

USE OF UV-C RADIATION FOR REDUCING STORAGE LOSSES OF POTATO TUBERS

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Abstract

Ultraviolet radiation in the C band to limit storage losses of potato was applied. Six edible potato varieties, *viz.*, Lord, Vineta, Owacja, Ditta, Finezja and Tajfun were used as test materials. UV-C radiation was emitted from a 15 W radiator. The wavelength of the light used to irradiate potato tubers was 253,7 nm and the power density from 80 to 100 $\mu\text{W}/\text{cm}^2$. The method of reduction of storage losses of potato tubers, based on their exposure to UV-C irradiation, can complement the presently used methods of potato crop protection during long-term storage.

Storage of potato crops is one of the final steps of production. Preparation of the tubers for storage and storage conditions are crucial for maintaining overall quality of potato tubers offered to consumers. It has been estimated that losses of potato tubers due to improper storage conditions can reach even up to 40% of tuber weight, while losses caused by periderm injuries (resulting in excessive transpiration and respiration) can account for further 10% loss (Wustman and Struik. 2007, Zgórska and Grudzińska 2012, Grudzińska *et al.* 2016). Apart from biological and chemical methods of crop protection during storage, physical methods can also be used to improve tuber condition (Kasyanov *et al.* 2013, Pietruszewski and Martínez 2015, Jakubowski *et al.* 2016). Biochemical transformations occurring during storage in potato tubers exposed to UV-C irradiation were investigated by Hassan *et al.* (2016).

Experiments conducted during 2013 to 2017 aimed to determine, under strictly controlled conditions, the impact of UV-C radiation on growth, development, yield and processes occurring during storage of potatoes (Jakubowski and Pytlowski 2013, Jakubowski and Pytlowski 2015). To achieve the objective, two test stations were constructed for UV-C irradiation of biological material. Test station 1 (Fig. 1) was a cube chamber with a volume of 0.63 m³ (0.55 × 0.95 × 1.2) and inner walls covered with aluminum foil (Jakubowski and Wrona 2012). The chamber was equipped with a UV-C radiator NBV15 (wavelength 253.7 nm and power density 80 - 100 $\mu\text{W}/\text{cm}^2$) with power of 15 W and a precise time-lag switch (Model AURATON 100). A hygro-thermometer (Model 445815) was secured inside the chamber. The UV-C radiator could be placed above the irradiated sample at a distance regulated in the range from 1.0 m to 0.4 m. Lifetime of the UV-C radiator NBV15 determining the stability of parameters of its action was 8000 hrs (radiation intensity of the UV-C radiator at the distance of 1 m was 0.9 W/m²). The radiator was equipped with a reflecting element made of high-quality aluminum with high coefficient of reflection (characteristics similar to mirror). During irradiation, potato tubers were kept on a flat wooden bottom with an area of 0.52 m² (0.55 × 0.95). Test station 2 (Fig. 2) was the same as test station 1 except that it was equipped with a system of replaceable parallel and movable rollers fulfilling the function of the bottom the chamber with an area of 45 - 55 mm (secured on a rail, a distance between rollers could be set at 15 to 25 mm). The rollers were driven by an electric motor system with cooling (and with control of the speed in the range from 20 to 35

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rev/min). Upper side of the chamber allowed for securing more than one UV-C radiator (from below, on a frame). The roller speed was chosen so that potato tubers situated on the rollers were set in rotating as against progressive movement in the direction of turning rollers. Test station 2 and technology for reduction of potato tuber losses during storage were the subject matter of patent

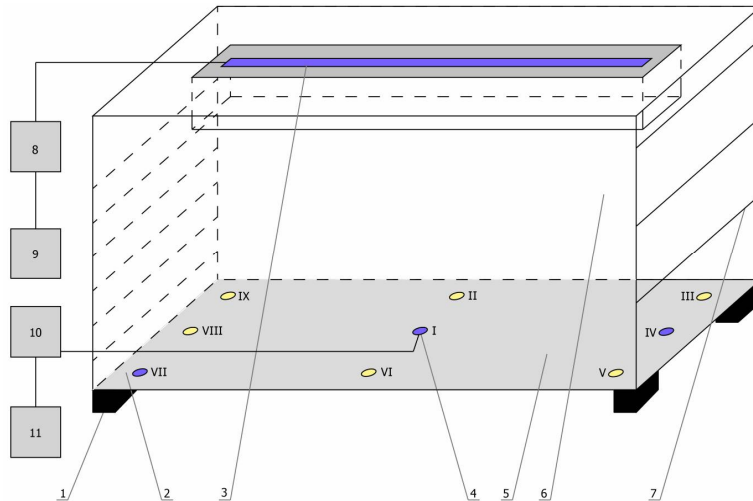


Fig. 1. Test station 1 for UV-C irradiation of potato tubers.

