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COLOUR CONTENT AND STABILITY IN RED PEPPER AS AFFECTED BY CULTIVAR, HARVEST TIME, AND TITANIUM SPRAY

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Paprika is one of the oldest and most important food colourants; its quality may be affected by cultivar, maturity, and processing. The objectives of this study were to investigate the effects of harvest time, variety, and application of a biological activity inductor (Ti^{4+}-ascorbate) on fruit yield and quality of spice red pepper. The influence of drying and grinding operations on quality parameters and thermo- and photostabilities of ground paprika during storage were also studied. Our results demonstrated that the Spanish cultivar, Albar, is the best of all studied pepper varieties due to the following factors: a) high fruit productivity, b) high fruit quality (total extractable red colour and red/yellow pigments ratio), c) high quality of processed spice red pepper, and d) high thermo- and photostabilities. Besides the cultivar selection, fruits from the first harvest showed the best quality parameters and if possible they should be used for paprika processing. The application of titanium ascorbate significantly improved fruit yield, fruit quality and ground paprika photostability during its storage; this is, therefore, a treatment that could help farmers and paprika manufacturers to improve their benefits, and consumers to find a food colourant of better quality.

Keywords: food colour, processing, red pigments, titanium, paprika

Seasoning paprika is one of the economically most important vegetable spices and the factor that most likely determines its quality is the red colour. During paprika processing, there are some steps, which produce a decrease of pigments and bioantioxidants, causing an important reduction of quality. The stability of the paprika pigments has been attributed to a number of factors, including cultivar (ALCARAZ et al., 1991; MARTÍNEZ-SÁNCHEZ et al., 1991a), plant nutrition (MARTÍNEZ-SÁNCHEZ et al., 1993), moisture content, stage of ripeness at harvest (KANNER et al., 1979), and antioxidant content (BIACS et al., 1992).

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CHOLNOKY (1939) in discussing Hungarian paprika, which may include as many as five harvests, stated that the first harvest was considered to be the most valuable. On analysing several varieties of paprikas for two yearly harvests, he found that with one exception, the total extractable colour was higher for the first harvest than for the second one (LEASE & LEASE, 1956).

Titanium exercises some beneficial effects on the biological activity of several crop species. On *Capsicum annuum* L. plants, it has some promotive effects on biomass production, on nutrient absorption, on several enzymatic system activities (catalase, peroxidase, lipoxygenase and nitrate reductase), on malic acid, leaf chlorophylls, fruit carotenoids and ascorbic acid contents, and it decreases plant starch concentration (CARVAJAL & ALCARAZ, 1998).

The aim of this study was to study the effects of the harvest time, variety (2 Spanish, 2 Hungarian, and 2 Bulgarian, which are the main European paprika-producing countries), and Ti^{4+}-ascorbate spray on fruit yield and quality of paprika pepper. The effects of processing (drying and grinding) on the quality of spice red pepper were also studied.

1. Materials and methods

1.1. Plants

Seeds of *C. annuum* L. had the following origin:

The Spanish varieties Albar and Negral were obtained from CEBAS-CSIC (Murcia) and from Ramiro Arnedo, S.A., respectively; the Hungarian KM-622 and Mihályteleki, from the Research Station for Paprika Development (Kalocsa) and from the Food Processing Enterprise (Szeged), respectively; both seeds were granted by the Central Food Research Institute (Budapest). The Bulgarian Buketen-50 and Gorogled-6 were given by the “Maritsa” Vegetable Crop Research Institute (Plovdiv).

