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CHANGES IN THE QUALITY OF SWEET PEPPER TYPES DURING THE POST-HARVEST RIPENING
PROMENE U KVALITETU SLATKIH PAPRIKA TOKOM PERIODA DOZREVANJA

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ABSTRACT

Our objectives were to find out how the colours of the fruits, the vitamin C content, and the peroxidase enzyme activity changes after harvest in different pepper types. The classification criterion was the colour of surface, which can indicate the level of maturity. The separated fruits were stored for 1 or 2 weeks at 18 °C. Our results showed that with half-matured peppers the vitamin C content increased during the first week and after that the values decreased due to dissimilation and ageing processes. With fully-matured peppers, there was a decrease in the vitamin C content from the start of storage. The change of POD activity was similar to the vitamin C content. Within half-matured peppers, it increased in the first period, and then decreased. The fully-matured samples produced stable low values, which changed slightly. Our experiments gave new detailed data about the ripening process of pepper on more maturity levels than previous studies.

***Keywords**: vitamin C, peroxidase enzyme activity, storage trial, maturity levels.*

REZIME

Naši ciljevi bili su da se sazna kako se boje voća, sadržaj vitamina C, i aktivnost enzima peroksidaze menja nakon žetve u različitim tipovima paprike. Kriterijum klasifikacije je boja površine, koja može da ukaže na stepen zrelosti. Odvojeni plodovi bili su skladišteni jednu ili dve nedelje na 18°C. Rezultati su pokazali da se kod poluzrelih paprika sadržaja vitamina C povećava tokom prve nedelje, a nakon toga vrednost opada zbog disimilacije i procesa starenja. Kod potpuno zrelih paprika, došlo je do smanjenja sadržaja vitamina C od početka skladištenja. Promena POD aktivnosti bila je slična promeni sadržaja vitamina C. Kod poluzrele paprike, sadržaj se u prvom periodu povećava, a zatim opada. Kod potpuno zrelih uzoraka dobijene su stabilne niske vrijednosti, koja su se malo menjale. Eksperimenti su dali nove detaljne podatke o procesu zrenja paprike različitih nivoa zrelosti od prethodnih ispitivanja.

***Ključne reči:** vitamin C, aktivnost enzima peroksidaze, skladištenje, nivoi zrelosti.*

INTRODUCTION

The pepper *(Capsicum annuum, L.)* is one of the most preferred and variable kind of vegetable in Hungary. The large bell shaped fruits show wide variety of size, shape, and colour diversity.

Among the varieties and types of varieties there are significant differences in flavour and quality of fresh fruit. The ripening stage of edible pepper fruit is very various too. Martinez distinguishes tree different ripening stages of green mature, breaker and red pepper *(Martinez et al., 2005)*. Almela analyzed green, unripe and fully ripe peppers. The scan of the different ripening stage shows that the sugar and vitamin C content usually increase with obtaining the optimal maturity stage. *(Almela et al., 1996)*

Generally, we can separate two groups of peppers by the colour changes during ripening. The 1st kind of peppers turns from white to red, and the 2nd goes from green to red. The „white" pepper shows colours from greenish white to deep red, white-yellow, orange, red, and deep red are also frequent. The varieties of the 2nd group can show shades from bright green to deep red. Through the "smutty" stage (it means green-brown-orange-red mixed) the fruits have red or deep red colour. Although the matured peppers have the best dietetic and nutrition qualities, the red, white, striped, smutty and others with different shades of colours in the half-matured stage are preferred too, and these posses excellent taste, look, and appetizing features.

The colour changes are visible signs of ripening, accompanied with the change of other parameters such as the vitamin C content. It is well-known that matured peppers include more vitamins, carotenoids, polyphenols and other effective materials, but we do not know how these values change exactly.

Judging from the results of our previous studies *(Gilinger et al.,2007, Gilingerné et al., www.mttt.hu)* in the samples picked at half-matured level such as white Cecei and Californian green the vitamin C content has increased during the first period of storage. After that the processes of dissimilation and aging intensified, and the vitamin C content has decreased. In the samples picked at fullly-matured level such as Pritamin and Californian red the vitamin C content has decreased in the 2nd week, and they couldn't ripe any more. The Kapia is a special type with very high storability; it kept its vitamin C content during the storage, as well as firmness, health, bright skin and excellent taste. The changes in POD activity were very similar to the changes found in the vitamin C content. The POD activity in the samples picked at half-maturity level has increased in the first period of storage, and decreased afterwards. The POD activity in fully-matured fruits was stable and low and it changed slightly.