1 - supports, 2 - bottom of the chamber, 3 - UV-C radiator, 4 - location of sensors (I-IX) of temperature, humidity and UV-C intensity, 5 - location of potato tubers, 6 - chamber interior, 7 - regulation of UV-C radiator height, 8 - time-lag switch, 9 - power supply, 10 - multimeter, 11 - data recorder.

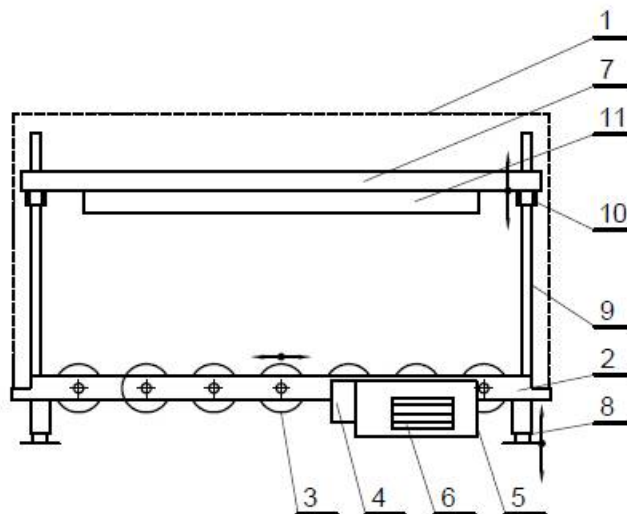


Fig. 2. Test station 2 for UV-C irradiation of potato tubers.

1 - housing of the chamber, 2 - frame of the device, 3 - rollers, 4 - stepless roller speed regulatory mechanisms and a switch, 5 - engine, 6 - engine cooling system, 7 - radiator frame, 8 - stand with regulated height (screw leveling system), 9 - guide rail of radiator's frame, 10 - stepless regulation of the height of UV-C radiators above the bottom of the chamber (rollers), 11 - UV-C radiators.

application filed in the Polish Patent Office. The main strength of the construction of test station 2 was that the whole area of potato tubers could be irradiated without the need to manually turn them on the bottom of the chamber. The experiment was conducted in compliance with methodology of agricultural studies, and statistical analysis was based on ANOVA at a significance level of $\alpha = 0.05$.

In 2013, the impact of UV-C irradiation of seed potatoes on the development of potato plants of Jelly variety was investigated (stage 1). Seed potatoes were irradiated in test station 1 for 1, 10 and 60 min at a constant distance of 0.7 m between UV-C radiator and the bottom of the chamber. During vegetation period, the rate of germination, flowering and withering of haulms, and stem length and number were determined. After harvesting the crop structure was evaluated for each plant. This experiment revealed that plants grown from seed potatoes exposed to UV irradiation for 1 min had a quicker germination rate compared to control sample.

Ultraviolet radiation was shown to produce a statistically significant effect on the development of aboveground parts of potato plants which had a greater number of longer stems compared to the control group. However, no differences in the yield of potato tubers were noted between potato plants grown from UV irradiated and control seed potatoes (Jakubowski and Pytlowski 2013).

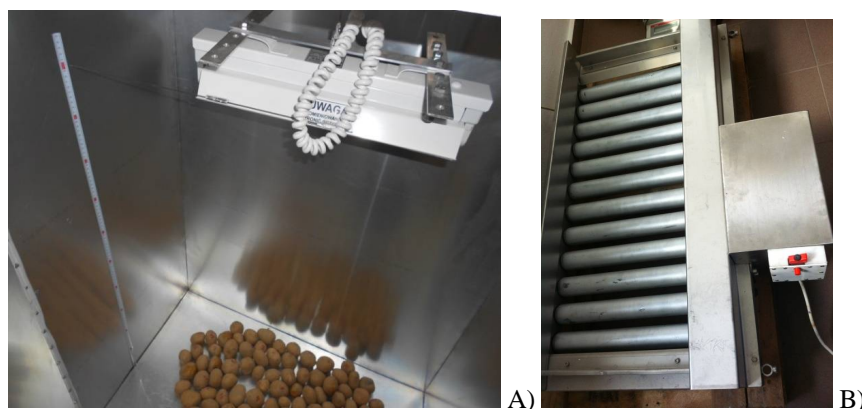


Fig. 3. A photograph of chamber interior in test station I (A) and roller conveyor, the basic component of test station II (B).

