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NUTRITIVE VALUE OF TOMATO GROWN UNDER COVERS WITH SOIL MULCHING

WARTOŚĆ ODŻYWCZA POMIDORA UPRAWIANEGO POD OSŁONAMI NA GLEBIE MULCZOWANEJ

Abstract: The experiment was carried out between 2010 and 2012 at the Experimental Station of Siedlce University of Natural Sciences and Humanities. The field experiment was established as a split-block design with three replicates. The effect of plant covering (without cover, under polypropylene non-woven and soil mulching with different kind of straw (rye, corn, rape, buckwheat) on the changes of selected nutrient components in 'Polfast F_1' tomato was investigated. The effect of straw was compared to a control plot without mulch. The content of dry matter, ascorbic acid, total sugars and flash acidity of tomato depended to a higher degree on weather conditions. The most favourable for accumulation of these components was warm and moderately wet 2011. The application of polypropylene non-woven at beginning of growing period of plant did not cause changes in chemical composition of fruits. The influence of straw mulch on the nutritive value of tomato was differentiated. The most of dry matter and ascorbic acid contained tomato cultivated on the rye and buckwheat straw. A higher content of total sugars and monosaccharides was found in fruits from plant cultivated on the corn and rye straw, respectively. Tomato cultivated on the mulch with buckwheat straw was characterized by higher flesh acidity of fruits.

Keywords: dry matter, ascorbic acid, sugars, flesh acidity, polypropylene non-woven, straw

Introduction

The chemical composition of vegetables is genetically determined as well as being modified by factors affecting the plant during growth, and particularly climatic conditions and agro-technology practices [1, 2]. Tomato, as a warm-season vegetable, requires relatively high temperatures for the proper growth and development. Low temperatures constitute the main cause of the large variability of tomato yield in field cultivation and contributing to worsen the quality of the fruits [3]. The application of plastic covers can have an influence on the tomato yield. Covers are used to modify plants natural environment in order to optimize plants growth, increases yields and improve their quality. In the study by Moreno et al [4] an application of polypropylene non-woven contributed to increased dry matter and ascorbic acid content in the edible

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parts of Chinese cabbage. Rekowska and Skupień [5] demonstrated that winter garlic plants grown under covers had significantly higher dry weight content in bulbs and total sugars in leaves. On the contrary, in the study by Majkowska-Gadomska [6] covers with polypropylene non-woven caused a decrease of dry matter, total sugars and disaccharides content in melon fruit.

Soil mulching is one way of soil water protection and also helps maintain a constant soil temperature within the root system of crops [7, 8]. It is particularly recommended for thermophilous vegetables, because mulch, by maintaining proper moisture and decreasing soil warming in summer months, improves soil conditions for plant growth and development. Mulches also suppress weed growth and contribute to reducing the use of herbicides in vegetable production [9]. A favourable effect of soil mulching on the chemical composition of vegetables was found by Samaila et al [10] and Majkowska-Gadomska et al [11] in tomato, Parmar et al [12] and Kosterna et al [13] in melon, Najafabadi et al [14] in garlic.

The study aimed to determine the effect of plant covering with polypropylene non-woven and soil mulching with organic mulch on the chemical composition of tomato fruit.

Material and methods

The experiment was carried out between 2010 and 2012 at the Experimental Station of Siedlce University of Natural Sciences and Humanities, which is located in central-eastern Poland (52°03′N, 22°33′E), 115 km east of Warsaw. According to the international system of FAO classification, the soil was classified as a Luvisol (LV) [15].

The experiment was established as a split-block design with three replicates. The effect of plant covering (without cover, under polypropylene non-woven and soil mulching with different kind of straw (rye, corn, rape, buckwheat) on the changes of selected nutrient components in 'Polfast F_1' tomato was investigated. The effect of straw was compared to a control plot without mulch.

The forecrop was triticale. In the autumn each year, preceding tomato cultivation, ploughing was performed. At the same time, farmyard manure was incorporated at a rate of 30 Mg · ha^{-1}. In the spring, two weeks before the seedlings were planted, disc harrowing was applied to loosen the upper soil layer and prepare it for planting. After that, mineral fertilisers were applied in the amount of supplementary content to the optimal level for tomato: 85 kgN, 104 P_2O_5, 234 K_2O per 1 ha. Mineral fertilisers were applied in the form of ammonium nitrate, triple superphosphate and 60 % potassium salt.

