

## The effect of cultivar and harvesting stage on the chemical composition of processing tomato fruit

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### Abstract

Field-grown processing tomatoes are harvested in the red stage, however a significant part of fruits remaining on the crop are at the turning stage and in the mature-green stage. This is a part of the crop that can still be used after post-harvest ripening. The aim of the study was to compare the quality of the three determinate tomato cultivars harvested in the field during the red stage with that of red tomatoes obtained after ripening on shelf (harvested in the turning and mature-green stages). Red fruits were analysed immediately after harvest. The remaining fruits were stored and analysed after they had reached the red stage. Experiment showed that unripe tomatoes harvested in mature green phase during shelf ripening can achieve a good fruit quality, comparable to those harvested red. There was found no impact of the degree of ripeness at harvest on the content of dry matter. The relationship between content of extract, soluble sugars and organic acids and the degree of ripeness at harvest depended on the vegetation period. In 2009 fruits harvested green or pink reached higher content of extract, soluble sugars and organic acids than fruits harvested red. In 2010 it was quite contrary; all parameters were worst in fruits collected green or pink. In 2011 there were no differences in extract, whereas level of sugars and organic acids were higher in fruits collected unripe, stored and analysed after they had reached the red stage. Regardless of the year of research, vitamin C level was always the highest in the fruits collected red.

**Keywords:** acidity; extract; L-ascorbic acid; ripeness stage; sugars

### Introduction

Field-grown processing tomatoes are harvested in the red stage and the raw material is processed quickly. As shown in our previous research (Jędrzczyk *et al.*, 2017), even after application of ethephon 8-14% of the fruits remaining on the plant are at the turning stage and 16-20% in the mature-green stage. This is a significant part of the crop that can still be used after post-harvest ripening. However, there are still doubts as to whether the quality of tomatoes harvested in the mature-green stage is comparable to that of tomatoes picked red from the plant. Weingerl and Unuk (2015), for example, report that tomatoes harvested at the commercial maturity stage have higher nutritional value and quality than those harvested in earlier stages of maturation and ripening in storage. On the other hand, the quality of red tomatoes deteriorates sharply after harvest, so they cannot be

stored for long. The stage of maturity at harvest is also linked to varied susceptibility to mechanical damage (Ferreira *et al.*, 2005).

The content of soluble sugars and organic acids is significantly correlated with flavour attributes (Gajc-Wolska *et al.*, 2000), and thus high content of these two components determines the palatability of the tomatoes. The conflict between early harvest of tomatoes and the reduction in sugars has yet to be resolved (Beckles, 2012). Import of sugars in fruit ripening on the plant increases in the late stages of maturation, whereas in fruit harvested earlier, starch degradation is a source of sugars. As a result, fruits ripening on the plant have more glucose and fructose than those harvested earlier and ripening on the shelf (Karapanos *et al.*, 2015). There are also doubts as to whether tomatoes ripening after harvest have similar antioxidant activity to that of tomatoes ripening on the plant (Ozgen *et al.*, 2012). High-lycopene tomatoes have higher antioxidant activity than traditional tomatoes due to their higher content of carotenoids, especially lycopene (Ilahy *et al.*, 2011; Garcia-Valverde *et al.*, 2013; Tigest *et al.*, 2013). The cultivar factor undoubtedly has a strong influence (Parker and Maalekuu, 2013), although Akbydak (2010) argues that the stage of ripeness may be more important for tomato quality than the cultivar. He reports that processing tomatoes harvested at 85-95% maturity will produce thicker pastes with higher content of acids and extract.

The aim of the study was to compare the quality of the three cultivars of processing tomato harvested in the field during the red stage with that of red tomatoes obtained after ripening of tomatoes harvested in the turning and mature-green stages, and to determine whether the additional red tomatoes are comparable in quality to those fully ripened in the field. In addition, we analysed the changes over time in selected components from the green stage to the red stage during post-harvest ripening.