1.2. Experimental crop conditions

Plants were grown in a greenhouse equipped with an automatic system to control temperature and humidity. Plants were disposed in polyethylene containers (25 l capacity) filled with a semi-inert substrate [a mixture of peat, murc and pine bark (1:1:1, v:v:v)]. Each container constituted an experimental plot in which four plants were grown. Six experimental blocks (ten containers per block) were randomly disposed in the greenhouse. Half of these experimental blocks were leaf-sprayed twice with a 42 mmol l^{-1} Ti^{4+}-ascorbate solution, pH 6 [the first Ti application was carried out before flowering (35 ml per plant), and the second one (35 ml per plant), 24 days later]. The other half of the plants were treated with identical volumes of 42 mmol l^{-1} ascorbic acid, pH 6, and were used as controls. The fertirrigation of the plants was carried out by an automatically controlled drip system, so that all the plants received identical doses of water, nutrients, phyto-sanitary treatments, etc. Over-ripe fruits were collected at different times: 4, 6, and 7 months after the first Ti application. In the laboratory, fruits were divided in peduncles, seeds, and pericarps; all these plant samples were washed with 10 g l^{-1} BRIJ 35 solution (non-ionic detergent) and then rinsed three times with deionized water. Half of each sample was frozen with liquid nitrogen and stored at –40 °C until analysis. The other half was dried in darkness, in an air-forced oven, at 50 °C for 2 days. In the industry, when peppers are dried in an oven, the temperature normally used is 65 °C. In our experiments, however, the temperature was decreased to 50 °C for reducing pigment oxidation and degradation. The dried pericarps were ground and stored at –20 °C in darkness until analysis.

1.3. Total extractable colour (ASTA, 1968)

Fresh pericarp cut into small pieces and dried-ground pericarp (0.5 g) were extracted with 100 ml of acetone for 1 h in the dark under agitation. Five ml of the supernatant was diluted to 50 ml with acetone and the absorbance was read at 460 nm against an acetone blank. The colour was expressed as ASTA units, according to the equation: [Colour] = 165 A I_f/w; in which: A = sample absorbance; I_f = deviation factor of the spectrophotometer, which was calculated using a standard 2030 NBS filter that indicates the relationship between the theoretical (A_t) and real (A_r) absorbances at 460 nm; w = sample weight; 165 is the molar extinction coefficient of a 1% capsanthin solution in acetone.

1.4. Red/yellow pigments ratio

Pericarp was extracted as for the ASTA determination. The absorbances were measured at 470 nm for red pigments and at 455 nm for the yellow ones (NAVARRO & COSTA, 1993).

1.5. Thermo- and photostability

Dried and ground pericarps were divided into two parts and introduced into an oven at 63.8 °C (Schaal Oven Test) or into a chamber illuminated with UV light with a photosynthetically active radiation (PAR) of 350 µmol m^{-2} s^{-1} for 5 days. Measurements were carried out every 24 h.

1.6. Data analysis

All measurements were replicated at least three times and data are expressed in a dry weight basis. The data were statistically analysed using the unpaired *t*-test.

2. Results and discussion

2.1. Fruit production

Results obtained for fruit production are shown in Table 1. It is evident from these data that the two Spanish cultivars (Albar and Negral) are much more productive than the other cultivars. The yield was more than 2-fold higher in the Spanish varieties as compared to the Bulgarian ones (Buketen-50 and Gorogled-6). A factor that could have contributed to this experimental finding is that both Albar and Negral are cultivars with several flowering and fructification cycles while in the rest of varieties, the pods of a given plant reach harvest maturity at the same time.

Table 1

Total fruit yield of several Spanish, Hungarian and Bulgarian red pepper (paprika, Capsicum annuum *L.) cultivars as affected by plant-leaf Ti^{4+}-ascorbate spray*

Cultivar	Fresh fruit yield (g plant^{-1})	Dry fruit yield (g plant^{-1})	Water content (%)
		Control plants	
Albar	810 d	193 e	76.2 b
Negral	806 d	188 de	76.7 b
KM-622	458 c	86 a	81.2 d
Mihályteleki	441 bc	107 b	75.7 b
Buketen-50	395 a	78 a	80.3 cd
Gorogled-6	414 abc	159 c	61.6 a
		Leaf-Ti sprayed plants	
Albar	839 d	203 ef	75.8 c
Negral	821 d	211 f	74.3 bc
KM-622	466 c	119 bc	74.5 b
Mihályteleki	471 c	122 c	74.1 b
Buketen-50	407 ab	82 a	79.9 d
Gorogled-6	450 c	174 d	61.3 a

Data are the average values from three individual samples. Values followed by the same letter, within the same column and type of plants (Ti-treated or not treated), are not significantly different at a P = 0.05 level (unpaired *t*-test).