Directly before seedling planting, the particular kind of straw was applied at a dose of 10 Mg · ha^{-1}. The thickness of the mulch layer depended on the kind of straw. In the case of rye and rape straw mulch thickness amounted to 7–8 cm on average; in the case of corn straw, the mulch layer amounted to about 5 cm; however, for buckwheat straw the average was 8–10 cm.

Tomato seedlings were grown in a heated greenhouse. The seeds were sown at the rate of 8 g to seedling containers with peat substrate on 18 March in 2010 and 2011 and 28 March in 2012. After cotyledon formed and at the beginning of first leaf emergence,

the seedlings were bedded into pots with a diameter of 8–10 cm (1 April in 2010 and 2011 and 11 April in 2012). Prior to transplanting the seedlings were hardened off and then moved permanently outdoors. Plants were planted in the successive study years on 20, 16 and 14 May, at a spacing of 60 × 40 cm.

Directly after seedlings planted suitable combinations were covered with polypropylene non-woven Pegas Agro 17UV. The cover removed after 3 weeks. After that, 50 kgN · ha^{-1} in the form of ammonium nitrate was applied (top dressing), each year. During the growing season, systematic tomato plant protection against fungal diseases was carried out. At 10-days intervals, the following plant protection sprays were applied: Infinito 687.5 SC, Amistar 250 SC and Ridomil Gold ® MZ Pepite 67.8 WG.

Tomato fruit harvesting was performed several times as the fruit ripened. The beginning of harvest occurred in the last 10 days of July and ended in the first 10 days of September. From each plot a fruit sample (20 fruits) was taken to perform chemical analyses. Tomato fruits intended for analysis were taken during full fruiting (mid-August). The following was determined:

– dry mass – by drying to a constant weight at 105 ^{o}C (Polish Standard PN-90/A-75101/03) [16],

– total sugars and monosaccharides – using the Luff-Schoorl method (Polish Standard PN-90/A-75101/07) [17],

– L-ascorbic acid – using the Tillmans method (Polish Standard PN-A-04019) [18].

The flesh acidity of tomato (g · 100 g^{-1} counted on lemon acid) was also estimated.

The results of the experiment were statistically analysed by means of the analysis of variance following the mathematical model for the split-block design. Significance of differences was determined by the Tukey test at the significance level of p = 0.05.

Weather conditions in the years of the study were varied (Fig. 1).

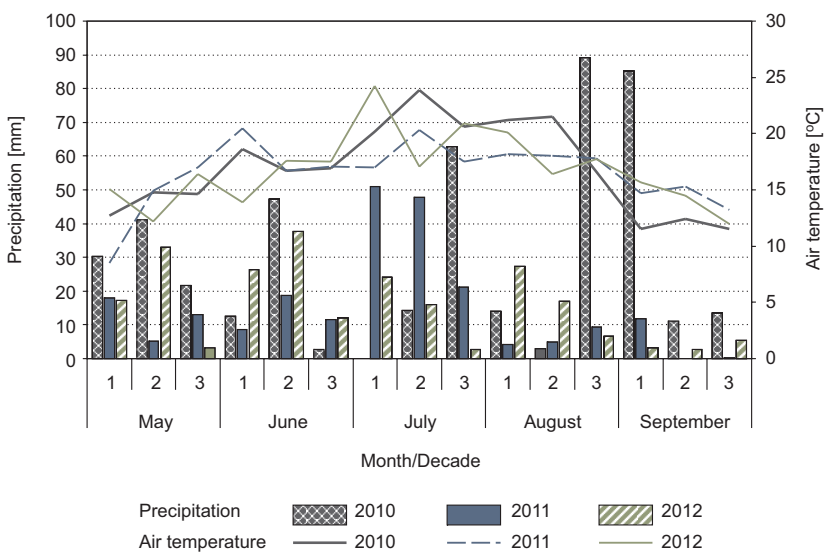

Fig. 1. Weather conditions in the vegetation period of tomato

Year 2010 was characterised by rather high air temperature but was also more moisture compared to the following years of the study, in particular during the final period of plant growth. Year 2011 was characterised by high and similar air temperature from the planting time to the beginning of harvest. Insufficiency of water in June, especially in the first 10-days, was compensated for by heavy rainfall in July. A lower rainfall at the end of vegetation period was profitable to fruits maturing. Mean air temperatures in 2012 were high, with only a slight fall in the temperature in the first 10-days of June. The drought in the last 10-days of May had no influence on the growth of plants. June, July and August were characterised by quite regular rainfall distribution.