## Materials and Methods

### *Experimental procedures*

The experiment was conducted in an open field at the Experimental Station of the Department of Vegetable and Medicinal Plants in Mydlniki, near Krakow, Poland, in the years 2009-2011. Three cultivars of determinate tomato (*Lycopersicon esculentum* Mill.) were included in the study: two of Polish breeding, 'Rumba' (Reguły) and 'Mieszko F<sub>1</sub>' (PlantiCo), and one Dutch cultivar, 'Polset F<sub>1</sub>' (Bejo Zaden). They are early cultivars, that go into full fruiting after 70-75 days from planting. Six-week seedlings were planted at 80 × 60 cm spacing at different times each year, depending on weather conditions - 21.05.2009, 29.05.2010, and 16.05.2011. May of 2010 was extremely wet (302 mm of precipitation), which delayed planting. The basic soil fertilization was adjusted to the results of soil analysis, with available forms of mineral constituents added to levels of (mg dm<sup>-3</sup>) 120 N; 80 P; 250 K; 80 Mg. Plots were weeded mechanically as needed. During the growing seasons chemical disease protection was carried out in accordance with the Plant Protection Programme. Irrigation was carried out only in 2009 to supplement precipitation as needed. Sprinkle irrigation provided 12 mm of water in June and July and 22 mm in August.

The experiment was set up as a split-block design with four replications. Each plot had an area of 57.6 m<sup>2</sup>.

### *Meteorological background*

Weather conditions, i.e. air temperature, precipitation totals and number of days with precipitation were monitored on the experimental plots (Table 1). Air temperature was recorded with HOBO Data Logger sensors (produced by Onset Company Corporation, USA) at the standard level of 2 m, and precipitation was measured with a Hellmann rain gauge at the standard level of 1 m.

Years of the study were highly varied in terms of temperature and precipitation. The conditions in 2009 were most favorable according temperatures and sum and the frequency of precipitation. In 2010 and 2011 the

precipitation totals registered on the experimental plots substantially exceeded the average for the region. In 2010, due to heavy and frequent rainfall in May (302 mm of precipitation), the plants could not be planted on schedule. Moreover, the level of rainfall in August of that year was nearly twice the average, which impeded correct and timely plant protection procedures.

**Table 1.** Mean monthly air temperature, total precipitation and number of days with precipitation during the growing period

Meteorological elements	Years	May	June	July	August	September
Mean temperature (°C)	2009	13.5	16.0	19.9	18.7	15.1
	2010	12.8	17.5	20.7	18.4	12.1
	2011	12.7	17.6	20.9	18.8	12.4
Total precipitation (mm)	2009	97.8	140.2	82.6	53.1	35.0
	2010	299.0	135.1	105.2	127.5	116.3
	2011	223.0	122.0	110.4	138.2	92.4
Number of days with precipitation	2009	17	21	15	10	11
	2010	27	12	14	16	18
	2011	11	16	23	9	6

#### *Harvest procedures*

Fruits were harvested on 7.09.2009, 14.09.2010 and 30.08.2011. All fruits were harvested from the plots, including those that were not yet ripe. Non-marketable fruits, i.e. those that were diseased, poorly developed, or very small, were not used for further observations. Properly shaped and well-developed fruits were divided into three groups, according to the maturity stage: a red group (80-90% of the fruit surface is red in colour), a turning group (including pink and turning fruits, where 30-60% of the fruit surface shows pink or light red colour), and a mature green group (including fully grown but green or breaker fruits, where 10-30% of the fruit surface is pale yellow).

#### *Postharvest proceedings*

Twenty properly shaped and well-developed fruits were collected for analysis from each maturity stage. Red fruits were analysed immediately after harvest. The remaining fruits were stored at 21 °C and relatively humidity of 85%, and the analysis was performed after they had reached the red stage.

In the next study changes in the chemical composition of the fruit during storage were examined. Every three days twenty tomatoes from each cultivar were chosen for analysis. The procedure was continued until the fruits of each cultivar were red. This was 14 days (5 analyses) in the case of 'Rumba' and 'Polset F<sub>1</sub>' and 17 days (6 analyses) for 'Mieszko F<sub>1</sub>'.

#### *Analysis of chemical composition*

The content of the chemical components of the tomato fruits was tested in three replications. The following parameters were determined:

- dry matter (% FW) by the oven-dry method (Pijanowski *et al.*, 2004)
- total acidity (% FW) by the titration method using sodium hydroxide (Pijanowski *et al.*, 2004)
- L-ascorbic acid (mg%) according to Tillmans by titration of extracts with indophenol solution (PN-71/A/75101)
- extract (°Brix) with a WYA Abbe refractometer in juice squeezed from the fruits (PN-90/A-75101/02)
- soluble sugars (% FW) by the anthrone colorimetric method (Yemm and Wills, 1954) following extraction with ethyl alcohol; their extinction was determined with a UV-VIS Helios  $\beta$  spectrophotometer.

*Statistical procedures*

The results were statistically analysed using analysis of variance for double classification by Tukey's HSD test for unequal N, with  $p < 0.05$ , in Statistica Software. This test was chosen due to the unequal numbers of analyses for different cultivars during ripening.

