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The effect of UV-C stimulation of potato tubers and soaking of potato strips in water on density differences of intermediates for French-fry production

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Abstract: The paper describes the effect of UV-C stimulation of potato tubers and immersing of potato strips in water on differences in density of intermediate products for French-fry production. The density difference used for description of the experiment was defined as a relationship between the post-treatment density and pre-treatment density. The study was conducted on tubers of the Innovator variety. The studies of density changes induced by absorption of water involved measurements of the mass of potato strips in air and in water. Potato strips measured 10 x 10 mm and 60 mm in length. The strips were cut lengthwise along the longest tuber axis set between the proximal and distal tuber end. Water absorption was investigated by immersing strips in water (1) at a temperature of 20°C for 15 min and (2) at 40°C for 20 min. In addition, the study included the group (3) where strips were blanched at a temperature of 90°C for 2 min and a control group (0) which was not immersed in water. Potato tubers were irradiated by UV-C in the following ways: (1) irradiation on one side for 30 min, (2) irradiation on both sides for 15 min each, (0) control group (no irradiation). The studies were conducted at two dates: (0) after harvest and (1) after 3-month storage. Laboratory and storage experiments were conducted in 2016-2017. The density difference was statistically significantly influenced by storage time, UV-C stimulation and immersion conditions of potato strips. The density difference increased with the increase in storage duration of tubers, immersion duration of strips, water temperature (up to starch gelification temperature) and UV-C stimulation.

1 Introduction

Density of potato tubers is a parameter which affects yield of dried and fried potato products. When density increases, energy required for water evaporation during drying and frying of potato products decreases. Density of potato tubers influences quality attributes of French fries and chips, is decisive for fat absorption during frying and significantly influences their consistency [1,2]. Studies of Sobol [3,4] indicate that tuber density increases during storage. It is mostly caused by tuber transpiration and at the end stage of storage process, also by sprout transpiration. Experiments conducted by Sobol [3,4] demonstrate that peeled potato tubers immersed in water absorb it and their density decreases. Dynamics of tuber density reduction caused by water absorption depends of the storage stage. Those studies suggest that to completely reverse the increase in density of a medium size tuber after an 8-month storage, it should be soaked in water for ca. 3.5 h. Tuber density reduction defined as a difference between density after and before water absorption depends also on tuber size, duration of diffusion process in tubers soaked in water, solvent (water) temperature and potato variety [4,5]. Studies of Sobol [6] also indicate that dynamics of reduction of density of intermediates for French fries and chips production caused by water absorption was many times greater compared with changes occurring in whole tubers. The time needed to balance water losses related to tuber transpiration during 8-month storage, for strips for French-fries production was 5.0 – 7.0% of the time needed for whole tubers and 2.-2.5 % for slices for chip production. According to the opinion of Pilarski et al. [7], the solar spectrum reaching the Earth's atmosphere encompasses a very wide range of wavelengths (from several hundreds to several thousands nm). This radiation crosses the atmosphere and undergoes absorption and scattering due to interaction with air atoms, molecules, and airborne aerosols and particles (natural or of anthropogenic origin). Oxygen, both its molecular and atomic form and ozone absorb UV radiation which changes spectrum of light reaching the Earth's surface. This spectrum is almost completely free of UV-C and UV-B radiation