Results and discussion

The content of dry matter in tomato fruits amounted on average 6.54 % (Table 1). The most of this component was noted in tomato cultivated on the buckwheat straw (7.66 %) and the least in fruits from plots mulched with rape straw (5.45 %). Similar content of dry matter (on average 5.30 %) had tomatoes fruits in the study by Majkowska-Gadomska et al [11]. In the study by Winiarska and Kolota [19] the content of dry matter in fruits ranged from 5.22 to 6.42 %, and in the study by Jankauskienë et al [20] from 4.59 to 5.67 %.

Table 1

Dry matter content [%] in tomato depending on covering and kind of mulching straw in the years 2010–2012

Specification		Kind of straw					Mean
		control	rye	corn	rape	buckwheat	
Years	2010	6.38	6.45	6.34	5.45	6.39	6.20
	2011	7.00	7.20	6.82	7.35	7.66	7.21
	2012	6.33	6.30	6.28	6.16	5.98	6.21
Covering	no cover	6.69	6.68	6.71	6.47	6.65	6.64
	polypropylene non-woven	6.45	6.63	6.25	6.17	6.70	6.44
Mean		6.57	6.65	6.48	6.32	6.68	6.54
$LSD_{0.05}$ for: years = 0.65; covering = n.s.; kind of straw = 0.21; years × kind of straw = 0.36; covering × kind of straw = n.s.							

Climatic conditions, mainly air temperature and precipitation have a decisive effect on vegetable yield and its quality [2, 21], what is confirmed in the present study. A higher content of dry matter in fruits was found in moderate wet 2011. The increase in dry matter amounted to 1.01 % compared to relatively wet 2010 and 1.00 % compared to 2012. The influence of weather conditions on the dry matter accumulation in tomato fruits was confirmed in the study by Skowera et al [22]. The amount of dry matter in the fruits of all tomato cultivars was the largest in 2009 (the most adequate to tomato water needs) and fluctuated between 4.7 and 5.4 %. According to Mitchell et al

[23] an optimal distribution of precipitation, especially in July and August (period of fruit setting), confirm not only higher yield but also the physical and chemical properties of fruits.

The study results did not indicate the effect of plants covering on the dry matter content in fruits. However, it was observed slightly and did not confirm tendency to higher accumulation of this component in fruit from non-covered cultivation. The slight increased of dry matter content in the fennel bulb in the cultivation without plant covering was confirmed in the study by Błażewicz-Woźniak [24]. In turn, in the study by Moreno et al [4] an application of polypropylene non-woven contributed to increased dry matter content in the leaves of Chinese cabbage on average by 18 % compared to non-covered control.

A significant influence on the dry matter content had the kind of organic mulch application (Table 1). A higher dry matter content was found in fruits from plots mulched with rye and buckwheat straw as well as in non-mulched control compared to fruits from object mulched with rape straw. The differences ranged from 0.25 to 0.36 %. The effect of the kind of straw on the dry matter content depended to a higher degree on the weather conditions in the study years. In 2010 a significantly the lowest content of dry matter accumulated fruits from plants cultivated on the mulch with rape straw. In 2011 more dry matter was found in fruits from plants cultivated on the buckwheat straw compared to rye and corn straw and control plot without mulch. The tomato grown on the rape straw was characterized by higher content of this component than cultivated on the corn straw. In 2012 the difference was small and was not statistically confirmed. In the studies by Majkowska-Gadomska et al [11] and Samaila et al [10], soil mulching contributed to a significant increase in dry matter content in tomato fruits compared to the control without mulch. In the study by Olfati et al [25], organic mulch applied in carrot cultivation did not have any influence on the dry matter content in roots. It was not found a significant influence an interaction between investigated factors on the dry matter content in tomato fruit.

