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THE IMPACT OF VARIETIES, RIPENESS, AND HEAT TREATMENT ON THE RETENTION OF VITAMIN C AND CONTENT OF SOLUBLE SOLIDS IN SWEET PEPPER

Magdaléna Valšíková, Marián Rehuš , Patrik Komár, Oleg Paulen

ABSTRACT

In the three-year field trial we have grown six varieties of sweet peppers and we observed a change in the content of soluble solids and vitamin C during aging and after heat treatment with the sterilization. The highest content of soluble solids was found in peppers collected in botanical maturity, where the average was 5.82% in 2012, 6.52 in 2013 and 6.13 in 2014. Lower average, we measured in the intermediate maturity, 4.25 in 2012, 5.2% in 2013 and 4.73% in 2014. The lowest soluble solids content was recorded for fruit harvested in technical ripeness, only 3.57% in 2012, 4.25% in 2013 and 4.10% in 2014. In the technical maturity we determined the average value of vitamin C by the years between 90.98 mg.100 g^{-1} and 103.86 mg.100 g^{-1}. The average in vitamin C content in fresh pepper fruits of intermediate maturity was ranging from 108.81 to 124.65 mg.100 g^{-1}. The highest average values of vitamin C were at the botanical maturity from 171.42 to 188.30 mg.100 g^{-1}. In the average of years and times of harvest it was found that the variety ´PCR´ and ´Slovakia´ had the first and second place in content of vitamin C (146.10 mg.100 g^{-1} – ´PCR´ and 143.72 mg.100^{-1} – ´Slovakia´). The least vitamin C was observed in a variety ´Katrena´ (120.80 mg.100 g^{-1}). For six varieties we have found that in technical maturity retained after sterilization on average 34.0% of vitamin C, in an intermediate maturity 47.16% and 42.10% of botanical maturity. Vitamin C was the highest in sterilized pepper variety of ´Slovakia´ and ´PCR´ in all three stage of maturity. The results show that the pepper is an excellent reservoir of vitamin C, not only in c fresh state, but also after heat treatment.

Keywords: sweet pepper; vitamin C; retention; soluble solids

INTRODUCTION

Paprika belongs to a large group of vegetables and crop plants that are for centuries purposefully selected, cultivated by man for its benefit **(Andrejiová and Kóňa 2010)**. In human nutrition vegetables are important sources of vitamins and minerals. Also contains bioactive substances, such as carotenoids, bioflavonoids and phenolic acids, which have beneficial effects on our health. Also suppress harmful bacteria protect against infections, they may prevent cardiovascular diseases and strengthens the immune system **(Jedlička 2012; Juríková and Balla 2012)**.

Paprika is one of the most valuable vegetables in terms of the high vitamin C content. Considerable amounts are found in Capsicum peppers at any stage of ripening, particularly when fully ripe **(Boslandand and Votava 2000; Rodríguez-Burruezo and Nuez 2006)**. Vitamin C is involved in the antioxidant capacity of peppers **(Hegedűsová et al. 2016)**. Similar context observed authors **Mlček et al. (2015)** on the onions.

Kopec (1998) indicates that the average vitamin C content of red pepper is 161.5 mg.100 g^{-1} and of the green fruit of pepper is 120.0 mg.100 g^{-1}. **Tilahun et al. (2013)** found in several varieties of peppers fresh range from 55.3 to 189.4 mg.100 g^{-1}.

The vitamin C content of fresh edible vegetable parts is variable depending on many factors, e.g. species, variety, maturity, weather conditions, production conditions, the method of post-harvest treatment, duration of storage, storage temperature, a heat treatment process and others **(Škrovánková et al. 2015)**.

In the results the authors **Guiamba et al. (2016)** was preserved in the dried fruit Mango 37.2 to 76.4% of vitamin C when was dried at 50 °C. At a drying temperature of 70 °C, the retention of vitamin C ranged from 51.3 to 60.1%.

A similar experiment was made with their foliage of parsley and celery. Vitamin C was analyzed in fresh, dried and frozen state **(Valšíková et al. 2016)**.