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and contains slight amounts of UV-A. Therefore, in general, UV-C radiation used for agricultural experiments has to be produced by artificial sources. UV radiation as a sterilization method, is currently used for food processing [8,9]. There were also attempts to use this physical method for soil disinfection in tree nurseries [10]. Błażejak et al. [11] performed studies on the use of UV radiation to obtain Gluconacetobacter xylinus mutants which then were applied for biotransformation of glycerol into DHA (the best mutant synthesized 18.00 mg DHA cm^{-3}, i.e. by 32% DHA more than the parent strain). Sławińska et al. [2002] investigated the effect of UV-C radiation on photodegradation of humic acids and demonstrated usefulness of absorption and fluorescence spectroscopy for determination of resistance to ultraviolet radiation-induced degradation. The effect of UV radiation on biological material (soy of the cultivar Augusta) was studied by Szwarc and Skórska [13]. The applied UV irradiation reduced photosynthesis intensity, chlorophyll content and had a negative effect on growth and biomass of above-ground plant parts. It was accompanied by defensive reactions, like increased synthesis of flavonoids and increased activity of antioxidant enzymes (peroxidase and catalase). Allende et al. [14] investigated efficiency of UV-C irradiation in reducing natural microflora inhabiting lettuce leaves. UV-C was also used in procedures aimed to improve quality of onion (Allium cepa L.) and tomatoes (Solanum lycopersicum) during storage [15,16] and asparagus (Asparagus offificinalis L.), especially to reduce pathogen level [17]. As for the potato, Jakubowski and Pytlowski [18] examined the effect of V-C radiation on seed potatoes of the cultivar Jelly and on later ontogenesis of plants. It was shown that irradiation had a significant effect on development of the above-ground parts of potato plants.

The aim of the present studies was to determine the effect of UV-C irradiation of potato tubers and immersion of potato strips in water on differences in density of intermediate products for French fries production at two storage times.

2 Material and Methods

Storage and laboratory experiments were carried out in 2016-2017. The studies were conducted on potato tubers of the variety Innovator. The Innovator potato is one of the most popular varieties used for French-fries production by European, also Polish, companies [19]. It is an early type B variety, with regular tubers round and oval in shape, with shallow eyes, and medium content of starch (14.6 %). This variety is very resistant to darkening of raw flesh and is easily stored after cooking. The studies on density changes induced by water absorption involved measuring the mass of study objects in air and in water. Potato strips measured 10 x 10 mm and 60 mm in length. Strips were cut lengthwise along the longitudinal tuber axis set between proximal and distal tuber end. Absorption process was studied by soaking the potato strips in water (1) at a temperature of 20°C for 15 min and (2) at 40°C for 20 min. In addition, in group (3) strips were blanched at 90°C for 2min. Control strips (0) were not soaked in water. In order to obtain equal measurement conditions, before measurement, the strips were immersed in water and immediately dried (in a two-stage process) using a dry paper towel every time. The same procedure was applied after water absorption was finished and strips were dried in two stages immediately after measurement [3-6]. Calculations of density changes caused by water absorption by potato strips were described in detail in earlier papers by Sobol [3-6]. Difference in density used in description of the experiment was defined as a relationship between post-treatment and pre-treatment density. The studies were conducted at two dates: (0) after harvest and (1) after 3-month storage. A device for UV-C irradiation of biological objects was a cube chamber measuring 0.63 m3 (0.55x0.95x1.2). Its inner walls were made of aluminum (with a high coefficient of reflection). The chamber was equipped with a radiator TUV UV-C NBV 15 W (irradiance of 253.7 nm line at the distance of 1m was 0.42 $W.m^{-2}$, total energy flux of 253.7 nm line was 4.0 W). The radiator was equipped with a reflecting element made of a high quality aluminum with high coefficient of reflection (characteristics similar to mirror). Radiator structure allowed for continuous regulation of the height above the chamber bottom in the range from 0.4 to 1.0 and was equipped with a precise time-lag switch (model AURATON 100). Durability of the UV-C radiator determining stability of parameters of its action was 8000 h. During irradiation, potato tubers were situated on a flat metal bottom with an area of 0.52 m2 (0.55x0.95). Detailed characteristics of the measuring device and method of UV-C irradiation were described in papers by Jakubowski & Wrona [21], Jakubowski & Pytlowski [18]. Potato tubers were irradiated with UV-C in the following ways: (1) irradiation of one side of the tuber for 30 min, (2) irradiation on both sides for 15 min each, and (0) control group which was not irradiated. The stimulation was performed 48 h before cutting potato strips and their immersion in water.