Our main aim was to study the post-harvest ripening processes circumstantial. We separated the harvested fruits for measurement and storage trial into 8 groups by the maturity level, which made detailed study possible. We assigned the numbers, the typical colours, the expectable changes, and the descriptions of the stages to the maturity levels, and formed a table from these data. (Table 1.) After the classification we stored separated

samples at 18 ^{0}C, and found that the ripening was very intensive. We were monitoring the colour, and the maturity level changes of three characteristic pepper types: *Cecei, Kápia, Californian*.

Table 1. Pepper classification by maturity level

Maturity level	Maturity type		Description
	from white to red	from green to red	
1	greenish white	dark green	fruit still enlarging, no final size and form, no skin lustre, weak crop wall, seed soft, immature, can't germinate, fruit will not ripen properly
2	white-yellow	bright green	skin bright lustre, waxy, firm crop wall seed not soft, well formed fruit will ripen limited
3	yellow	green-brown	skin bright lustre, waxy, firm crispy crop wall, seed mature, germinate fruit will ripen under proper conditions
4	turn to orange	turn to red	orange /red colour covering 10-30% of fruit fruit will ripen quickly
5	yellow-orange	green-brown-red	orange /red colour covering 30-60% of fruit fruit will ripen quickly
6	orange-red	brown-red	orange /red colour covering 60-90% of fruit fruit will ripen quickly
7	red	red	red colour covering 90% of fruit, full matured, damage of rot and wilting
8	deep red	deep red	deep red colour covering 100% of fruit, soft elastic crop wall, over matured, damage of rot and wilting

MATERIAL AND METHODS

Pepper types and varieties involved

The variety samples in different ripening stage were harvested from greenhouse in the Postcontrol Station of the Central Agricultural Office Monor on 8th September. All the fruit was harvested from 5 plants which are marketable. We classified the fruits by maturity levels from 1 to 8. (Table 1.).

Paprika types, variety:

White Cecei, Emese: typical Hungarian Cecei type, white colour before maturity, red colour at maturity, triangular shape, excellent sweet favour

Kapia, Kárpia: deep green colour before maturity, red colour at maturity, narrow triangular shape, thick wall, sweet, excellent storability

Californian, Bendingo: dark green colour before maturity, red colour at maturity, narrow rectangular shape, thick wall, sweet

Storage trial

The storage trial and the laboratory analyses were conducted in the Food-Chemistry Laboratory at the Department of Dietetics and Nutritional Sciences of the Semmelweis University. The temperature for the storage was 18 ^{0}C, which is similar to the uncooled shelves of shops, and supermarkets. This is not an optimal storage temperature for keeping quality of pepper, however we wanted to study the process of ripening.

Laboratory analysis

Our working team used traditional spectrophotometric methods to determine the vitamin C content of the samples (Gilingerné and Varga, 2005). After watery solution, we added ferrichloride and 2,2,-dipiridil reagent to determine the quantity of ascorbic acid with measuring colour intensity of dipiridil-ferro-ascorbate complex by spectrophotometer (modified Spanyár-method).

The peroxidase enzyme activity was also analysed with spectrophotometric method. We added o-phenilen-diamine reagent and H2O2 substrate to the watery solution buffered to pH 5,0. The final values were calculated from the time-absorbance line, 1 enzyme-activity unit means 1x10-3 change in absorbance per 1 minute. The POD activity unit was counted into 1 gram fresh sample.

The surface colours were observed by eyesight, and were kept by digital photos.

RESULTS AND DISCUSSION

Changes in fruit colour during the post-harvest ripening

The samples of the low maturity level (1.stage) did not show colour changes, and withered more than the more matured fruits. The 2nd-5th maturity levels showed intensive after-harvest ripening: 1 week later they get one level upper on the scale, and the samples which were stored for two weeks produced 2 mature stages upper. The characteristic exception was the Cecei type fully orange sample (4.stage), which one produced the most intensive result: during 1 week, it „stepped ahead" two level. Those samples which were stored at the yellow-orange phase showed minimal colour changes. Fruits of the Cecei pepper withered considerable during the 1st week, and consequently this type was excluded from any further research. The Californian showed the sign of withering in the 2nd. The Kapia samples did not decay in the 2nd week; the exceptions were the low-, and over matured fruits. The blossom-end rot, deep-red, (8+ maturity level) faultless ones colour, and consistence were not change.

Changes in the vitamin C content

The details of the vitamin C content were visualised in *Table 2*. The data present four measurement periods. We counted the average and the standard deviation from 4 repeated samples.