**Results**

In 2009, tomatoes of the 'Mieszko F<sub>1</sub>' cultivar harvested at the mature-green stage had 8% more dry matter than tomatoes harvested when they were red (Table 2). In the case of the 'Rumba' cultivar, red fruits had 10% more dry matter than fruits harvested in other stages. The dry matter of the 'Polset F<sub>1</sub>' tomatoes did not vary depending on the harvesting time. The 'Mieszko F<sub>1</sub>' tomatoes harvested at the green and turning stages contained 18% more extract than the tomatoes harvested in the red stage. The 'Rumba' and 'Polset F<sub>1</sub>' fruits had the highest content of this component when they were harvested at the turning stage: by 6% and 21% more than those picked in the red stage. The content of soluble sugars in the 'Mieszko F<sub>1</sub>' and 'Rumba' tomatoes did not depend on the time of harvest. 'Polset F<sub>1</sub>' tomatoes harvested during the green and turning stages had 26% more sugars than those harvested in the red stage. The 'Mieszko F<sub>1</sub>' tomatoes harvested in the green stage had the highest content of organic acids, by 19% more than in the fruits harvested in the red stage. The reverse was true for 'Rumba', with 9% more acids noted in the fruits harvested in the turning and red stages. 'Polset F<sub>1</sub>' tomatoes harvested in the green and turning stages had 31% higher acidity than tomatoes harvested in the red stage. The 'Mieszko F<sub>1</sub>' and 'Polset F<sub>1</sub>' tomatoes harvested in the turning and red stages contained more ascorbic acid (48% and 23% more than those harvested in the green stage). 'Rumba' tomatoes did not vary in ascorbic acid content depending on when they were harvested.

**Table 2.** Content of selected components in ripe tomatoes of three cultivars harvested at different stages of ripeness in 2009

Stage of ripeness at harvest	Cultivar	Dry matter (% FW)	Extract (°Brix)	Soluble sugars (% FW)	Organic acids (% FW)	Ascorbic acid (mg %)
Green	'Mieszko F <sub>1</sub> '	5.96 b*	5.02 bc	2.25 bc	0.38 d	10.3 a
Turning		5.70 ab	5.02 bc	2.14 abc	0.32 b	15.2 b
Red		5.52 a	4.30 a	2.25 bc	0.29 a	15.2 b
Green	'Rumba'	5.38 a	4.82 b	2.17 bc	0.32 b	19.6 c
Turning		5.42 a	5.22 cd	2.06 ab	0.35 c	19.2 c
Red		5.92 b	4.92 b	2.23 bc	0.35 c	20.5 c
Green	'Polset F <sub>1</sub> '	5.70 ab	4.88 b	2.36 c	0.42 e	16.4 b
Turning		5.63 ab	5.38 d	2.40 c	0.42 e	19.7 c
Red		5.54 a	4.42 a	1.89 a	0.32 b	20.5 c
Green	Mean	5.68 A	4.90 B	2.26 B	0.37 C	15.4 A
Turning		5.58 A	5.20 C	2.20 B	0.36 B	18.0 B
Red		5.66 A	4.55 A	2.05 A	0.32 A	18.7 C

\*Values marked with the same letter within the same components and for means do not differ significantly

Analysis of the averages for the three cultivars in 2009 of the effect of the stage of maturation at harvest on the content of selected components in ripe tomatoes showed that the dry matter content in fruits varied from 5.58 to 5.68% of fresh weight and the impact of harvesting phase was not significant. The level of extract varied from 4.55 to 4.90 °Brix. Tomatoes harvested in the turning stage had the most extract, 14.5% more than those harvested in the red stage, which had the least extract. Tomatoes harvested in the green and turning stages had 2.20-2.26% FW soluble sugars and it was 8.8% more than tomatoes harvested in the red stage. The content

of organic acids after ripening the tomatoes harvested when they were green was 0.37% FW. It was 15.6% higher than in tomatoes harvested in the red-ripe stage. The least ascorbic acid was accumulated in the tomatoes harvested in the green stage (15.4 mg%), in comparison with the fruit harvested in the red stage (18.7 mg%).