In general, the fruit yield of all of these plant cultivars was enhanced after titanium application by leaf spray. There is an important incidence of the crop system (greenhouse or field) on the plant biomass and fruit yield (MARTÍNEZ-SÁNCHEZ et al., 1991b, 1992; CARVAJAL et al., 1992). In these studies, a gradation response was observed as follows: field crop under flooding irrigation > field crop under fertirrigation > greenhouse under fertirrigation. These same authors concluded that these different beneficial responses were caused by the different approximation to the optimal nutrient conditions promoted by the different crop system. Besides, CARVAJAL and co-workers (1995b) proposed that a Ti-leaf increase induces the iron uptake as well as the cell iron active fraction, with these effects being the pathway by which titanium induces the increases of the plant's biological activity. In our own study, *Capsicum annuum* plants were grown under highly controlled and optimised conditions (an almost inert substrate and optimal nutrition through fertirrigation were used); thus the low statistical significance of the differences in fruit production is logical and was the expected result.

In a previous study (CARVAJAL et al., 1994a), it has been demonstrated that the enhancement of both the biomass production and the biological activity in Ti^{4+}-ascorbate sprayed plants was induced by the cation (Ti^{4+}), whereas the anion (ascorbate) did not have any effect. Therefore, all positive effects caused by the titanium ascorbate spray in our own study should also be attributed to the action of Ti^{4+}.

2.2. Fruit quality

In this section we studied the effects of two variables, harvest time and Ti spray, on the quality of red peppers. Fruit morphology (weights of seeds, pericarp, and peduncles), average weight of fruits (g per fruit), water content, colour, and red/yellow pigments ratio were the parameters selected to determine the quality of the peppers (Table 2).

The first conclusion obtained from data in Table 2 is that fruits of the Albar, Negral, KM-622, and Mihályteleki varieties were not completely developed at the first harvest (fruit weights were always statistically higher at the second harvest than at the first one), and the fruits were still growing. Thus, it can be considered that 2nd-harvest fruits were riper than 1st-harvest fruits. However, fruits picked from the two Bulgarian cultivars (Buketen-50 and Gorogled-6) were ripe at both harvest times and their fresh weights were statistically equal ($p = 0.05$). Ripening of fruits is a very important factor, because only over-ripe fruits are actually ready for drastic industrial operations of spice red pepper (lower water content, less energy requirement during the drying operations, and higher levels of coloured substances and antioxidant compounds).

Table 2

Fresh weights of seeds, peduncles, and pericarp, average weight of fruit (g fruit^{-1}), and water content (%) of several Spanish, Hungarian and Bulgarian red pepper (paprika, Capsicum annuum *L.) cultivars as affected by harvest time and plant-leaf Ti^{4+}-ascorbate spray*

