

**THE EFFECT OF POSTHARVEST HEAT TREATMENT ON THE HEALTH
CONDITION AND CONTENT OF VITAMIN C IN APPLES STORED**

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Abstract

Apples of Idared, Jonagold, Ligol, Šampion and Topaz varieties were subject to thermotherapy in water at temperature of 45, 50, 52, 55°C for 60, 120, 180 and 240 seconds. After three-month storage the content of L-ascorbic acid in fruits was determined by using the spectrophotometric method. After 16-week storage and during so called the simulated trade turnover the fruits were checked for health condition. The research shown a favorable effect of hot baths on health condition of the apples, optimal the temperature range of 45-52°C for 120-180 seconds used in thermotherapy. The content of vitamin C in apples was different depending on variety, treatment temperature and washing time.

Key words: storage diseases, L-ascorbic acid, thermotherapy treatment, apples

1. INTRODUCCION

The regular intake of fresh fruits and vegetables is a common issue in the twenty first century due to advantageous effect on human health (Liu 2003). At the same time more and more attention is paid to fruit protection against pathogens by using environmentally friendly methods (Klein and Lurie 1992, Grahovac et al. 2011). The highest apple losses during storage are caused by infestation with the fungi, namely *Gloeosporium* spp, *Botrytis cinerea*, *Neonectria galligena*, *Penicillium expansum*, *Alternaria alternata* as well *Monilia* spp., that promote fruit rotting (Tian 2007, Kelderer et al. 2010, Maxin et al. 2012). The short time post-harvest fruit immersion in warm water can reduce the occurrence of infectious diseases in storage (Fallik et al. 1996, Schirra et al. 2000, Kelderer et al. 2010). However, the treatment can affect the quality of fruits (Lurie 1998).

Vitamin C belongs to the group of exogenous ingredients necessary for proper functioning of human body and therefore should be delivered with a food. It performs many of crucial functions, including biosynthesis of collagen, catecholamines and metabolism of lipids. Like vitamin E, it is a main antioxidant in human blood and body fluids, has an effect on iron absorption and is assigned an ability to keep cholesterol at specified level as well as a stimulating impact on organism immunity (Borek-Wojciechowska 2007, Silalahi 2002, Wierzbicka and Kuskowska 2002, Wojdyla et al. 2008). Fresh fruits and vegetables are very important source of vitamin C (Melo et al. 2006, Sikora et al. 2008). In Poland apples constitute about 70% of all fruits and are available all year around and rich of various nutrient ingredients, including vitamins (Dyngus 2010, Pyryt and Wrzeński 2011). According to Pyryt and Wrzeński (2011) the content of vitamin C in desert apples ranges between 5 – 18 mg•100 g-1 depending on cultivar. Lee and Kader (2000) think that the abundance of this vitamin in fruits depends on such factors as genotype differences, climate conditions during growing, fertilizing and post-harvest fruit handling (storage temperature, CO₂ concentration, heat treatment). So far there are little research studies on changes of the content of vitamin C in various apple cultivars treated in hot water baths.

The aim of this experiment carried out in the years 2010-2012 at the the Department of Pomology and Apiculture at the University of Agriculture in Kraków was to examine an effect of water temperature

and exposition time during thermotherapy treatment of apples after harvesting on the health condition and on the content of vitamin C in the form of L-ascorbic acid in several apple cultivars.

2. MATERIAL AND METHODS

The examinations covered the four trade leading apple cultivars – ‘Idared’, ‘Jonagold’, ‘Ligol’ ‘Šampion’ and the scab resistant variety Topaz. The fruits were taken from the Department of Pomology and Apiculture at the University of Agriculture in Kraków in Garlica Murowana. The mechanically undamaged apples that showed no disease symptoms were harvested in optimal maturity time from various tree crown parts.

Directly after harvesting the fruits were subject to water bath. For each apple cultivar 16 sets of 60 apples were prepared and successively treated with hot water. The subject of the experiment was both water temperature (45, 50, 52, 55°C) as well as thermotherapy time (60, 120, 180, 240 seconds). After washing the fruits were quickly dried and cooled with air stream generated by fans and then placed in plastic boxes in typical cooler (temperature of 3°C, humidity of 92%) and covered with polyethylene foil to reduce transpiration. The control was untreated fruits.