In the case of fresh, low matured samples we find 20 mg/100g vitamin content. During the ripening the values were rising to 100 mg/100g, and the average value was gained at the 80% of maturity level.

Deep red, over-matured pepper fruits produced less L-ascorbate. We separated the blossom-end rot fruits of Kapia, and operated with that apart from the others. These samples are not decayed or damaged as much as that we can say the nutrition qualities get lower. The spots caused by temporary Ca^{2+} shortage, generally appear under the axis of the fruit, and contain decayed materials. The colour of the blossom-end rot fruits are deep red, but that is caused by the forced maturating process, but because of that the tissues of the fruit cannot fully evolve, and usually the vitamin C content also lower than we expect. The damaged, deep red samples contain minimal vitamin C.

Table 2. Vitamin C content in pepper fruits on different maturity level (mg/100)

Maturity level	Vitamin C	Maturity level	Vitamin C	Maturity level	Vitamin C
fresh		stored 1 week		stored 2 weeks	
CECEI					
1	19	2	28		
2	70	3	43		
3	72	4	53		
4	83	6	87		
5	104	6	103		
6	111	7	106		
7	101	8	65		
8	95				
KAPIA					
1	13	1	24	1	23
2	57	3	97	4	48
3	105	4	87	5	81
4	100	5	65	6	96
5	99	6	80	7	95
7	145	7	114	7	93
8	64			8	53
8+	51				
CALIFORNIAN					
1	13	1	20	1	35
2	58	2	47	2	40
3	102	4	103	5	103
5	101	6	99	7	90
6	71	6	105	7	86

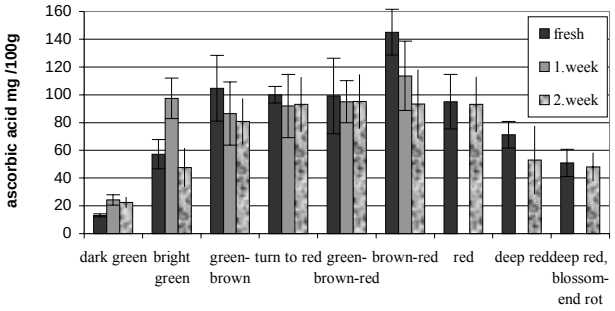

Fig.1. Changes in vitamin C content during the storage in Kapia type on different maturity level (ascorbic acid mg/100g; SD, n=4)

The low-matured peppers could not ripen after harvest, and could not find considerable colour changes, neither L-ascorbate. The samples at the 2nd-3rd maturity level produced different changes. Contents in Cecei type got lower, although the 3rd staged fruits produced intensive colourisation. The Californian type at 2nd level showed decrease of the vitamin content, but in the 3rd stage the values gained and held 100mg/100g. The Kapia type at the 2nd maturity level increased the L-ascorbate content very intensive, and showed relevant colour changes, summarize that we find intensive ripening *(Figure1.)*. The 2nd week samples stopped producing the processes, and the values started to decrease, which can trace back to the flagging of the fruits depot. The 4th level included the samples which could get and hold the high vitamin C content. Between the 4th to 7th levels we could not demonstrate differences at this point, although the standard deviations were high, and the covering colours and biological maturity did not connected with each other perfectly. The blossom-end rot spotted and damaged samples vitamin contents continued the decreasing during the further storage trial.

Changes in peroxidase enzyme activity

The results of measurement of peroxidase enzyme activity are presented in *Table 3.* The Cecei type fresh sample showed that the low-matured fruits peroxidise activity were relative high, the medium (2nd- 6th) levels produced lower activity, and in the red staged ones the POD values got higher. That was not caused by the ripening, but rather the deterioration processes. In the case of stored samples we had seen the most characteristic and intensive increasing in the half-matured samples. Furthermore, it is indicated that the intensive ripening, it caused that the depots of reserve were tapped out out, and the destruction and decay processes got dominance, on that source the fruits were ruined at the 2nd week. *(Figure 2.)*

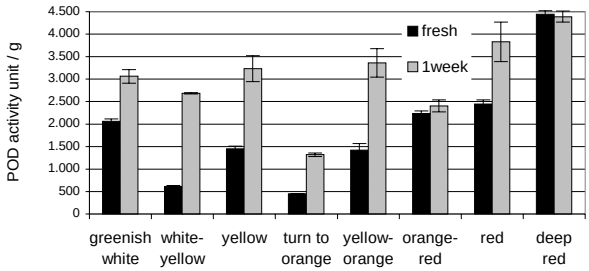

Fig. 2. Changes in POD activity during the storage in CECEI type on different maturity level (POD activity unit/g; SD, n=4)