3 Results and Discussion

The three-way analysis of variance demonstrated that all experimental factors, i.e. storage time (1), stimulation (2), immersion conditions of potato strips (3) produced a statistically significant effect on density difference (Tab. 1). The analysis also revealed that two iterations between the experimental factors were statistically significant, namely 1-3 and 2-3.

The effect of storage time (Fig. 1) on density difference was in line with the previous studies by Sobol [3,4,6]. The increase in density difference from |-

0,0034| [g·cm^{-3}] at measurement time (0), i.e. after harvest, to |-0,0061| [g·cm^{-3}] at measurement time (1), i.e. after 3-month storage, was caused by water deficit (increased osmotic pressure) in tubers stored for 3 months vs. measurement after harvest, which developed due to transpiration.

Table 1. Analysis of variance in multiple classification. Effect of storage, stimulation and immersion conditions on the density difference.

Qualitative predictor	Sum of squares	Degrees of freedom	Mean square	F	p
Word free	0,015206	1	0,015206	782,3437	0,000000
{1} Storage term	0,001274	1	0,001274	65,5661	0,000000
{2} Stimulation	0,000163	2	0,000081	4,1914	0,015537
{3} Conditions of immersion of the intermediate	0,011952	3	0,003984	204,9741	0,000000
1*2	0,000111	2	0,000055	2,8526	0,058418
1*3	0,001075	3	0,000358	18,4389	0,000000
2*3	0,000829	6	0,000138	7,1056	0,000000
1*2*3	0,000114	6	0,000019	0,9780	0,439101
Error	0,012595	648	0,000019		

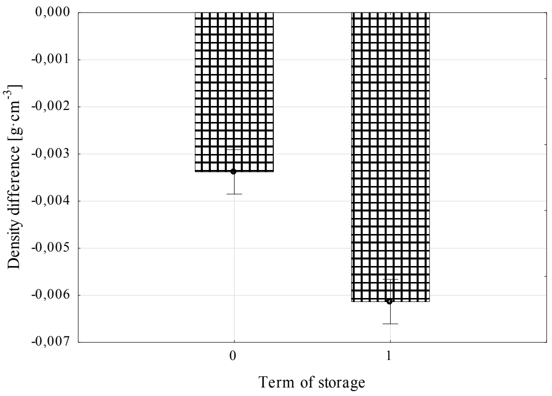

Fig. 1. Effect of storage term on density difference.

Thus, strips cut from tubers stored for 3 months absorbed more water, so a greater density difference was measured. Analysis of the data on the impact of UV-C radiation indicated that irradiation of tubers significantly influenced the density difference of potato strips soaked in water (Tab. 1, Fig. 2).

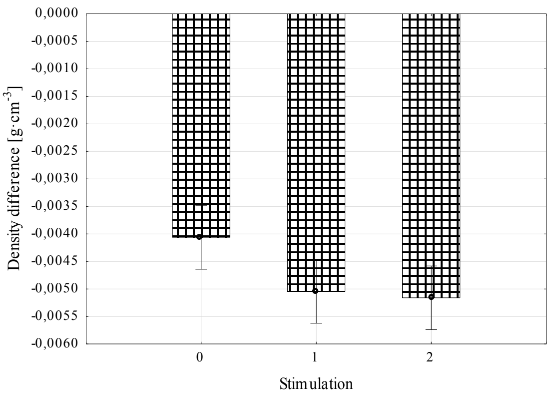

Fig. 2. The effect of the stimulation on the density difference.

The Duncan test (Tab. 2). divided potato strips into two groups depending on the density difference: group 1 comprising strips from stimulated tubers (pooled, irrespectively of stimulation parameters) |-0,0052| [g·cm^{-3}] stimulation 2, |-0,0050| [g·cm^{-3}] stimulation 1, and group 2 containing strips from unstimulated tubers |-0,0041| [g·cm^{-3}].