After three months a sample of 15 apples was taken randomly from each combination. From each fruit two parenchyma parts were taken with skin, one from a coloured side and one from an opposite side and were mixed in oxalic acid to obtain a mixed sample. Three weighed amounts were prepared for each combination of 20 g and moved into measuring flasks of 100 mL in capacity. The samples complemented with an extraction solution were kept in dark for 40 minutes, and then mixed and filtered. The content of L-ascorbic acid was determined spectrophotometrically according to the Polish standard PN-A-04019 (1998) by using the spectrophotometer PHARO 100 of MERC and wavelength = 500 nm. The content of vitamin C was expressed in $\text{mg} \cdot 100 \text{ g}^{-1} \text{ s. m.}$

The obtained results were subject to statistical computations with the variance analysis method by using the NIR Fisher test at the significance level $\alpha = 0.05$. The calculations were made with the computer program STATISTICA 9.

The fruits were checked for overall condition after 16 weeks in storage and during so called the simulated trade turnover. The number of apples showing symptoms of fungal infestation was recorded and expressed in percentage of all stored fruits subject to the same treatment.

3. RESULTS AND DISCUSSION

The thermotherapy treatment used after fruit harvesting can affect their qualitative features (Fallik et al. 1996, Skrzyński 2007). Tahir (2006) showed that heat treatment causes changes in fruit wax envelope that by dissolving can form an uniform structure and submerge fungi spores. Klein i Lurie (1992), and Tahir et al. (2009) think that the fruits exposed to higher temperatures are more compact, better taste and colour. The researches carried out indicate a different effect of thermotherapy treatment used directly after apple harvest on variations in the content of vitamin C in fruits depending on cultivar, treatment temperature and treatment time.

No statistically significant differences compared to the control were found for the Jonagold cultivar treated with water at 45°C for 60, 120 and 180 seconds (Fig. 1), where the content of vitamin C ranged from 15.5 to 17.1 $\text{mg} \cdot 100 \text{ g}^{-1} \text{ s. m.}$ The value of this parameter decreased with increased treatment temperature. The lower values were recorded for exposition time of 240 seconds compared to other treatments – min. content increased up to 10.0 $\text{mg} \cdot 100 \text{ g}^{-1} \text{ s. m.}$

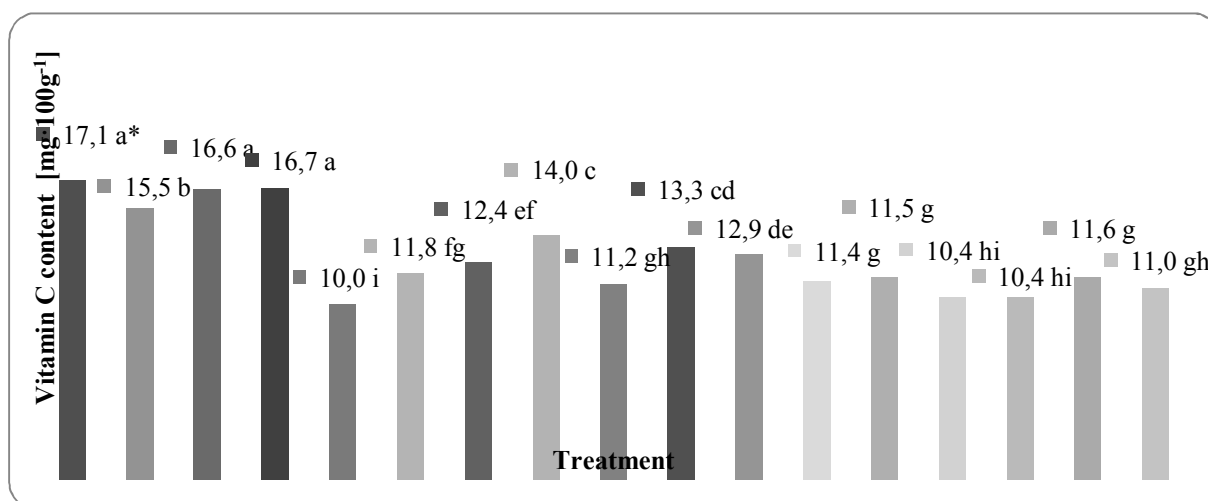


Fig. 1. The content of vitamin C of 'Jonagold' apples in the years 2010-2012;

*means followed by the same letter do not differ at a significance $\alpha = 0.05$

An advantageous effect of treatment at 45°C (regardless of exposition time) compared to the control was observed for cultivars Idared (Fig. 2) and Ligol (Fig. 3). The experiments performed by Trierweilera et al. (2003) showed a similar relationship for the cultivar Elstar treated at 53°C for 120 seconds.