Cultivar	Seeds (g)	Pedun. (g)	Peri. (g)	Fruit (g)	Water content (%)	Seeds (g)	Pedun. (g)	Peri. (g)	Fruit (g)	Water content (%)
	1st harvest					2nd harvest				
	Control plants									
Albar	1.58 cd	0.88 bc	7.45 a	9.91 a	73.3 c	1.70 def	0.70 a	9.97 b	12.3 b	70.4 b
Negral	1.46 c	0.75 a	7.50 a	9.71 a	74.8 c	1.67 de	0.86 b	11.2 cd	13.7 cd	69.7 b
KM-622	1.50 c	1.37 e	10.26 cd	12.1 b	88.0 e	1.53 cd	1.61 de	16.1 e	19.2 e	78.6 c
Mihályteleki	1.02 a	1.61 g	6.55 a	9.18 a	70.4 bc	1.63 de	1.62 de	15.3 e	18.6 e	78.5 c
Buketen-50	1.05 a	1.18 d	6.97 a	9.19 a	78.9 d	1.02 a	1.09 c	7.88 a	10.0 a	67.4 b
Gorogled-6	1.60 cde	0.74 a	6.62 a	8.96 a	64.7 a	1.36 c	0.90 b	6.88 a	9.14 a	56.6 a
	Leaf-Ti sprayed plants									
Albar	1.74 e	0.96 c	9.19 bc	11.9 b	75.8 c	1.74 ef	0.88 b	10.3 bc	12.9 bc	69.2 b
Negral	1.66 de	0.94 c	7.15 a	9.75 a	71.5 b	1.89 f	0.89 b	11.9 d	14.7 d	69.2 b
KM-622	1.69 de	1.42 ef	10.42 d	12.5 b	71.0 b	1.63 de	1.66 de	18.1 f	21.4 f	76.1 c
Mihályteleki	1.17 b	1.57 g	8.87 b	12.6 b	74.5 c	1.67 de	1.69 e	16.2 e	19.6 e	74.5 c
Buketen-50	1.15 b	1.57 fg	9.45 bcd	12.2 b	82.3 d	1.15 b	1.52 d	10.3 bc	13.0 bc	69.0 b
Gorogled-6	1.70 de	0.80 ab	6.81 a	9.31 a	66.2 a	1.58 de	0.81 a	7.60 a	9.99 a	58.7 a

Data are the average values from three individual samples. Values followed by the same letter, within the same column and type of plants (Ti-treated or not treated), are not significantly different at a $P = 0.05$ level (unpaired *t*-test).

Fruit pericarp was the fraction that most contributed to the total weight of fruit; its contribution ranged from 71 to 84%. On the other hand, peduncles were the fraction with the lowest contribution to the total fruit weight, approximately 5–18%. Usually seeds and peduncles are removed from the pericarp before drying and grinding operations, thus, from an industrial point of view the KM-622 is the most interesting cultivar because its pericarp percentage is the highest of all studied cultivars, approximately 84%. On the other hand and from this same point of view, the Bulgarian Gorogled-6 is the less interesting cultivar; its pericarp countered for only 74–75%.

The Hungarian cultivars (KM-622 and Mihályteleki) and the Bulgarian Gorogled-6 produced the fruits with the highest and lowest average weights, respectively. Fruits were as heavy as 12.13 g and 19.22 g for the KM-622 plants at the first and second harvests, respectively, and as light as 8.96 g and 9.14 g for the Gorogled-6 peppers at the first and second harvests, respectively.

All cultivars increased the weights of all fruit fractions after the plants were leaf-sprayed with Ti^{4+} during the crop cycle. This effect could be attributed to the previously demonstrated biological activation induced by this trace element in these plants (MARTÍNEZ-SÁNCHEZ et al., 1993; CARVAJAL et al., 1994a, b; 1995a; CARVAJAL & ALCARAZ, 1995).

Another parameter contributing to the pepper fruit quality is the water content because it determines, among other factors, the amount of energy necessary for drying and the shelf life of the processed paprika. In general, the cultivars with higher mean weight of fruit also have higher water content. In control plants, the Hungarian, Spanish, and Bulgarian cultivars had water contents of 78.9, 72.1, and 66.9%, respectively, and fruit weights of 14.77, 11.40, and 9.32 g, respectively. During the senescence or over-ripening period the fruits lose water (WOODS, 1990; THOMPSON et al., 1998). The fact that the Gorogled-6 fruits had the lowest water content among the studied cultivars at both times of harvest (Table 1) indicated that Gorogled-6 is the most precocious cultivar. Gorogled-6 fruits were picked in a later state of development compared to the rest of cultivars and its fruits can be considered as being over-ripe.