Table 2. Duncan's test results. Homogeneous groups for stimulation.

Density difference [g·cm^{-3}]			
Stimulation	Mean	1	2
2	-0,0052	****	
1	-0,0050	****	
0	-0,0041		****

Therefore, UV-C stimulation of tubers increased the water absorption effect of strips cut from them. In available literature, the reaction of plants to UV-C is poorly understood. In an attempt to explain the obtained result, namely the UV-C-induced increase in absorption effect of potato strips, it is necessary to analyze possible reactions of biological objects to exposure to ultraviolet radiation because plants developed defensive mechanisms protecting them from its harmful effect. This role is played by flavonoids (flavonols and anthocyanins) able to reduce transmission of UV through epidermis, concomitantly preserving transparency for PAR. Shielding effect protects photosynthetic apparatus and plant parts from DNA damage. Different epidermis formations, like hairs are an additional protective measure because they can scatter up to 70% of incident UV radiation. Besides flavonoids, carotenoids also belong to the dyes able to protect plants from harmful UV effects, due to their antioxidant and reactive oxygen species quenching properties [7,22-24]. UV-C radiation is defined as the

100-280 nm wavelength band. The 100-200 nm wavelength band, called Schumann UV, is not biologically active because it is absorbed by oxygen and water vapor. This limitation causes that biologically active UV-C band is in the 200-280 wavelength range, with the most active 250-270 range (254 nm). This information is important because is allows for focusing on a narrower range in our studies. No information on the effect of absorption (also adsorption) UV-C radiation by potato tubers was found in the available literature. At this stage of research, it can be assumed that the interaction of electromagnetic waves with plant material can be similar to that described in physiotherapy [25]. Following the same reasoning, it can be assumed that the 184.9-290 nm radiation (the range used in phototherapy) penetrates into the potato tuber to the depth of 2 mm (i.e. to a depth of peridermis and directly adjacent flesh). In addition, the irradiated object has to fulfill the Grotthuss-Draper law which states that photochemical transformation in a reactive system can be induced only by radiation absorbed by this system [26-28]. The UV acts on biological material and triggers photochemical reactions (photosynthesis, photolysis, photoisomerization, oxidation, reduction). From the point of view of the present studies, photochemical effect causing photoisomerization seems to be particularly important. This reaction in the potato tuber involves photon-induced transformation of some chemical compounds (organic dyes, like flavonoids) into other isomers [29,30]. Although isomers possess an identical molecular formula as compounds from which they were created, they differ in the sequence and type of atomic bonds, and in stereomeric formula. The above considerations should be treated as hypothetical and as a justification of further studies in this direction. Water immersion conditions had a significant effect on density difference. The greatest difference |-0,011| [g·cm^{-3}] was observed for conditions in which strips were soaked in water at 40°C for 20min. When strips were immersed in water at a temperature of 20°C for 15 min, the density difference was ca. |-0,006| [g·cm^{-3}], while immersion at 90°C for 2min resulted in density difference of |-0,002| [g·cm^{-3}](fig. 3). Such distribution of density difference for soaking strips in water at a lower temperature than starch gelatinization temperature is confirmed by earlier studies by Sobol [5] and result from the following regularities:

- an increase in solvent (water) temperature from 20°C to 40°C caused reduction of its density, thus, the effect of diffusion was more pronounced
- an increase in the time of diffusion (between water and potato strip tissue) elevated density difference.

The lowest difference of strip density was obtained after soaking them in water heated to 90°C for 2 min which resulted from a short duration of diffusion and formation of a layer of gelatinized starch on the strip surface, which formed partly an barrier for water absorption. The Duncan test (Tab. 3) divided the studied strips according to the density difference into three groups, i.e. each combination of soaking conditions statistically significantly influenced the parameter under study.