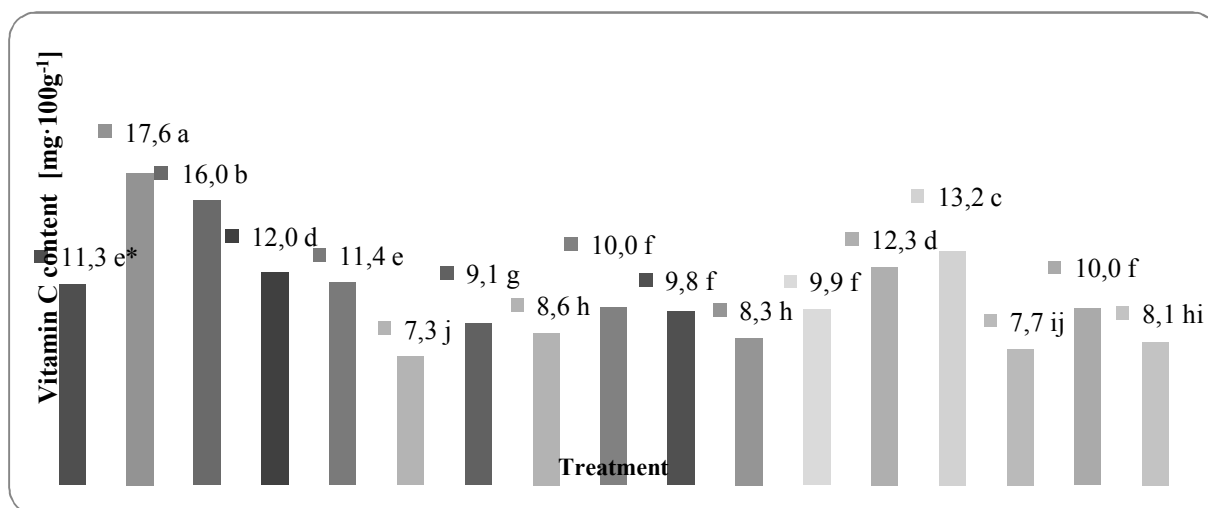


Fig. 2. The content of vitamin C of 'Idared' apples in the years 2010-2012; *see Fig. 1

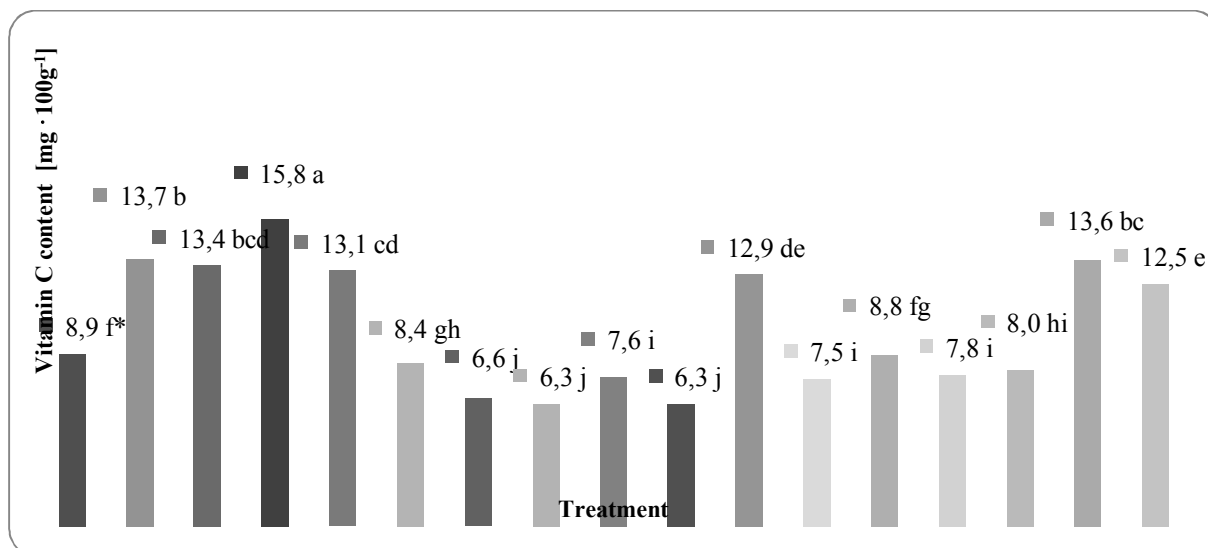


Fig. 3. The content of vitamin C of 'Ligol' apples in the years 2010-2012; *see Fig. 1

However, a significant decrease in the content of vitamin C in washed apples for cultivars under investigation was found for Šampion (Fig. 4) and Topaz (Fig. 5). The cultivar Topaz featured of highly variable effect of temperature and exposition time on the parameter (8.3-19.2 mg·100 g⁻¹ š. m.). The lowest content of vitamin C was recorded for treatments at 52°C/180 s, 52°C/240 s, 55°C/180 s and 55°C/240 s. Also Trierweilera et al. (2003) showed increasing amount of vitamin C by using temperature of 53°C for 120 seconds.

