2015).
25. Keutgen, A. J. Pobereżny, J. Wszelaczyńska, E. Murawska, B. Sychaj-Fabisiak, *Inżynieria i Aparatura Chemiczna*, **2**, 86-88, (2014).
26. R. E. Wrolstad, D. E. Smith, *Color Analysis*. In: *Food Analysis* (Eds. Nielsen S. S.). Springer New York Dordrecht Heidelberg London, 574-586 (2010).
27. J. Xiuhong, L. Rivers, Z. Zielinski, M. Xu, E. MacDougall, J. Stephen, S. Zhang, Y. Wang, R. G. Chapman, P. Keddy, G. S. Robertson, C. W. Kirby, J. Embleton, K. Worrall, A. Murphy, D. D. Koeyer, H. Tai, L. Yu, E. Charter, J. Zhang, *Food Chem.* **133**, 1177–1187 (2012).
28. P. Zapotoczny, M. Zielińska, *Żywność. Nauka. Technologia. Jakość*, **1** 42, 121 – 132, (2005).
29. M. Zielińska, M. Markowski, *Int. J. Food Properties* **15**, 450-466, (2012).
30. Z. Kowalczyk, M. Cupiał, *Contemporary Research Trends in Agricultural Engineering BIO Web Conf.*, **10** (2018)
31. M. Cupiał, Z. Kowalczyk, *Contemporary Research Trends in Agricultural Engineering BIO Web Conf.*, **10** (2018)