The biological value of the edible parts of vegetables is determined by ascorbic acid content. The content of vitamin C in vegetables can be influenced by various factors such as genotypic differences, climatic conditions and cultural practices, maturity and harvesting methods. The higher the intensity of light during the growing season, the greater is vitamin C content in plant tissues [2]. In the present study, the ascorbic acid content in tomato fruit ranged from 15.95 to 22.34 mg · 100 g^{-1} f.m. (Table 2). A similar content of this component in fruits was found by Winiarska and Kolota [19]. The content of vitamin C depending on cultivar ranged from 14.44 to 20.65 mg · 100 g^{-1} f.m. In the study by Majkowska-Gadomska et al [11] the content of ascorbic acid was higher and fluctuated between 27.7 and 32.9 mg · 100 g^{-1} f.m. In turn, in the study by Caliman et al [26] the content of ascorbic acid depending on the cultivation way amounted from 12.83 to 17.02 mg · 100 g^{-1} f.m.

Weather conditions in the years of the study significantly differentiated the content of ascorbic acid in tomato. A significantly more of ascorbic acid was found in tomato cultivated in moderately wet 2011 and 2012. The differences compared to 2010 amounted to 4.97 and 3.74 mg · 100 g^{-1} f.m., respectively. The content of L-ascorbic

acid in tomato fruit in the experiment by Skowera et al [22] was significantly different in the years of the study, however authors did not confirm dependence between L-ascorbic acid content and the hydrothermal index (K).

Table 2

Ascorbic acid content [mg · 100 g^{-1} f.m.] in tomato depending on covering and kind of mulching straw in the years 2010–2012

Specification		Kind of straw					Mean
		control	rye	corn	rape	buckwheat	
Years	2010	17.50	15.95	16.00	16.36	17.60	16.68
	2011	21.49	22.34	21.13	21.17	22.15	21.65
	2012	20.33	20.53	20.42	20.49	20.31	20.42
Covering	no cover	19.90	18.89	20.00	18.89	20.00	19.54
	polypropylene non-woven	19.65	20.31	18.36	19.79	20.04	19.63
Mean		19.77	19.60	19.18	19.34	20.02	19.58
$LSD_{0.05}$ for: years = 1.60; covering = n.s.; kind of straw = 0.52; years × kind of straw = 0.90; covering × kind of straw = 1.33							

The effect of successive kinds of straw on the ascorbic acid accumulation depended on weather conditions. In 2010 a significantly more of ascorbic acid was obtained in fruits from objects mulched with buckwheat straw and non-mulched control compared to the remaining kinds of straw. In 2011 a significantly higher content of this component were characterized fruits from plant cultivated on the rye and buckwheat straw compared to the remaining kinds of straw. In 2012 the content of ascorbic acid was on the similar level. In the study by Majkowska-Gadomska et al [11] soil mulching in tomato cultivation had no influence on the ascorbic acid accumulation. It was only observed slight and did not statistically confirm tendency to increase of this component in plot without soil mulching. Similarly in the study by Sekhon et al [27] significantly higher content of ascorbic acid in sweet pepper fruits cultivated in a control plot without mulch, compared to the plots with organic mulch was observed.

The study results showed a significant influence of the interaction between the covering and the kind of straw applied to soil mulching on the ascorbic acid content in fruits. In the cultivation under polypropylene non-woven more of ascorbic acid was noted in fruits from plants grown on the rye, rape and buckwheat straw compared to corn straw. In the study by Majkowska-Gadomska [6] plant covering and soil mulching exerted a similar effect on the L-ascorbic acid content of the edible parts of melon fruit. A tendency towards higher L-ascorbic acid concentrations in melon plants grown in mulched soil was noted.

The flavor of tomato fruit is also dependent on the concentrations of sugars. The increase of sugars concentration improved the flavor of fruits. The content of total sugars in tomato fruit ranged from 2.40 to 2.86 % f.m. and monosaccharides from 0.93 to 1.06 % f.m. (Tables 3 and 4).

Table 3

Total sugars content [% f.m.] in tomato depending on covering and kind of mulching straw in the years 2010–2012

Specification		Kind of straw					Mean
		control	rye	corn	rape	buckwheat	
Years	2010	2.63	2.40	2.61	2.60	2.60	2.57
	2011	2.72	2.86	2.79	2.72	2.72	2.76
	2012	2.56	2.69	2.69	2.53	2.61	2.62
Covering	no cover	2.60	2.58	2.68	2.71	2.75	2.66
	polypropylene non-woven	2.68	2.72	2.71	2.52	2.54	2.63
Mean		2.64	2.65	2.70	2.61	2.65	2.65
$LSD_{0.05}$ for: years = 0.16; covering = n.s.; kind of straw = 0.06; years × kind of straw = 0.10; covering × kind of straw = 0.09							