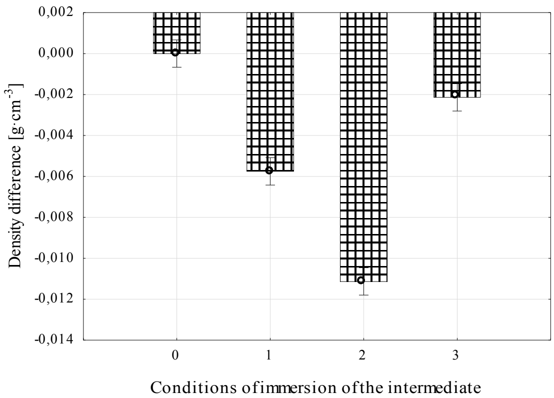

Fig. 3. Influence of immersion conditions on the density differences.

Table 3. Duncan's test results. Groups homogeneous for immersion conditions of intermediates

Conditions of immersion of the intermediate	Mean	1	2	3
2	-0,0111	****		
1	-0,0058		****	
3	-0,0021			****

Detailed analysis of the obtained results (Fig. 4) indicated that the highest density difference |-0,013| [g·cm^{-3}] was obtained for the second combination of soaking conditions, i.e. at 40°C for 20 min.

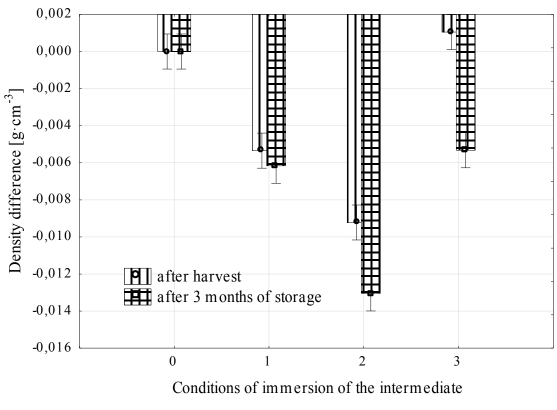

Fig. 4. Influence of immersion conditions of the intermediates, within the storage period, on the density difference.

On the other hand, the highest difference in density change between measurements conducted immediately after harvest and after 3-month storage (ca. |-0,005| [g·cm^{-3}] was obtained for the third combination of soaking conditions, namely at 90°C for 2min. Most probably it was caused both by a high osmotic pressure in cells and low density of water. Analysis of the effect of soaking conditions within groups exposed to different modes of UV stimulation (Fig. 5) on density difference showed that in the second combination of soaking conditions there was a significant difference in this parameter of ca. |-0,005| [g·cm^{-3}] between strips from UV-C-stimulated tubers and unstimulated tubers. No statistically significant diversity in density difference was seen for the remaining combinations of soaking conditions.

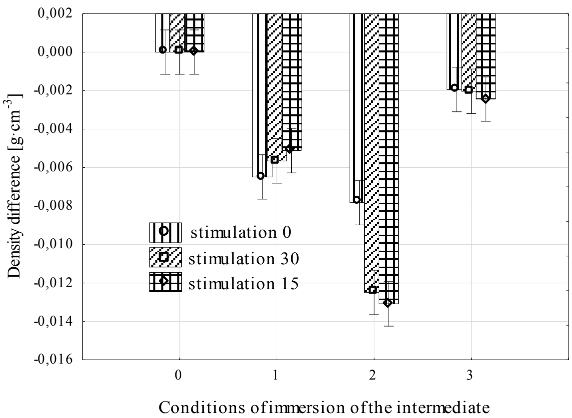

Fig. 5. Influence of immersion conditions of the intermediates, within the applied stimulation, on the density difference.

4 Conclusions

1. Difference in density of potato strips is statistically significantly influenced by storage time, UV-C stimulation and strip soaking conditions.
2. Prolongation of tuber storage increases strip density difference.
3. The used UV-C stimulation of tubers augments difference in strip density.
4. Increase in soaking duration and water temperature (up to starch gelatinization temperature) enhances density difference.