The total extractable colour of the peppers was expressed as the official ASTA units, which are generally used for determining peppers and spice red pepper quality. This is the most important fruit quality parameter and the decision about which cultivar should be chosen for processing and commercial purposes is usually based on this parameter. Results showing the red colour values of fresh pericarp are summarised in Table 3. At the first harvest, the highest colour contents were found in the Spanish cultivar Albar, with intermediate values in the two Bulgarian varieties (Buketen-50 and Gorogled-6), and Negral and the two Hungarian varieties (KM-622 and Mihályteleki) having the lowest contents of this parameter. However, this order drastically changed in the second harvest; at this point Buketen-50 and Negral were the cultivars with the highest and lowest colour contents, respectively. The Albar-fruits started the production cycle having the highest value of this quality parameter and finished having the lowest content (with statistically equal values in Negral and Gorogled-6 fruits). In general, 2nd-harvest fruits had a lower content of total extractable colour than 1st-harvest fruits, implying that the quality of fruits declined after reaching a maximum value. These results agree with CHOLNOKY's (1939) statement that the first harvest-peppers were the most valuable fruits in Hungarian paprika. Capsorubin and capsanthin, whose esters were the main source of red colour, were present in the greatest amount in the first harvest, however, carotene and cryptoxanthin content increased in the second harvest.

All cultivars increased their fruit pericarp colour when the plants were leaf-sprayed with Ti^{4+} (Table 3). The most positive effect was shown by the Mihályteleki cultivar (36.1% at the first harvest), and in all other cases the effect of titanium on pericarp could be quantified between 3.4% (Buketen-50, first harvest) and 22.5% (KM-622, first harvest).

Fruits of the two Spanish varieties (Albar and Negral) presented higher red/yellow pigments ratios than the other studied fruits; the cultivars with the lowest red/yellow pigments ratios were KM-622 and Gorogled-6. In general, this ratio increased from the first to the second harvest in all cultivars studied, indicating that during the ripening process some new red pigments are formed (2nd-harvest fruits were riper than 1st-harvest fruits).

Table 3

Total extractable colour in fresh pericarp from several Spanish, Hungarian and Bulgarian red pepper (paprika, Capsicum annuum *L.) cultivars as affected by time of harvest*

Cultivar	Colour (ASTA units)		Red/Yellow ratio	
	1st harvest	2nd harvest	1st harvest	2nd harvest
		Control plants		
Albar	791 e	319 ab	1.0058 d	1.0112 de
Negral	401 b	309 a	1.0008 cd	1.0156 e
KM-622	354 a	340 ab	0.9879 a	1.0084 bc
Mihályteleki	435 c	396 cd	0.9999 c	1.0128 e
Buketen-50	497 d	425 d	0.9904 b	1.0101 cd
Gorogled-6	509 d	318 ab	0.9890 ab	1.0011 a
		Leaf-Ti sprayed plants		
Albar	934 d	362 bc	1.0068 d	1.0133 b
Negral	415 a	337 ab	1.0094 d	1.0197 c
KM-622	457 a	428 d	0.9883 a	1.0106 ab
Mihályteleki	681 c	481 e	1.0009 c	1.0146 bc
Buketen-50	550 b	526 e	0.9929 b	1.0128 b
Gorogled-6	578 b	404 cd	0.9928 b	1.0074 a

Data are the average values from three individual samples. Values followed by the same letter, within the same column and type of plants (Ti-treated or not treated), are not significantly different at a P = 0.05 level (unpaired *t*-test).

2.3. Effect of drying

It is well known that spice paprika is usually ground to a fine powder of about 0.5 mm particles. This process increases the surface area and thus allows higher lipid oxidation (CARVAJAL et al., 1998). In our study paprika peppers were processed in a similar way as in spice processing (drying in an air-forced oven at 50 °C for 2 days and grinding using a coffee mill) to study how these operations influence the quality attributes of paprika. The drying process significantly affected both the total extractable colour and the order of the six varieties previously established according to the colour quality of fresh pericarp.

The level of total extractable colour and red/yellow pigments ratio for the dried and ground pericarp are shown in Table 4. The Hungarian Mihályteleki had the highest levels of red colour and intermediate values of the ratio red/yellow pigments. On the other hand, the Spanish Negral presented the highest red/yellow ratio but very low levels of total extractable colour at both harvests.