In 2010 no differences were noted in the dry matter of the tomatoes of the cultivars depending on the stage of ripening at harvest (Table 3). Extract in the 'Mieszko F<sub>1</sub>' tomatoes harvested in the red stage was somewhat higher (by 6%) than in those harvested at the turning and green stages. No significant differences in extract were noted in the 'Rumba' tomatoes. The 'Polset F<sub>1</sub>' tomatoes harvested in the turning stage had the most extract, 6% more than those harvested in the other stages. The 'Mieszko F<sub>1</sub>' and 'Polset F<sub>1</sub>' fruit collected in the red stage had the highest content of soluble sugars, which was 36% and 17% more than in the case of the tomatoes harvested in the turning and green stages. The reverse was observed for the 'Rumba' tomatoes, which contained more sugars when harvested in the green and turning stages, 49% more than those harvested in the red stage. The content of organic acids in the 'Mieszko F<sub>1</sub>' fruits did not depend on when they were harvested. The 'Rumba' tomatoes had the highest acidity when they were harvested in the red stage – 38% higher than those harvested in the turning stage, which had the lowest acidity. The 'Polset F<sub>1</sub>' fruits harvested at different stages of maturation varied only slightly in their content of acids. The 'Mieszko F<sub>1</sub>' and 'Polset F<sub>1</sub>' tomatoes harvested in the turning stage had the most ascorbic acid - 37% and 70% more than in the fruits of these cultivars harvested in the red ('Mieszko F<sub>1</sub>') and green ('Polset F<sub>1</sub>') stages. The 'Rumba' fruit harvested in the red stage had the highest content of ascorbic acid, 75% more than fruits of this cultivar harvested in the green stage.

**Table 3.** Content of selected components in ripe tomatoes of three cultivars harvested at different stages of ripeness in 2010

Stage of ripeness at harvest	Cultivar	Dry matter (% FW)	Extract (°Brix)	Soluble sugars (% FW)	Organic acids (% FW)	Ascorbic acid (mg %)
Green	'Mieszko F <sub>1</sub> '	4.70 bcd*	3.94 bc	1.38 cd	0.32 a	16.2 d
Turning		4.80 cd	3.94 bc	1.31 c	0.34 ab	19.4 e
Red		4.99 d	4.19 d	1.82 f	0.35 ab	14.2 bc
Green	'Rumba'	4.41 abc	3.95 bc	1.45 de	0.36 b	15.8 cd
Turning		4.50 abc	4.08 cd	1.48 e	0.32 a	24.0 f
Red		4.30 ab	3.89 b	0.98 b	0.44 c	27.6 g
Green	'Polset F <sub>1</sub> '	4.12 a	3.74 a	0.84 a	0.55 e	10.8 a
Turning		4.34 abc	4.04 c	0.84 a	0.51 d	18.4 e
Red		4.21 a	3.84 ab	0.98 b	0.52 de	13.9 b
Green	Mean	4.41 A	3.88 A	1.22 A	0.41 B	14.2 A
Turning		4.54 A	4.02 B	1.21 A	0.39 A	20.6 C
Red		4.50 A	3.97 B	1.26 B	0.44 C	18.6 B

\*Values marked with the same letter within the same components and for means do not differ significantly

On average for the cultivars in 2010 the effect of the stage of ripening at harvest on dry matter content was not significant. For the fruit collected in the turning and red stages, 3% more extract was noted than for the tomatoes harvested at the green stage (3.94 °Brix). Tomatoes harvested at the red stage had 1.26% FW sugars, it was 4% more than tomatoes harvested in other stages (1.21-1.22% FW). The highest acidity (0.44% FW) was shown in the case of fruit harvested when it was red, and the lowest (0.39% FW) in the fruit harvested at the turning stage (by 12.8%). The tomatoes harvested in the turning stage had the most ascorbic acid (20.6 mg%), 45% more than those harvested in the green stage (14.2 mg%).

The analyses conducted in 2011 showed that the dry matter of the 'Mieszko F<sub>1</sub>', 'Rumba' and 'Polset F<sub>1</sub>' tomatoes did not significantly depend on when they were harvested (Table 4). The highest extract content was noted in the 'Mieszko F<sub>1</sub>' tomatoes harvested at the green stage - 11% higher than in the tomatoes harvested