References

1. Sobol Z., Hebda T., Łapczyńska-Kordon B. Technical Sciences, **20(2)** (http://www.uwm.edu.pl/techsci/index.php/no-20-2-2017) (2017)
2. Sobol Z. Agricultural Engineering, Vol. 20, No. **4** , pp.183 -194 (2016)
3. Sobol Z. Acta Agrophysica, **139**, Vol. 8(1), 219-228 (2006a)
4. Sobol Z. Inżynieria Rolnicza, **6(94)**, 231-240 (2007a)
5. Sobol Z. Acta Agrophysica, **142**,Vol. 8 (4), 985-993 (2006 b)
6. Sobol Z. Acta Agrophysica, **151**, Vol. 10(1), 219-228 (2007b)
7. Pilarski; J.; Tokarz; K.; Kocurek; M. Prace Instytutu Elektrotechniki, **256** (2012)
8. Gabriel A. Food Control. 25(2):425–432 (2012)
9. Taze B., Unluturk S., Buzrul S., Alpas H. Journal of Food Science and Technolgy, **52(2)** 1000–1007 (2015)
10. Słowiński, K. Inżynieria Rolnicza, **6(131)**, 207-213 (2011)
11. Błażejak S, Stasiak-Różańska L., Markowski K., Lipińska EActa Sci. Pol., Biotechnologia **10(2)**, 17-24 (2011)
12. Sławińska D., Polewski K. , Rolewski P., Pluciński P., Sławiński J. EJPAU **5(2)**, available online: http://www.ejpau.media.pl/volume5/issue2/environment/art-05.html (2002)
13. Szwarc W., Skórska E. Biuletyn Instytutu Hodowli i Aklimatyzacji Roślin, **245**, 215-221(2007)
14. Allende, J.L. McEvoy, Y. Luo, I. Artes and C.Y. Wang. Food Microbiol. **23** 241-249 (2006)
15. Kasım R., Kasım M. Journal of Agricultural Faculty of Uludag University, **24(1)**, 71-80 (2010)
16. Liu C., Cai L., Lu X., Han X., Ying T. Journal of Integrative Agriculture, **11(1)** 159–165 (2012)
17. Hassenberg, K.; Huyskens-Keil, S.; Herppich, W.B. Journal of Applied Botany and Food Quality, **85(2)**, 174-181 (2012)
18. Jakubowski T., Pytlowski T. Inżynieria Rolnicza. Nr **3** (145). s. 99-107 (2013)
19. Lin Q., Xie Y., Liu W., Zhang J., Cheng S., Xie X., Guan W., Wang Z. J Food Sci Technol. **54(1)** 55–61 (2017)
20. Lisińska G. Zesz. Probl. Post. Nauk Roln. z. **511** część I, 81-94 (2006)
21. Jakubowsk T., Wrona P. Acta Scientiarum Polonorum - Technica Agraria, nr **11** (1-2), 33–41 (2012)
22. Jakubowski, T., Pytlowski, T. Inżynieria Rolnicza, **2(154),** 35-43 (2015)
23. Tevini M In: Tevini M (ed) Lewis, Boca Raton, pp 125–154 (1993)
24. Robin, C.; Hay M.; Newton, P.; Greer, D. Annals of Botany, **74** (1994)
25. Cockeel, C.; Churio, M.; Previtali, C. Biological Reviews **74** (1999)
26. Poon, T.; Barnetson, R.; Halliday, G. Journal of Investigative Dermatology, **125(4)** (2005)
27. Negash, L.; Björn, L., Physiologia Plantarum, **66** (1986)
28. Worrest, R.; Häder, P. Photochemistry and Photobiology, **65(2)** (1997)
29. Reddivari, L.; Hale, A.; Miller, J. Journal of Agricultural Food Chemistry, **55** (2007)
30. Keutgen, A.; Pobereżny, J.; Wszelaczyńska, E.; Murawska, B.; Spychaj-Fabisiak, E. Inżynieria i Aparatura Chemiczna, **53(2)** (2014)