Table 4

Monosaccharides content [% f.m.] in tomato depending on covering and kind of mulching straw in the years 2010–2012

Specification		Kind of straw					Mean
		control	rye	corn	rape	buckwheat	
Years	2010	0.99	1.06	1.00	1.06	0.95	1.01
	2011	0.96	1.05	1.02	0.99	0.95	0.99
	2012	0.99	0.97	0.95	1.00	0.96	0.97
Covering	no cover	0.97	1.01	1.00	1.02	0.97	1.00
	polypropylene non-woven	0.99	1.04	0.98	1.01	0.93	0.99
Mean		0.98	1.03	0.99	1.01	0.95	0.99
$LSD_{0.05}$ for: years = n.s.; covering = n.s.; kind of straw = 0.03; years × kind of straw = 0.04; covering × kind of straw = n.s.							

In the study by Winiarska and Kolota [19] the content of total sugars in fruits amounted on average 3.11 % f.m. and monosaccharides 2.84 % f.m. According to Majkowska-Gadomska et al [11] the content of total sugars in tomato amounted from 3.4 to 4.6 % f.m. In turn, in the study by Caliman et al [26] the content of monosaccharides fluctuated between 2.06 and 2.71 % f.m. According to Davies and Hobson [28], there may be a great variation in the content of reducing sugars (from 1.66 to 3.99 g $100 \cdot g^{-1}$) among genotypes, even when they are cultivated in the same environment.

Weather conditions in the study years had a significant influence on the total sugars contents in fruits but did cause any change in monosaccharides. A higher content of

total sugars found in 2011, which was more favourable for tomato cultivation. The influence of weather conditions on the sugars content in melon fruits was confirmed in the study by Majkowska-Gadomska [6]. On the contrary, in the study by Skowera et al [22] was not found an influence of weather conditions on the sugars content in tomato fruits.

Weather conditions significantly differentiated total sugars and monosaccharides content on the successive kind of straw. The content of total sugars in 2010 significantly decreased soil mulching with rye straw. However, more monosaccharides compared to remaining kinds of straw and non-mulched control contained fruits from plots mulched with rye and rape straw. The cultivation on the corn straw also increased the content of monosaccharides compared to buckwheat straw. In turn in 2011, more favourable influence both on the total sugars and monosaccharides had cultivation on the mulch with rye straw. It was also observed an increased in monosaccharides content in tomato cultivated on the corn straw compared to buckwheat and control plot. A higher content of total sugars in 2012 was noted in fruits from plots mulched with rye and corn straw and monosaccharides from rape straw. In the study by Samaila et al [10], soil mulching with rice straw caused a significant increase of carbohydrates in tomato fruits compared to the control without mulch. Parmar et al [12] was found that soil mulching with straw and dry leaves in melon cultivation caused an increased of monosaccharides and total sugars contents compared to non-mulched control.

The interaction between investigated in the experiment factors significantly differentiated content of total sugars, however had no influence on the monosaccharides (Tables 3 and 4). In the non-covered plots a higher content of total sugars were characterized fruits from plants grown on the mulch with corn, rape and buckwheat straw. However, in the cultivation under polypropylene non-woven more of this component was found in fruits from plots mulched with rye and corn straw and non-mulched control compared to remaining kinds of straw. In the study by Majkowska-Gadomska [6] a higher content of total sugars was observed in simultaneously mulched and covered plots and monosaccharides in plots covered only. On the contrary, in the study by Caliman et al [26] tomatoes cultivated under cover was contained significantly less of monosaccharides than grown in the open field. According to Beckmann et al [29] the lower reducing sugar content of fruits produced in the protected environment may be related to lower light intensity, approximately 25 % lower than in the field. The greater sugar content in the fruits produced in the field may be due, in part, to the greater light intensity in this crop environment and greater photosynthetic plant activity. The influence of solar radiation on sugar content in cherry tomatoes also has been found in the study by Rosales et al [30].

According to Mahakun et al [31] the genetic factor is the major acid content determinant in tomato plant fruits. These authors reported variation in fruit acidity (% citric acid) for different accessions of *Lycopersicon esculentum*, from 0.40 % to 0.91 %. According to Davies and Hobson [28] during fruit development, acidity increases, reaching a maximum value at the first signs of yellow coloration and progressively decreasing with the appearance of the red color. In the present study flesh acidity of tomato amounted to average 0.41 g · 100 g^{-1} (Table 5).