in the other stages. The 'Rumba' fruits harvested at different stages of ripeness did not clearly differ in their content of this component. The 'Polset F<sub>1</sub>' tomatoes harvested at the red stage contained the most extract, 16% more than those picked at the turning stage. The tomatoes of all cultivars harvested at the red stage contained the least soluble sugars, 52% less than those harvested at the turning stage ('Mieszko F<sub>1</sub>'), 44% less than tomatoes picked at other stages ('Rumba'), and 55% less than fruit harvested at the green stage ('Polset F<sub>1</sub>'). The highest content of organic acids was found in the tomatoes of all cultivars harvested in the green stage; this was 27% and 15% more than in the tomatoes harvested in other stages ('Mieszko F<sub>1</sub>' and 'Rumba') and 42% more than in those harvested in the red stage ('Polset F<sub>1</sub>'). The fruit harvested at the red stage contained the most ascorbic acid. This was true for all cultivars tested: they had 40% more of this compound than the tomatoes harvested in the green stage ('Mieszko F<sub>1</sub>'), and 62% and 42% more than the tomatoes collected at the green and turning stages ('Rumba' and 'Polset F<sub>1</sub>').

**Table 4.** Content of selected components in ripe tomatoes of three cultivars harvested at different stages of ripeness in 2011

Stage of ripeness at harvest	Cultivar	Dry matter (% FW)	Extract (°Brix)	Soluble sugars (% FW)	Organic acids (% FW)	Ascorbic acid (mg %)
Green	'Mieszko F <sub>1</sub> '	5.82 bc*	5.35 cd	2.39 e	0.42 c	17.4 ab
Turning		5.84 c	4.85 ab	2.56 f	0.32 a	19.8 b
Red		5.86 c	4.75 ab	1.24 b	0.34 ab	24.4 c
Green	'Rumba'	5.24 ab	4.45 a	2.20 cd	0.38 bc	17.0 a
Turning		5.01 a	4.88 b	2.22 cd	0.35 ab	16.5 a
Red		5.41 abc	4.65 ab	1.25 b	0.32 a	27.2 d
Green	'Polset F <sub>1</sub> '	5.80 bc	5.00 bc	2.35 de	0.54 e	17.1 a
Turning		5.18 a	4.70 ab	2.05 c	0.48 d	16.0 a
Red		5.46 abc	5.45 d	1.05 a	0.38 bc	23.4 c
Green	Mean	5.62 B	4.93 A	2.31 B	0.45 C	17.2 A
Turning		5.34 A	4.80 A	2.28 B	0.38 B	17.4 A
Red		5.58 AB	4.95 A	1.18 A	0.35 A	25.0 B

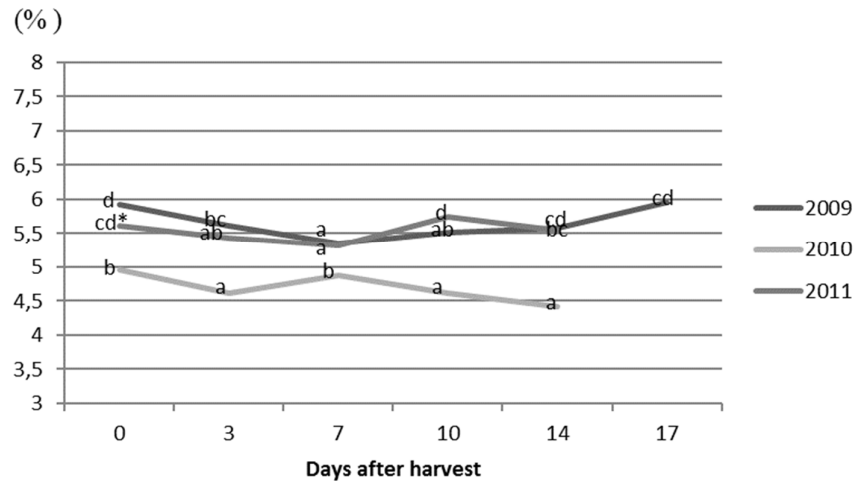
\*Values marked with the same letter within the same components and for means do not differ significantly

On average in 2011 dry matter content in fruit varied from 5.34 to 5.62% FW. The tomatoes harvested in the green stage had the highest dry matter content after ripening: 5% higher than that of tomatoes harvested at the turning stage. The ripening stage at harvest was not found to affect the content of extract in the tomatoes ready for processing. The content of soluble sugars in the tomatoes harvested at the turning and green stages varied from 2.28 to 2.31% FW and was on average 47% higher than in the fruit collected in the red stage (1.18% FW). The content of organic acids in the tomatoes harvested when they were red was 29% lower than in the tomatoes harvested at the green stage (0.45% FW). The tomatoes harvested in the green and turning stage contained the least ascorbic acid (17.2-17.4 mg%), with those harvested at the red stage having 45% more of this compound (25 mg%).