Durability of vegetables may be extended by canning. Pepper is also an important raw material for the processing industry. Sterilization is the most widely used method of preserving peppers.

The goal was to identify differences in the content of vitamin C in fruits of six fresh pepper varieties of different maturity and compared with fruits in a sterilized condition. The stored amount of vitamin C is expressed in % of retention.

MATERIAL AND METHODOLOGY

Field experiment was established in the premises of the complex in the Botanical Garden of Agriculture in Nitra in 2012, 2013 and 2014. In the trials were included six varieties of sweet peppers named: ´Amy´, ´Slovakia´, ´PCR´, ´Semaroh´, ´Katrena´ and ´Alma´. Determination refractive solids and vitamin C was carried out at the Department of vegetable production at Slovak University of Agriculture in Nitra.

Sweet pepper seedlings were grown from sowing, which was held on 24.2.2012, 25.2.2013 and 27.2.2014. Seedlings were planted 5.24.2012, 5.21.2013 and 22.5.2014 in pre-aligned land plot. We planted to spacing of 0.6 x 0.3 m in three repeats **(Valšíková 2014)**. The doses of fertilizers were based on agrochemical soil analysis and according to the normative for pepper **(Uher et al. 2009)**.

Basic information about the field trial:

- Total area of the plots: 32.4 m^2
- Number of varieties: 6
- Spacing: 0.3 x 0.6 m
- Repetitions: 3
- Number of plants in the repetition: 10
- Total number of all plants: 180

During vegetation we collected fruits in three terms - stages of maturity:

1. Technical maturity (green)
2. Transitional maturity (between technical and botanical)
3. Botanical maturity (red)

Growing conditions were identical for all varieties. The pepper fruits were collected for analyzes and sterilization in terms which are in Table 1. At each maturity stage were measured by varieties the refractometric solids and analyzed to determine the content of vitamin C. Part of the collection was preserved by sterilization in the form of pepper slices in glass jars in a volume of 0.7 liters.

Composition of the brine for preservation: water – 68,8%, 8% strength vinegar – 23.6%, table salt – 1.9%, sugar – 5.7%. Sterilization lasted 15 minutes at 80 °C. The canning variants were analyzed vitamin C after 3 months of storage. The vitamin C content was determined by HPLC method and the soluble solids content was measured by a digi refractometer of mark KRÜSS DR201 – 95 in the laboratory of Slovak University of Agriculture in Nitra.

For statistical evaluation were used standard methods using statistical software Statgraphics Centurion XVII (StatPoint Inc. USA) - Multi-factor analysis of variance (MANOVA), LSD test.

RESULTS AND DISCUSSION

Soluble solids

Average soluble solids content in% of fresh paprika fruit reached in all stages of maturity the highest value of a variety ´Semaroh´ and the lowest at variety ´Katrena´. With respect to evaluation years, the highest refractive solids were achieved in 2013 and the lowest in 2012 in all maturity. Green fruits contain the least soluble solids and

Table 1 Table 1 Harvest date in the experimental years.

Year 2012	Year 2013	Year 2014
30.07.2012	31.07.2013	28.07.2014
13.08.2012	19.08.2013	14.08.2014
06.09.2012	10.09.2013	11.09.2014