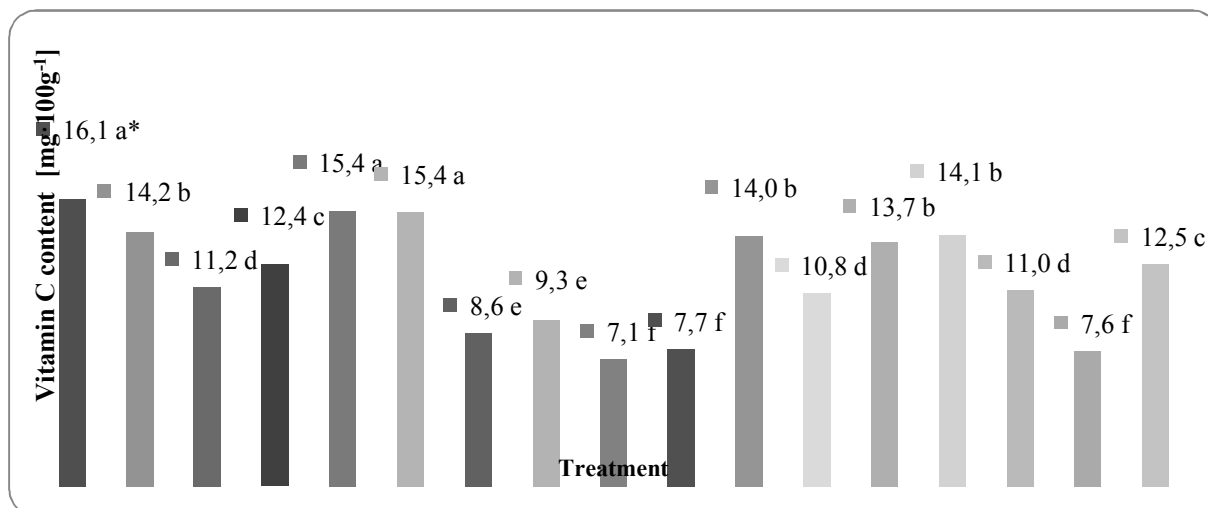


Fig. 4. The content of vitamin C of 'Šampion' apples in the years 2010-2012; *see Fig. 1