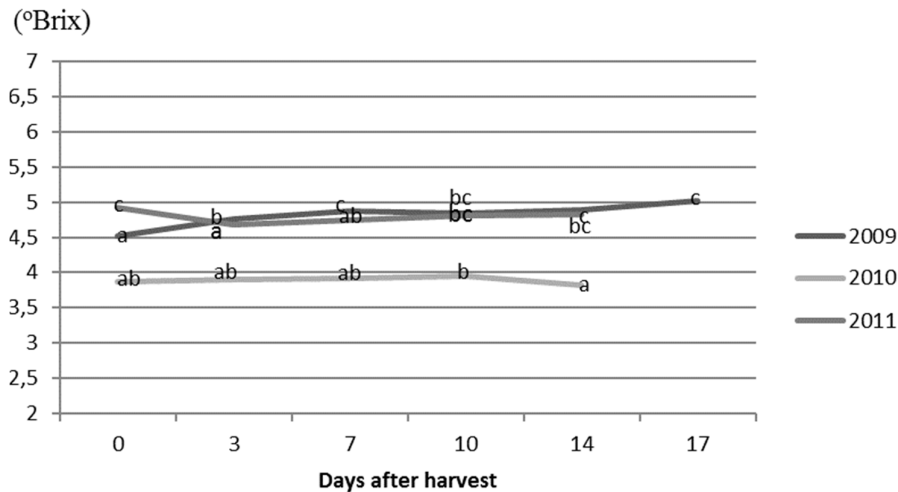
Figure 1 shows the changes in the content of dry matter during the ripening of harvested green tomatoes until they became sufficiently ripe for processing. In 2009 the tomatoes contained the driest matter at the moment of harvest. It then decreased somewhat (by 9.6% after 7 days) and then increased again to its original level. Similar changes were observed in 2011 (5.3% decrease after one week). In 2010 the driest matter was also noted after harvest. Since 7<sup>th</sup> day on shelf definitely decrease was observed (by 11.1% in accordance to the beginning level).

In 2009 the lowest content of extract in the tomatoes was noted at harvest (Figure 2), after which it gradually increased, and the red fruit had 11% more of this component than the green fruit. In the following

year there was no pronounced change in extract throughout the experiment. In 2011 the content of extract in the first few days of ripening decreased by 5% and then again rose to its initial level.



**Figure 1.** Changes in dry matter (% FW) content during tomato ripening in the three years of the experiment (means for three cultivars). \*Values marked with the same letter within the same year do not differ significantly



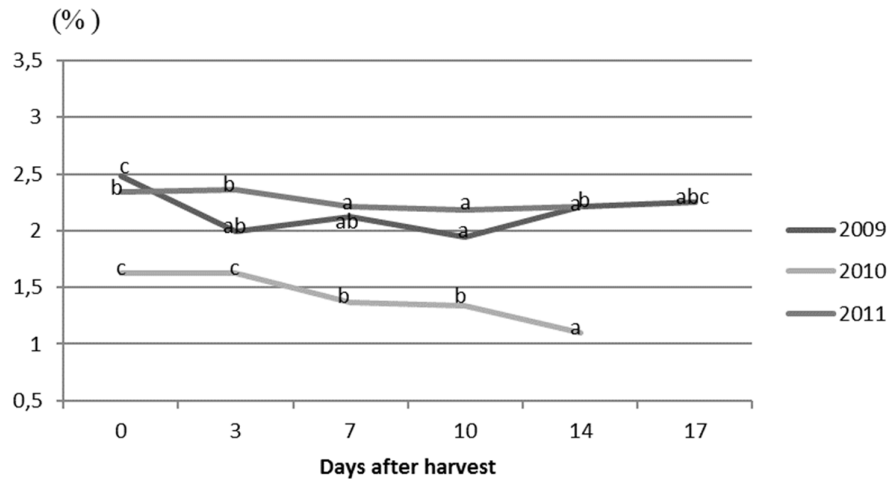
**Figure 2.** Changes in content of extract (°Brix) during tomato ripening in the three years of the experiment (means for three cultivars). \*Values marked with the same letter within the same years do not differ significantly

In the first year of the study the highest content of soluble sugars was noted in the harvested green tomatoes (Figure 3). Between the first and third day of ripening their content decreased by nearly 20%, and then again approached their initial level. The content of sugars in the tomatoes harvested in 2010 decreased throughout the ripening period (ultimately by 32%), with significant reductions noted between the 3<sup>rd</sup> and 7<sup>th</sup> days and between the 7<sup>th</sup>, 10<sup>th</sup> and 14<sup>th</sup> days. The sugar content in the fruit harvested in 2011 remained at a fairly stable level; only between the 3<sup>rd</sup> and 7<sup>th</sup> day of ripening was a 6% decrease observed.