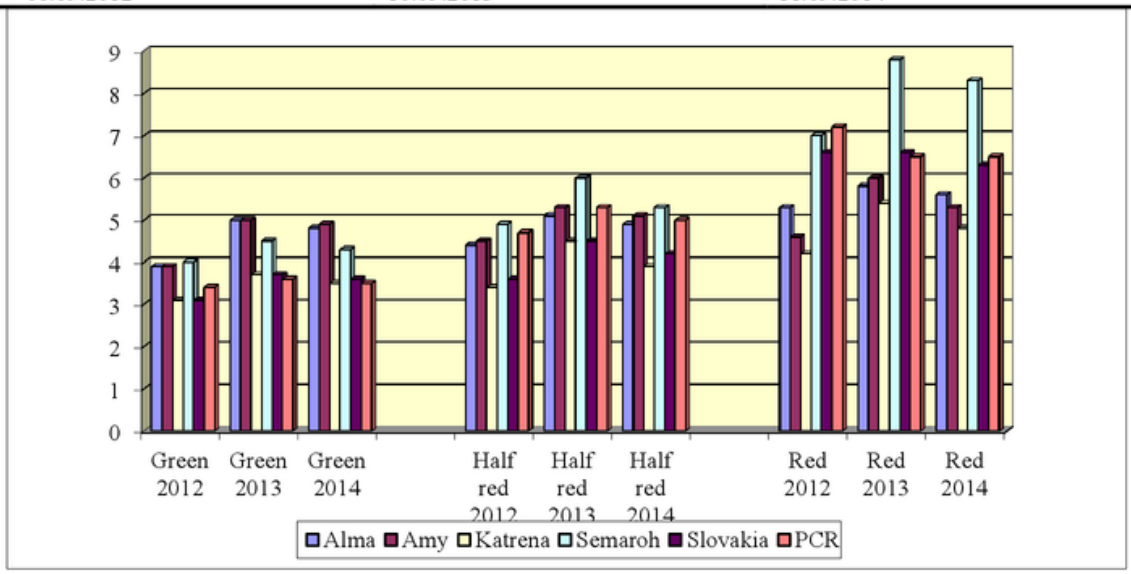

Figure 1 Soluble solids content in fresh peppers by varieties, years and maturity (%).

the most the red fruits in the botanical maturity.

Soluble solids content of all pepper varieties in the experiment tended to increase during the course of vegetation. In the technical maturity has been achieved average of six studied varieties and average of three years 3.97% of soluble solids. In the transitional maturity it was 4.83% and 6.16% in the botanical maturity (Figure 1).

The results show that the soluble solids content in the pepper fruits depend on maturity. Clearly the peppers reached the highest soluble solids content when harvested in botanical maturity. Soluble solids content in the pepper cultivars is consistent with the results of authors **Tomaľová and Valšíková (2012)**, they measured the average value in the range from 1.72 to 6.43%. In soluble solids content in fresh peppers by variants, varieties and years was found significant differences by LSD test, 95%.

Vitamin C in fresh pepper fruits

The average level of vitamin C in fresh pepper fruits at different maturity, varieties and years is documented in the Figure 2. In Table 2 is evaluated significance of differences in the content of vitamin C in fresh fruit, depending on the variants, varieties and years.

In the average of years and times of harvest it was found that the variety ´PCR´ and ´Slovakia´ had the first and second place in content of vitamin C (146.10 mg.100 g^{-1} – ´PCR´ and 143.72 $mg.100^{-1}$ – ´Slovakia´). The least vitamin C was observed in a variety ´Katrena´ (120.80 mg.100 g^{-1}).

In the monitored experiment was found the lowest vitamin C content of fresh peppers in variety of ´Semaroh´ in technical maturity (75.88 mg.100 g^{-1}), closely followed by variety ´Katrena´ where we found 83.13 mg.100 g^{-1}. The results show that vitamin C in fresh pepper fruits grow during the whole vegetation period. The highest value reached in botanical ripeness.

In technical maturity we determined the average value of vitamin C by the years between 90.98 mg.100 g^{-1} and 103.86 mg.100 g^{-1}. The average of vitamin C content in intermediate maturity was ranging from 108.81 to 124.65 mg.100 g^{-1}. The highest average was at the botanical maturity (171.42 to 188.30 mg.100 g^{-1}).