The next stage (2) was carried out in the storage season 2015 - 2016. It involved irradiation of Jelly potato tubers prior to storage and determination of weight loss after 5-month storage (unpublished data due to the requirements of filing a patent application in the Polish Patent Office). This stage was conducted also with the use of test station 1. The experiment included the following combinations: Irradiation of tubers from stage I and their storage, irradiation of tubers non-irradiated at stage I and their storage, storage of potato tubers from stage I. In both the above combinations, first tubers were irradiated on one side then they were manually turned over and irradiated on the other side. This experiment included the control group and parameters of chamber operation as at stage I. A positive result of this experiment, i.e. a smaller weight loss vs control group, was evidenced only for tubers irradiated on both sides. The statistically significant effect was obtained for 10 min irradiation. This result justified continuation of research on possibility to reduce potato tuber losses during storage by UV-C irradiation. Hypothesis assumed that UV-C irradiation of potato tubers prior to storage would reduce agrophages inhabiting the

periderm which would indirectly reduce storage losses. It was assumed that irradiation at a wavelength 253.7 nm could limit population of pathogens characteristic of storage processes leading to more efficient repair of periderm damage caused during mechanical harvest, transport and pre-storage (Test station 1 was modernized and test station 2 was constructed, Fig. 3).

Table 1. The impact of UV-C irradiation on weight loss of potato tubers during storage (chosen study results*, storage season 2015 - 2016).

Independent variable			Dependent variable
Variety	Combinations	Exposure time of UV-C (min)	loss of weight (%)
Vineta	K1	5	2,1 ^a
		10	1,9 ^a
		15	1,9 ^a
	K2	5	8,9 ^b
		10	9,4 ^b
		15	8,2 ^c
	K3	5	8,1 ^c
		10	6,4 ^e
		15	6,1 ^e
Ditta	K1	5	2,0 ^a
		10	2,1 ^a
		15	1,9 ^a
	K2	5	8,8 ^b
		10	8,6 ^b
		15	8,5 ^b
	K3	5	7,0 ^d
		10	6,2 ^e
		15	6,6 ^e

Snedecor test value $F = 23.11$, assumed significance level $\alpha = 0.05$, a, b, c, d, e - homogeneous groups.

*Lord, Owacja, Finezja and Tajfun - did not show statistically significant changes in mass losses.

To verify the hypothesis, a preliminary study was performed with test station 2 aiming to determine the impact of UV-C on storage losses of potato tubers of Lord, Vineta, Owacja, Ditta, Finezja and Tajfun varieties. One sample comprised of 90 tubers (3 replicates). Potato tubers at full technical maturity were injured by periderm puncture. Tubers were injured with the use of a universal testing machine MTS Insight 2 (Córdova *et al.* 2013) which allows for introducing a pin into potato tuber flesh to produce an injury of exactly the same shape and dimensions regardless of the size, weight or mechanical properties of tubers. The cone-shaped pin ($\phi = 5$ mm) with an apex angle of 60° was pressed into the tuber to a depth of 10 mm. Tubers were injured at three locations, namely at the top, and in the stolon and middle zones. At 24 - 49 hrs after injury, tubers were weighed, UV-C irradiated (for 5, 10 and 15 min, at a constant roller speed of 25 rev/min and a constant height of the radiator above the bottom of the chamber of 0.7 m) and transferred to a storage facility. The samples were stored in compliance with potato tuber storage technology for 5 months. The experiment comprised of 3 combinations: Tubers without visible periderm injury (K1), mechanically injured tubers using MTS insight 2 machine (K2) and mechanically injured tubers using MTS insight 2 machine and UV-C irradiated (K3). After the storage was completed, each tuber was weighed (and the number and weight of sprouts and wastes caused by pathologies - culled tubers were recorded). Natural weight loss was determined as a difference between tuber weight before and after storage. The results demonstrated that the samples exposed to UV-C radiation for 10 and 15 min showed a smaller weight loss compared to K2 sample. Reduction of

weight loss was statistically significant for two potato varieties (Table 1). The greatest number of waste tubers was observed in K2 combination (mean loss of 6.21 tubers which corresponded to 8.1% of sample weight) and the lowest in K1 and K3 samples (2.20 and 2.67 tubers corresponding to 2.1 and 2.8% of sample weight, respectively).

It may be assumed that, besides reduction of pathogen population inhabiting periderm, this phenomenon was caused by reduction of pathogens occurring in a close vicinity of periderm injury. Such action of UV-C could cause not only quicker repair of damage but also could facilitate wound healing supported by tissues of damaged potato flesh (at injury site) thus limiting excessive tuber transpiration (caused by periderm damage).

The method of reduction of storage losses of potato tubers described above, based on their exposure to UV-C irradiation can complement the presently used methods of potato crop protection during long-term storage. The method described above can be recommended mostly in the case of mechanical damage caused by tuber periderm injury due to agrotechnical and logistic procedures (harvest, transport, unloading, etc.). At present, experiments aimed to determine the impact of UV-C radiation on processes occurring in potato tubers during storage are continued and include additional combinations (longer UV-C irradiation, different speed of roller conveyer, different height of the radiator above the bottom of the chamber) and examine the applicative aspect, namely reduction of acrylamide in fried potato products.

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