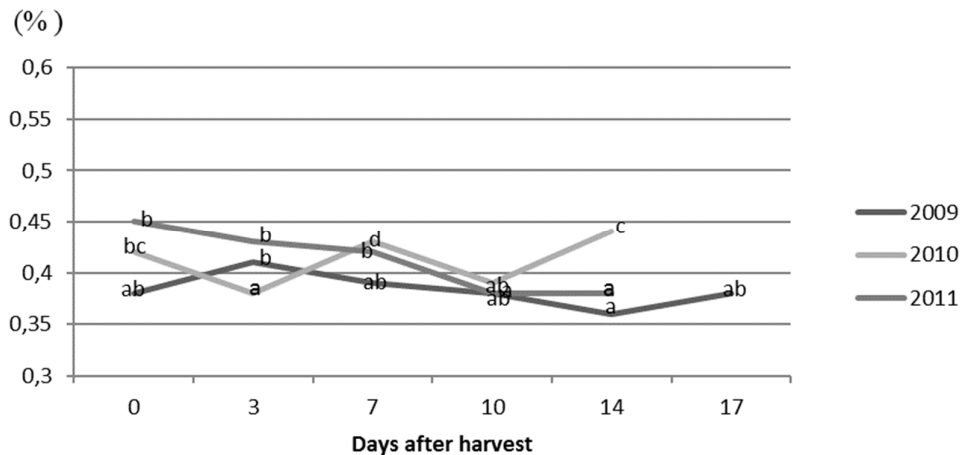
Changes in acidity during tomato ripening in 2009 were minor and not statistically significant (Figure 4). In 2010 no differences were noted in the content of organic acids in the green and red tomatoes, but acidity decreased significantly between harvest and the 3<sup>rd</sup> day of ripening and between the 7<sup>th</sup> and 10<sup>th</sup> days of ripening,

and increased significantly between the 3<sup>rd</sup> and 7<sup>th</sup> days and also between the 10<sup>th</sup> and 14<sup>th</sup> days. In 2011 the red tomatoes had 15% lower content of organic acids than the tomatoes at the moment of harvest; a decrease in their content occurred between the 7<sup>th</sup> and 10<sup>th</sup> days of ripening.

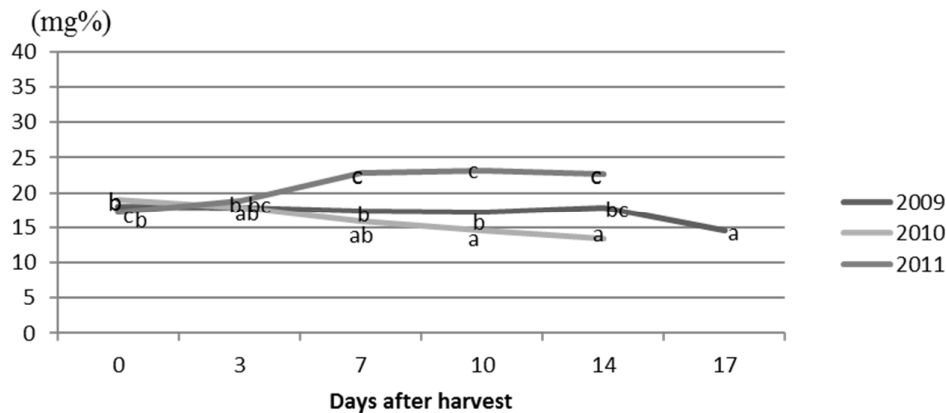
The highest ascorbic acid content in 2009 was noted in the green tomatoes (Figure 5). Only after 14 days of ripening did it decrease by about 19%. Similarly, in 2010 the tomatoes after harvest contained the highest content of this compound. During ripening, ascorbic acid content decreased at a uniform rate, ultimately by 25%. In 2011 the reverse tendency was observed: the least ascorbic acid was observed in the harvested tomatoes. Within the first seven days its content increased by about 33% and remained at this level until the tomatoes were fully ripe.