The author **Michalik (2010)** was found the three-year average range in the dry matter content in four sweet

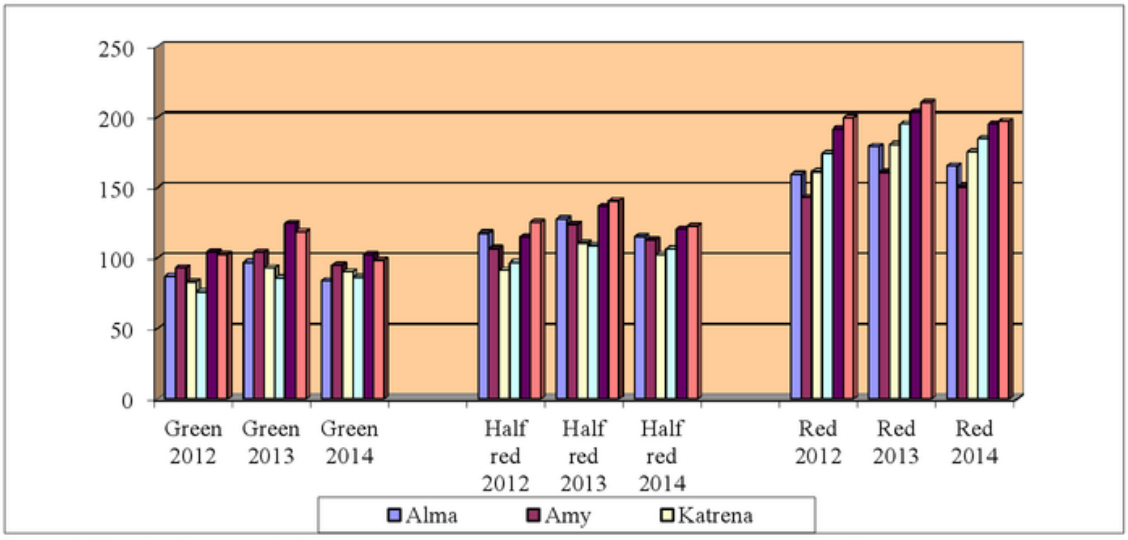

Figure 2 Vitamin C content in fresh pepper fruits by varieties, years and the maturity level.

Table 2 Differences in vitamin C of fresh peppers (Method: 95.0 percent LSD).

Variants	Count	LS Mean	LS Sigma	Homogen. groups
GM	54	95.8469	1.43644	a
TM	54	115.578	1.43644	b
BM	54	179.222	1.43644	c
Varieties	Count	LS Mean	LS Sigma	Homogen. groups
Katrena	27	120.804	2.03143	a
Amy	27	121.094	2.03143	a
Semaroh	27	123.749	2.03143	a
Alma	27	125.82	2.03143	a
Slovakia	27	143.721	2.03143	b
PCR	27	146.105	2.03143	b
Years	Count	LS Mean	LS Sigma	Homogen. groups
2012	54	123.739	1.43644	a
2014	54	127.967	1.43644	b
2013	54	138.94	1.43644	c

Note: GM = technical maturity, TM = Transitional maturity. BM = botanical maturity.

pepper varieties between 5.24 to 7.48%. The average content of ascorbic acid in these pepper fruits ranged from 110.46 to 148.72 mg.100g^{-1}.

Petříková, Hlušek et al. (2012) report an average level of vitamin C in green pepper 80.4 mg.100 g^{-1} and 127.7 mg.100 g^{-1} of red fresh peppers. Our average values ranged from 75.88 mg.100 g^{-1} in technical ripening of variety ´Semaroh´ up to 203.44 mg.100 g^{-1} in variety ´Slovakia´ of botanical ripeness. **Kopec (1998)** shows the average value of vitamin C in red peppers 161.5 mg.100 g^{-1} and 120 mg.100 g^{-1} in green peppers.

Vitamin C in sterilized pepper fruits

At the time of harvest at different times and maturity we conserved pepper slices. Three 3 months after sterilization pepper slices were analyzed for vitamin C. In 2012, the average vitamin C content of all varieties conserved in the technical maturity was 30.55 mg.100 mg^{-1}. In intermediate maturity it was 53.67 mg.100 g^{-1} and in botanical ripeness 69.06 mg.100 g^{-1}. In 2013, these values were the highest, 33.94 mg.100 g^{-1}, 57.62 mg.100 g^{-1} and 76.23 mg.100 g^{-1}. In 2014, the average measured amount of vitamin C in sterilized pepper slices (32.59, 62.23 and 81.06 mg.100 g^{-1}) was larger than in 2012 but lower than in 2013.