Table 4

Total extractable colour in dry pericarp from several Spanish, Hungarian and Bulgarian red pepper (paprika, Capsicum annuum *L.) cultivars as affected by time of harvest*

Cultivar	Colour (ASTA units)		Red/Yellow ratio	
	1st harvest	2nd harvest	1st harvest	2nd harvest
		Control plants		
Albar	333 b	275 c	1.0123 d	1.0153 d
Negral	324 b	256 b	1.0194 d	1.0159 d
KM-622	307 a	326 d	1.0006 ab	1.0027 a
Mihályteleki	398 c	384 e	1.0032 c	1.0105 c
Buketen-50	298 a	284 c	1.0014 bc	1.0051 b
Gorogled-6	302 a	244 a	0.9952 a	1.0068 bc
		Leaf-Ti sprayed plants		
Albar	365 d	290 cd	1.0130 e	1.0175 e
Negral	330 b	260 a	1.0192 f	1.0166 de
KM-622	355 cd	370 e	1.0010 bc	1.0034 a
Mihályteleki	500 e	390 f	1.0043 d	1.0123 c
Buketen-50	297 a	299 d	1.0021 cd	1.0099 bc
Gorogled-6	339 bc	280 bc	0.9964 a	1.0082 b

Data are the average values from three individual samples. Values followed by the same letter, within the same column and type of plants (Ti-treated or not treated), are not significantly different at a $P = 0.05$ level (unpaired *t*-test).

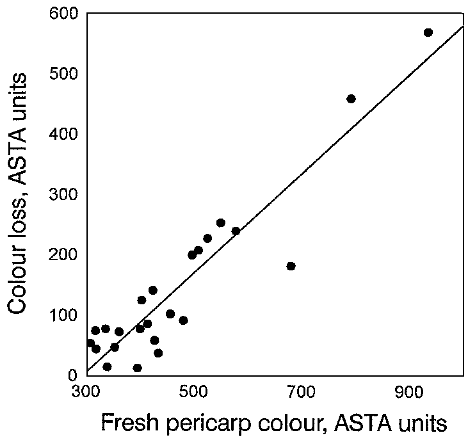

Fig. 1. Relationship between the red colour loss during the drying and grinding operations and the fresh pericarp colour of several Bulgarian, Hungarian and Spanish varieties. Both parameters are expressed in ASTA units. [(Color loss) = 0.82 × (Fresh pericarp colour) – 242; P<0.001]

There is a varietal incidence on the effects of drying and grinding operations on the total extractable colour and the red/yellow pigments ratio, but these effects were also dependent on the initial values of these two parameters in the fresh pericarp. Figure 1 shows the positive relationship (P<0.001) between the fresh pericarp colour and the total extractable colour loss. The Bulgarian and Spanish varieties suffered from a higher loss of colour during the drying and grinding operations (41, 38, 34, and 20% for Buketen-50, Albar, Gorogled-6, and Negral, respectively; these percentages are the mean of both Ti-treated and nontreated plants) as compared to the Hungarian cultivars (14 and 13% for Mihályteleki and KM-622, respectively). The losses were always higher for the first harvest (mean of 33%) than for the second one (20%).

A similar pattern to that already described for fresh pericarp was recognised in Ti-treated samples of dried and ground pericarp. However, higher levels of total extractable colour and red/yellow pigments ratios were obtained in all the studied varieties after Ti spray.

2.4. Thermostability of spice paprika

The thermostability of spice paprika, as expressed by the changes in its total extractable colour, was analysed and results are summarised in Fig. 2 (data have been divided into two different graphics to avoid overlapping of lines). There was a strong influence of heat (63.8 °C) on the degradation process of the pigments, reducing the initial values by 70–85%. The varieties with the highest and the lowest reductions in the total extractable colour were Buketen-50 (84.3% and 82.5% in control and Ti-treated plants, respectively) and Gorogled-6 (74.4% and 74.5% in control and Ti-treated plants, respectively). The rate of colour degradation was higher at the beginning of the thermostability experiment and decreased with time. The red/yellow pigments ratio (data not shown) also underwent a general decrease with time, indicating that there was a higher effect of heat on red pigments than on yellow ones. Values for this parameter ranged from approximately 1.102 at time zero to 0.800 at the end of this experiment (120 h).