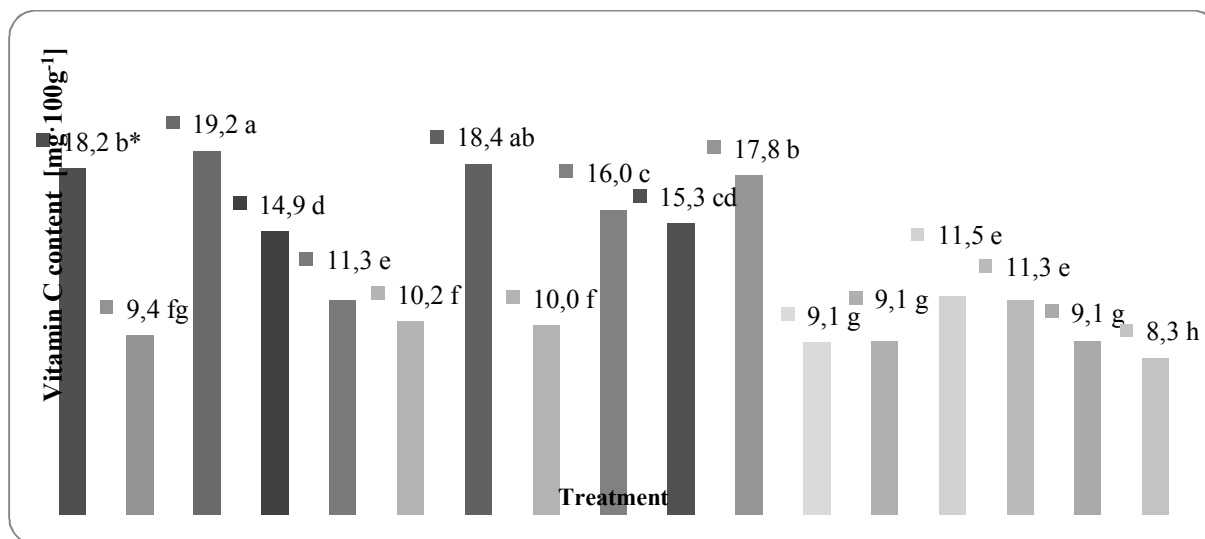


Fig. 5. The content of vitamin C of 'Topaz' apples in the years 2010-2012; *see Fig. 1

The obtained results indicate also that the higher water temperature used during water treatment of apple varieties under investigation, statistically reduce the content of vitamin C in fruits. According Mazurka and Jamroz (2010) vitamin C is susceptible to increasing temperature and belongs to undurable vitamins. So far a few researches on this topic (Trierweiler et al. 2003) indicate that the changes in the content of vitamin C in apples washed in hot water directly after harvesting depend on variety, thus they are consistent with the present paper. Skrzyński (2007) underlines the fact that to optimize the thermotherapy treatment is important to learn an effect of hot baths on quality features of stored fruits.

During the first year of experiment much severe infestation of stored fruits was recorded compared to that of the next analyses season. Most likely this was related to weather conditions in the orchard in individual years. The after-harvest heat treatment had a crucial effect on health state of the 'Ligol' (Table 1) and 'Sampion' (Table 2) cultivars of apples achieved both in storage and simulated trade turnover. The lowest water temperature used (45°C) allowed the reduction of infested apples compared to the control. The effectiveness of thermotherapy as a method of fruit protection against rots during storage was confirmed also, among others, by Fallik et al. (1996), Trierweiler et al. (2003) and Auinger (2005).

Table 1. Percentage infection of 'Ligol' apple with pathogens

Treatment	Number of infected apples [%]			
	1 year		2 year	
	after 16 weeks	simulated trade turnover	after 16 weeks	simulated trade turnover
control	6.0	7.1	4.0	0.0
45°/60s	2.0	2.3	2.0	0.0
45°/120s	2.0	2.3	0.0	0.0

45°/180s	0.0	2.2	0.0	0.0
45°/240s	2.0	0.0	0.0	0.0
50°/60s	0.0	0.0	0.0	0.0
50°/120s	2.0	2.3	0.0	0.0
50°/180s	0.0	0.0	0.0	0.0
50°/240s	0.0	0.0	0.0	0.0
52°/60s	0.0	0.0	2.0	0.0
52°/120s	0.0	2.2	0.0	0.0
52°/180s	0.0	0.0	0.0	0.0
52°/240s	0.0	0.0	0.0	0.0
55°/60s	0.0	2.2	0.0	2.2
55°/120s	0.0	0.0	0.0	0.0
55°/180s	0.0	0.0	0.0	0.0
55°/240s	0.0	0.0	0.0	0.0

Table 2. Procentage infection of 'Šampion' apple with pathogens

Treatment	Number of infected apples [%]			
	1 year		2 year	
	after 16 weeks	simulated trade turnover	after 16 weeks	simulated trade turnover
control	9.1	6.7	7.3	4.4
45°/60s	5.5	0.0	7.3	0.0
45°/120s	7.3	0.0	3.6	0.0
45°/180s	0.0	4.0	3.6	4.2
45°/240s	3.6	0.0	0.0	4.0
50°/60s	5.5	0.0	7.3	4.4
50°/120s	1.8	0.0	3.6	0.0
50°/180s	0.0	0.0	0.0	4.0
50°/240s	0.0	0.0	0.0	8.0
52°/60s	5.5	0.0	0.0	0.0
52°/120s	0.0	0.0	0.0	0.0
52°/180s	1.8	0.0	0.0	0.0
52°/240s	0.0	2.0	3.6	0.0
55°/60s	0.0	0.0	0.0	4.0
55°/120s	0.0	0.0	0.0	0.0
55°/180s	0.0	0.0	0.0	0.0
55°/240s	0.0	0.0	0.0	0.0

However, an adverse effect of treatment temperature of 55°C on quality parameters of 'Šampion' apples was observed. The peel of fruits treated with water at that temperature (regardless of exposition time) was creased already after 16 weeks in storage. A similar effect was noted for the cultivar 'Topaz'. For this cultivar the null fruit infestation was observed in the temperature range 50-55°C for 120-240 s (Table 3).