The highest content of Vitamin C was in sterilized variety ´Slovakia´ and ´PCR´ in all three stages of maturity. The highest measured value of vitamin C in the sterilized samples linked to the maximum level in the fresh state and vice versa. The table 3 shows the percentages of retention (preservation) of vitamin C.

The lowest percentage of vitamin C retention in sterilized pepper slices were recorded by technical ripening in variety ´Alma´. In intermediate ripening it was variety ´Katrena´ and in botanical ripening variety ´Amy´. In the green maturity, the average retention value of vitamin C in all varieties was 34%. In the intermediate maturity, the average retention was 47.16% and 42.10% in slices of red ripeness. Comparison of vitamin C in fresh fruits and sterilized in different varieties, variants and years is shown in Figure 3.

According to the results of authors **Bernhardt and Schlich (2006)**, the cooking pepper retains about 76% of vitamin C and cooking with steam can be kept to 94% of vitamin C of the initial volume of fresh weight. A similar conclusion was reached by the authors **Valšíková and Chrenko (1983)**, who point out the relationship between the original content of ascorbic acid and its retention after sterilization. They found an average level of vitamin C in fresh fruit of nine pepper varieties of 115.1 mg.100 g^{-1}. Vitamin C decreased after sterilization to 76.4 mg.100 g^{-1}. Retention in nine varieties was in the range 49 – 85%.

Valšíková and Paulen (2013) point out that after sterilization and storage of pepper slices retained on average 48.6% ascorbic acid content of the original. This finding corresponds with our results where we have reached average retention of vitamin C from 34% to 47.16%. **Valšíková, Minárová and Paukova (1984)** found that on average, the eleven varieties of peppers was retained 49.24% of vitamin C after sterilization and 5[illegible]% after freezing of pepper fruits.

Castro et al. (2008) studied the effect of pressure treatments of 100 and 200 MPa (10 and 20 min.) and of

Table 3 Three-year averages retention of vitamin C in sterilized pepper fruits.

Varieties	Technical maturity (green) Retention (%)	Transitional maturity (half red) Retention (%)	Botanical maturity (red) Retention (%)
Alma	30.03	48.82	41.70
Amy	33.38	45.97	43.42
Katrena	32.80	44.21	43.87
Semaroh	37.33	46.12	41.53
Slovakia	35.44	50.69	40.80
PCR	34.77	46.47	41.75
Average of varieties	34.00	47.16	42.10

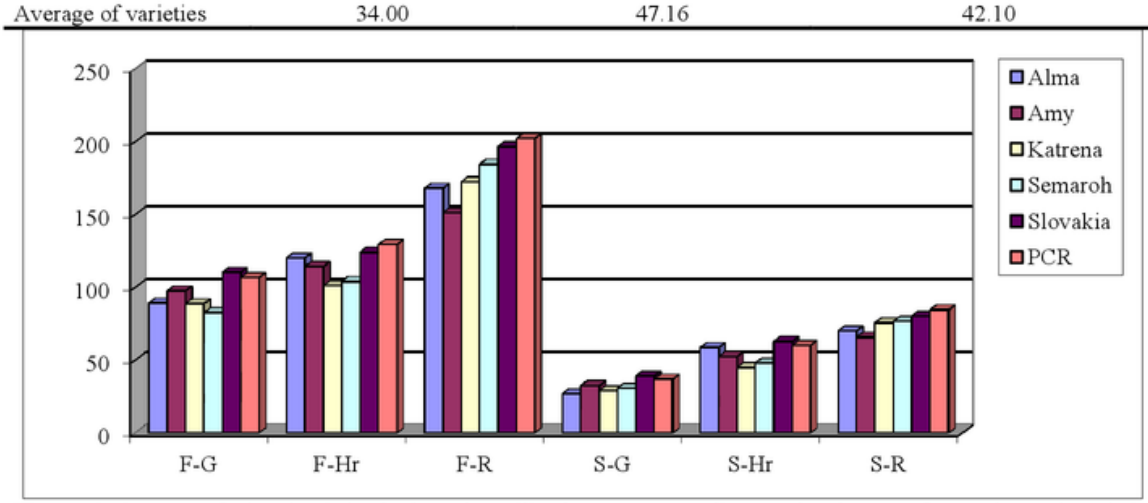

Figure 3 Content of vitamin C in fresh and sterilized pepper according to the degree of maturity and varieties (Note: F = fresh pepper, S = sterilized pepper slices, G = technical maturity, Tr = transitional maturity. R = botanical maturity).