The Californian fruits showed similar trend in the case of fresh samples like the Cecei type. The low-matured samples showed only minimal changes, because ripening was also minimal. Bright green and turn to red levels produced intense increase of the POD activity. In the case of this type, the after harvesting ripening was the most significant in these maturity levels. *(Figure 3.)*

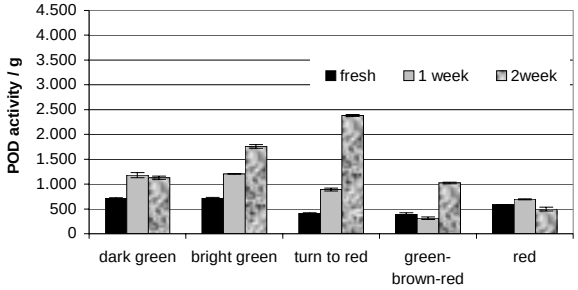

Fig. 3. Changes in POD activity during the storage in Californian type on different maturity level (POD activity unit/g; SD, n=4)

Studying the Kapia we got results that the green (1st and 2nd level) samples posses the highest POD activity values. *(Figure4.)* Medium maturity level fruits gave low activity, and the damaged or spotted ones had got also high content. It caused by decay and destruction processes just like in other pepper types. The most interesting result from data of the stored samples was the values of medium matured fruits. These were changed only minimal. That indicates the best storability. As POD activity is in correlation with decreasing processes and the values of activity are low, the vitamin C and other characteristic contents are also stabile. Consequently, the duration of these maturity levels within counter conditions is affected and the depots were not tapped out. These values are in accordance with the changes of vitamin C.

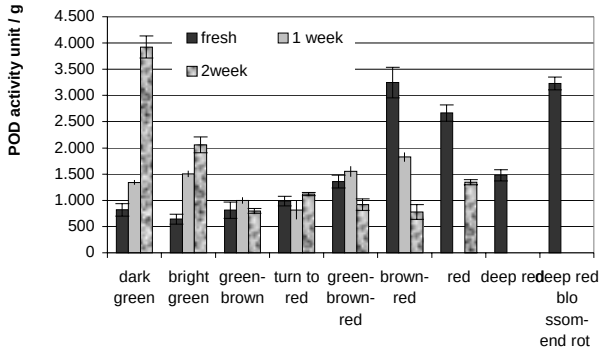

Fig. 4. Changes in POD activity during the storage in KAPIA type on different maturity level (POD activity unit/g; SD, n=4)

Table 3. Peroxidase enzyme activity in pepper on different maturity level

Maturity level	POD unit/g	SD	POD unit/g	SD	POD unit/g	SD
fresh			stored 1 week		stored 2 weeks	
CECEI						
1	2057	61	3064	152		
2	615	16	2685	12		
3	1450	60	3232	289		
4	449	7	1320	40		
5	1419	152	3362	318		
6	2238	54	2404	136		
7	2447	88	3829	442		
8	4442	81	4391	126		
KAPIA						
1	819	117	1341	45	3923	211
2	643	92	1507	61	2056	152
3	813	152	998	59	800	48
4	985	92	817	178	1119	29
5	1358	124	1550	100	918	109
7	3244	293	1824	89	782	140
8	2665	154			1346	46
8+	3226	120				
CALIFORNIAN						
1	707	20	1181	50	1127	33
2	705	30	1207	6	1758	40
3	412	7	890	29	2385	17
5	396	25	312	24	1024	15
6	586	3	692	12	497	38

The correlation between the L-ascorbate and POD activity is the most descriptive in the Californian samples although we should notice than the two values (vitamin C and POD) shifted for each other. It was caused by the biological features of the plants, and within this category, the peppers too. The POD activity shows the process which indirectly produces L-ascorbate.

CONCLUSION

Our results showed that the medium maturity level samples of Kapia type can hold the vitamin C content, and because of that, the storability was the best with this type compared to all the peppers which we studied. Generally, we can find high vitamin C content in fruits at medium-high levels of maturity, and lower vitamin content in the low-matured and over-matured fruits. The POD activity was high in the case of low- and over-matured samples included the damaged ones. Nevertheless, while in the first case the cause is the ripening; over-matured, and damaged samples showed the increase of POD, and the decrease of L-ascorbate because of the destruction processes. The correlation between POD and vitamin C were indicated by our results. We could also draw the inference that they shifted for each other.

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