Table 3. Procentage infection of 'Topaz' apple with pathogens

Treatment	Number of infected apples [%]			
	1 year		2 year	
	after 16 weeks	simulated trade turnover	after 16 weeks	simulated trade turnover
control	16.0	5.9	0.0	0.0
45°/60s	0.0	0.0	0.0	0.0
45°/120s	0.0	0.0	0.0	0.0
45°/180s	8.0	10.5	0.0	0.0
45°/240s	8.0	0.0	0.0	0.0
50°/60s	4.0	4.8	0.0	0.0
50°/120s	0.0	0.0	0.0	0.0
50°/180s	0.0	0.0	0.0	0.0
50°/240s	2.0	0.0	0.0	0.0
52°/60s	0.0	4.6	0.0	0.0
52°/120s	0.0	0.0	0.0	0.0
52°/180s	0.0	0.0	0.0	0.0
52°/240s	0.0	0.0	0.0	0.0
55°/60s	0.0	0.0	0.0	0.0
55°/120s	0.0	0.0	0.0	0.0
55°/180s	0.0	0.0	0.0	0.0
55°/240s	0.0	0.0	0.0	0.0

The null infestation 'Jonagold' fruits was observed in the temperature range 50-55°C for 120-180 s both in storage and simulated trade turnover (Table 4).

Tabele 4. Procentage infection of 'Jonagold' apple with pathogens

Treatment	Number of infected apples [%]			
	1 year		2 year	
	after 16 weeks	simulated trade turnover	after 16 weeks	simulated trade turnover
control	8.0	2.4	8.0	0.0
45°/60s	2.0	0.0	4.0	0.0
45°/120s	2.0	0.0	4.0	0.0
45°/180s	0.0	0.0	0.0	0.0
45°/240s	0.0	0.0	4.0	0.0
50°/60s	2.0	0.0	2.0	0.0
50°/120s	0.0	0.0	0.0	0.0
50°/180s	0.0	0.0	0.0	0.0
50°/240s	2.0	0.0	0.0	0.0
52°/60s	0.0	6.7	0.0	0.0
52°/120s	0.0	0.0	0.0	0.0
52°/180s	0.0	0.0	0.0	0.0
52°/240s	0.0	0.0	0.0	0.0
55°/60s	6.0	0.0	0.0	0.0
55°/120s	0.0	0.0	0.0	0.0
55°/180s	0.0	0.0	0.0	0.0
55°/240s	0.0	0.0	0.0	0.0

For the cultivar 'Idared' there was no reduction in the number of infected fruit treated with hot water in relation to the control (Tabele 5).

Tabele 5. Procentage infection of 'Idared' apple with pathogens

Treatment	Number of infected apples [%]			
	1 year		2 year	
	after 16 weeks	simulated trade turnover	after 16 weeks	simulated trade turnover
control	0.0	2.2	0.0	0.0
45°/60s	4.0	4.7	0.0	0.0
45°/120s	0.0	2.2	0.0	0.0
45°/180s	4.0	0.0	0.0	0.0
45°/240s	0.0	0.0	0.0	0.0

50°/60s	0.0	0.0	0.0	0.0
50°/120s	0.0	0.0	0.0	0.0
50°/180s	0.0	0.0	0.0	0.0
50°/240s	0.0	0.0	0.0	0.0
52°/60s	0.0	2.2	0.0	0.0
52°/120s	4.0	0.0	0.0	0.0
52°/180s	0.0	0.0	0.0	0.0
52°/240s	0.0	0.0	0.0	0.0
55°/60s	2.0	0.0	0.0	0.0
55°/120s	2.0	0.0	0.0	0.0
55°/180s	0.0	0.0	0.0	0.0
55°/240s	0.0	0.0	0.0	0.0

4. CONCLUSIONS

One can conclude that hot water treatment of apples is an effective method for reducing storage losses caused by pathogens. The infestation of tested cultivars apples with fungi was lower in most combinations used compared to that of the control. Safe the temperature range of 45-52°C for 120-180 seconds used in thermotherapy.

A water temperature increase in after-harvest thermal treatment used commonly for the apple cultivars under investigation decreases the content of vitamin C in fruits. The bath at temperature of 45°C for 60, 120, 180 seconds for Idared and Ligol cultivars increase of the content of vitamin C, while no statistically changes were found for the cultivar Jonagold. The thermotherapy decreased statistically significant decreased content of vitamin C in apples 'Šampion' and 'Topaz'.

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