thermal blanching at 70 °C, 80 °C and 98 °C (1 and 2.5 min.), on sweet green and red bell peppers. Pressure treated peppers showed a lower reduction on soluble protein and ascorbic acid contents. Red peppers presented even an increased content of ascorbic acid (15 – 20%), compared to the untreated peppers.

Valšíková, Čurda and Kopec (1986) investigated the loss of vitamin C in varieties of peppers in botanical and technological maturity. The green fruit has retained from 43.6 to 55% of vitamin C and red peppers from 46.5 to 73%. **Authors Oruna-Concha et al. (1998)** found that unblanched beans and peppers lost 97% of their vitamin C within 1 month of freezing, whether or not were contained in bags sealed under vacuum. The beans vitamin C content was reduced after blanching by 28%, but limited further decreases to between 3 (vacuum sealed) and 10% (no vacuum) in 12 months.

Vitamin C and carotenoids are the antioxidant components of vegetable species. According to the authors **Andrejiová et al. (2016)** no significant correlation was obtained with monitored antioxidant constituents.

Vitamin C may also be included among the substances with antioxidant properties. The highest content of vitamin C in our experiments had pungent pepper varieties PCR in temporarily and botanical maturity. According to the results **Škrovánková et al. (2017)** was the highest in antioxidant activity chilli pepper compared with sweet varieties.

CONCLUSION

Soluble solids content in our experiments was influenced by the maturity of pepper fruits. The highest content was found in peppers collected in botanical maturity, where the average was 5.82% in 2012, 6.52 in 2013 and 6.13 in 2014. Lower average, we measured by the intermediate maturity, 4.25 in 2012, 5.2% in 2013 and 4.73% in 2014. The lowest soluble solids content was recorded for fruit harvested in technical ripeness, only 3.57% in 2012, 4.25% in 2013 and 4.10% in 2014.

It can be concluded that the variety ´Semaroh´ showed higher values than other varieties, especially in half red and red pepper fruits. If we evaluate the years, most refractive solids had fresh fruit in 2013, and the least in the year 1012.

The average level of vitamin C in all years was highest in fresh red peppers. The richest in this vitamin were varieties ´PCR´ and ´Slovakia´ Last vitamin C was in varieties ´Amy´ and ´Alma´. The lowest average content of vitamin C was recorded in varieties harvested in the technical maturity. In 2012 it was variety ´Semaroh´ (75.88 mg.100 g^{-1}). In 2013 the least vitamin C content (85.90 mg.100 g^{-1}) had also ´Semaroh´ variety and in 2014 it was ´Alma´ variety with among of vitamin C 84.00 mg.100 g^{-1}only. When evaluating the years in terms of average vitamin C level in peppers fresh fruit, the best year was 2013 and the weakest year 2012.

The highest content of vitamin C in sterilized fruits of the pepper was measured in varieties harvested in botanical ripeness in all years. Average in vitamin C of all sterilized varieties in 2012 was 69.06 mg.100 g^{-1}. In 2013 the average value was 76.55 mg.100g^{-1} and in 2014 it was 81.06 mg.100 g^{-1}. The three-year averages of vitamin C in all maturity were highest in varieties ´Slovakia´ and ´PCR´.

Retention of vitamin C in sterilized fruits of the pepper we expressed in% as retention. For six varieties we have found that in technical maturity retained after sterilization on average 34.0% of vitamin C, in an intermediate maturity 47.16% and 42.10% of botanical maturity. In percentage terms, the retention of vitamin C between varieties is not statistically significant but significant difference is between the retention of vitamin C in various stages of maturity.

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