**Figure 3.** Changes in content of soluble sugars (% FW) during tomato ripening in the three years of the experiment (means for three cultivars). \*Values marked with the same letter within the same years do not differ significantly



**Figure 4.** Changes in content of total acidity (% FW) during tomato ripening in the three years of the experiment (means for three cultivars). \*Values marked with the same letter within the same years do not differ significantly



**Figure 5.** Changes in L-ascorbic acid (mg %) content during tomato ripening in the three years of the experiment (means for three cultivars). \*Values marked with the same letter within the same years do not differ significantly

## Discussion

It has long been disputed whether the quality of tomatoes harvested when they are fully-developed but green and ripened off the plant to the stage of commercial maturity can equal that of tomatoes reach this stage on the plant (Hong and Lee, 1999). According to Saltveit (2005), there is no substantial difference between them, while Moneruzzaman *et al.* (2008) claim that tomatoes harvested when they are fully ripe contain the most sugars and extract, while tomatoes picked when they are half-ripe contain the most vitamin C and titratable acids. Our three-year study of tomatoes of the 'Mieszko F<sub>1</sub>', 'Rumba' and 'Polset F<sub>1</sub>' cultivars harvested at different stages of ripeness has shown that the degree of ripeness at harvest did not affect the content of dry matter in the processing tomatoes or influenced it to a small degree. In the case of ascorbic acid, the results are also conclusive. The lowest level of this compound was detected in the tomatoes harvested in the green stage and the highest in those picked during the red or turning stage. The correlation between content of extract and the phase of fruit ripeness in individual years of research is not clear. It is probably strongly dependent on the weather conditions over the growing season. The highest content of extract in the crop from 2009 and 2010 was detected in the tomatoes harvested at the turning stage, while in 2011 it was not varied. In a study on the 'Roma VF' and 'Marglobe' cultivars, the most extract was also noted in tomatoes at the turning stage, and the least in fruit harvested during the green stage (Getinet *et al.*, 2008). The content of soluble sugars and organic acids decreased as the fruit ripened in 2009 and 2011, while in 2010 the reverse trend was observed, as the red tomatoes contained the most sugars and organic acids. This is probably related to the course of rainfall in these growing seasons. The year 2011 was marked by very intense and frequent rainfall during fruit ripening (August, September).

During the ripening of green tomatoes, no constant trend was observed in the changes in the components analysed, which were minor. In 2010 we observed a decrease in dry matter, soluble sugars and L-ascorbic acid content. This decrease in 2010 year is in contrast to other years of investigation, with more favourable precipitation course, where the ingredients remained at the same level. Perhaps this is related to the condition of the fruit at harvest. Studies by other authors do not provide conclusive answers. According to Arah *et al.* (2015), turning tomatoes have the highest acidity, which rapidly decreases as the fruit ripens. Takahashi *et al.* (2014) also report that acidity and sugar content decrease in turning tomatoes as they ripen. On the other hand, Moneruzzaman *et al.* (2009) state that the titratable acidity and content of soluble sugars in Roma VF tomatoes harvested at various stages of ripeness increased during storage at 28 °C and 75% relative humidity, while vitamin C content decreased. Similar observations were made by Hatami *et al.* (2013). On the

other hand, Oms-Oliu *et al.* (2011) claim that the content of L-ascorbic acid increases up to the turning stage and subsequently decreases. Toor and Savage (2006) report that during storage of tomatoes harvested in the turning stage they observed a slight increase in the content of ascorbic acid. Javanmardi and Kubota (2006) reported that extract remained unchanged in turning and red tomatoes of the Clermont cultivar stored at room temperature, while a similar experiment with 'Chali' tomatoes showed an increase in this component (Abiso *et al.*, 2015).

The results of the experiment indicate that unripe tomatoes harvested in the mature green phase during shelf ripening can achieve good fruit quality. In years with favourable weather conditions there were no decreases in content of dry matter, sugars and L-ascorbic acid in fruits during shelf ripening.

### Conclusions

Experiment showed that unripe tomatoes harvested in mature green phase during shelf ripening can achieve a good fruit quality, comparable to those harvested red. There was found no impact of the degree of ripeness at harvest on the content of dry matter. The relationship between content of extract, soluble sugars and organic acids and the degree of ripeness at harvest depended on the vegetation period. In 2009 fruits harvested green or pink reached higher content of extract, soluble sugars and organic acids than fruits harvested red. In 2010 it was quite contrary; all parameters were worst in fruits collected green or pink. In 2011 there were no differences in extract, whereas level of sugars and organic acids were higher in fruits collected unripe, stored and analysed after they had reached the red stage. Regardless of the year of research, vitamin C level was always the highest in the fruits collected red.

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### Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

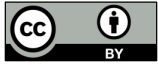
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