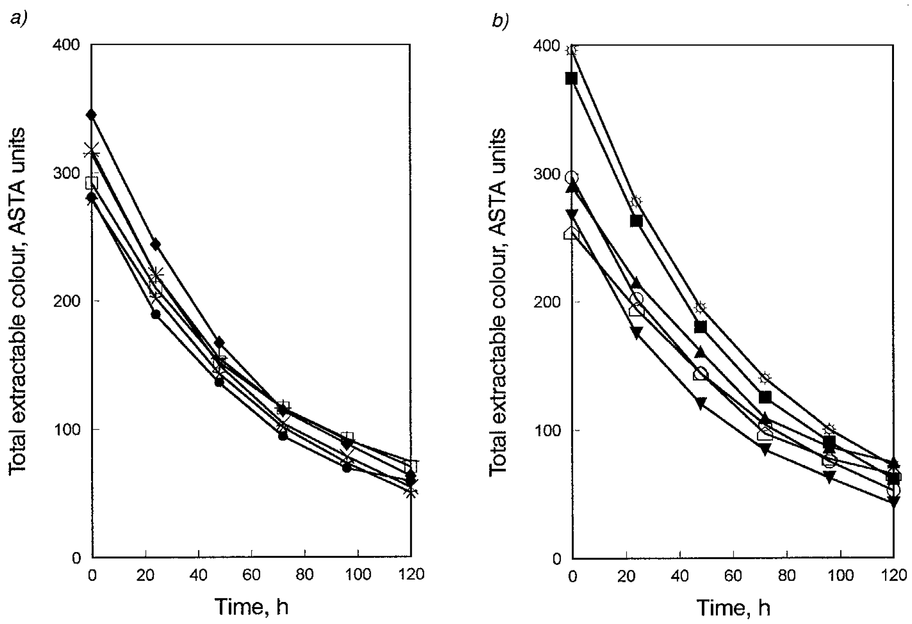

Fig. 2. Thermostability at 63.8 °C of ground paprika from several Bulgarian, Hungarian and Spanish pepper varieties, as expressed by the changes in the total extractable colour with time. (Ti: titanium sprayed.) a) ●: Albar; +: Albar-Ti; *: Negral; □: Negral-Ti; X: KM-622; ♦: KM 622-Ti; b) ■: Mihály; ✧: Mihály-Ti; ▼: Buketen; ❍: Buketen-Ti; ⌂: Gorogled; ▲: Gorogled-Ti

2.5. Photostability of spice paprika

The photostability of spice red pepper pigments from control and Ti-treated plants was studied and results are shown in Fig. 3. The UV light catalyses the degradation of the pigment content due to an increase in oxidation (PHILIP & FRANCIS, 1971), therefore, a decrease in the total extractable colour was observed in both control and Ti^{4+}-treated-spice paprika. However, the decrease caused by the UV light (PAR 350 µmol m^{-2} s^{-1}) was significantly lower than that caused by the heat (63.8 °C), and ranged from 11% (Albar – treated paprika) and 32.5% (KM-622 control paprika).

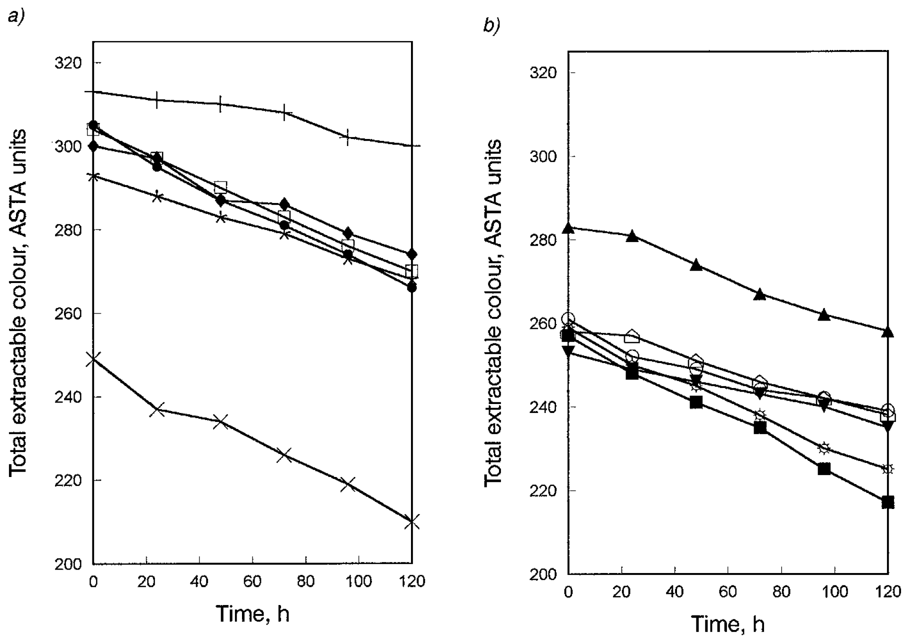

Fig. 3. Photostability against UV light (PAR 350 µmol m^{-2} s^{-1}) of ground paprika from several Bulgarian, Hungarian and Spanish pepper varieties, as expressed by the changes in the total extractable colour with time. (Ti: titanium sprayed.) a) ●: Albar; +: Albar-Ti; *: Negral; □: Negral-Ti; X: KM-622; ♦: KM 622-Ti; b) ■: Mihály; ✧: Mihály-Ti; ▼: Buketen; ○: Buketen-Ti; ⌂: Gorogled; ▲: Gorogled-Ti

Throughout the photostability assay, there was a major pigment content in spice paprika from Ti-treated peppers (cultivars Albar, KM-622, and Gorogled-6) as compared with control spice. These results showed that the protective factors developed in Ti^{4+}-treated plants are thermosensitive but phototolerant. In a previous study

(CARVAJAL et al., 1998), it was found that all these six pepper cultivars increased their fruit pericarp antioxidant (ascorbic acid and α-tocopherol) concentrations when plants were leaf-sprayed with Ti^{4+} during the crop cycle. The ascorbic acid reached a higher level than α-tocopherol, the average increase being 40% for ascorbic acid and 15% for α-tocopherol. Since the seeds were removed from the pericarp before the drying and grinding operations, the ascorbic acid seems to be responsible for the major photo-stability of Ti^{4+}-treated paprika as compared to control spice paprika. The fact that Ti^{4+}-treated spice paprika and the control spice were equally sensitive to heat, which was likely due to the fact that the most thermoresistant bioantioxidant, α-tocopherol, was present in a lower concentration in the final spice paprika than the most thermosensitive ascorbic acid.

3. Conclusion

Spice red pepper must have high values of total extractable red colour before processing because the loss of quality during the drying, grinding, packaging, storage, and commercialisation operations may be as high as 80–85%. The highest colour contents were found in the fruits of the first harvest, thus if possible these are the peppers to be used for paprika processing. The Spanish cultivar Albar showed the highest colour level and red/yellow pigments ratio of all studied varieties and together with the Hungarian Mihályteleki also showed the best quality after the drying and grinding operations. The negative effect of UV light on the colour content was significantly lower (10–33%) than that of heat (70–85%). Once again, ground paprika from the Albar cultivar was the most thermo- and photostable, with results being similar for the Gorogled-6 cultivar. Peppers from Ti^{4+}-ascorbate treated plants had a better quality than those from control plants and the protective factors developed by this treatment (increased levels of ascorbic acid and α-tocopherol) were thermosensitive but phototolerant.

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