Table 5

Flesh acidity of tomato [g · 100 g^{-1} counted on lemon acid] depending on covering and kind of mulching straw in the years 2010–2012

Specification		Kind of straw					Mean
		control	rye	corn	rape	buckwheat	
Years	2010	0.38	0.36	0.36	0.36	0.38	0.37
	2011	0.46	0.47	0.45	0.46	0.48	0.46
	2012	0.41	0.41	0.41	0.41	0.40	0.41
Covering	no cover	0.41	0.40	0.42	0.40	0.42	0.41
	polypropylene non-woven	0.42	0.42	0.39	0.41	0.42	0.41
Mean		0.42	0.41	0.41	0.41	0.42	0.41
$LSD_{0.05}$ for: years = 0.03; covering = n.s.; kind of straw = 0.01; years × kind of straw = 0.02; covering × kind of straw = 0.03							

The flash acidity in the study by Caliman et al [26] was relatively lower and amounted from 0.31 to 0.35 %. According to authors, the determination of fruit acidity at complete maturation, when acidity declines, is likely the reason for the low values.

The flesh acidity of the tomato fruit diversified in each year of the study (Table 5). The fruits were characterized by the highest acidity (0.45–0.48 g · 100 g^{-1}) in 2011, whereas the fruits from 2010 had the lowest (0.36–0.0.38 g · 100 g^{-1}). A similar dependence was observed in the study by Skowera et al [22]. The authors found that the highest flesh acidity had fruits in moderately wet 2008 and the lowest in 2010, which was characterized by the most unfavourable for tomato rainfall distribution.

The effect of the kind of straw on the flesh acidity depended on weather conditions. The higher flesh acidity in 2010 was characterized fruits from plants cultivated on the mulch with buckwheat straw and in control plot. In 2011 a higher acidity had fruits cultivated on the buckwheat straw. It was not found a difference between fruit acidity in 2012. In the study by Parmar et al [12] soil mulching with straw and dry leaves slightly reduced flesh acidity of melon fruit.

On the basis of the obtained results, a significant influence of the covering and the kind of straw applied to soil mulching on tomato flesh acidity was found. In the covered plots the fruits acidity increased cultivation on the mulch with rye and buckwheat straw and in non-mulched control.

Conclusions

1. Weather conditions in the years of the study had a higher degree of influence on the chemical composition of tomato fruits. The highest content of nutritive compounds was characterized fruits in warm and moderately wet 2011.

2. The application of polypropylene non-woven covers in tomato cultivation did not cause changes in the content of investigated compounds in fruits.

3. The investigated in the experiment organic mulches influences on the selected compounds of nutritive value without regular pattern.

4. Irrespective of covering, accumulation of dry matter and ascorbic acid favoured cultivation on the mulch with rye and buckwheat straw. A higher content of total sugars was found in fruits from plots mulched with corn straw and monosaccharides with rye straw. However, cultivation on the buckwheat straw contributed to increase flesh acidity of tomato fruits.

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WARTOŚĆ ODŻYWCZA POMIDORA UPRAWIANEGO POD OSŁONAMI NA GLEBIE MULCZOWANEJ

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Abstrakt: Badania przeprowadzono w latach 2010–2012 w Stacji Doświadczalnej należącej do Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach. Doświadczenie polowe założono w układzie split-blok w trzech powtórzeniach. Badano wpływ osłaniania roślin (bez osłony, włóknina polipropylenowa) i mulczowania gleby różnymi rodzajami słomy (żytnia, kukurydziana, rzepakowa, gryczana) na zmiany zawartości wybranych składników odżywczych pomidora 'Polfast F_1'. Wpływ mulczu ze słomy porównano z obiektem kontrolnym bez słomy. Zawartość suchej masy, kwasu askorbinowego, cukrów ogółem oraz kwasowość miąższu pomidora zależały w dużym stopniu od warunków pogodowych. Najbardziej korzystne warunki do gromadzenia tych składników panowały w ciepłym i umiarkowanie wilgotnym roku 2011. Zastosowanie

osłony z włókniny polipropylenowej w początkowym okresie wzrostu roślin nie powodowało zmian w składzie chemicznym owoców. Wpływ mulczu ze słomy na wartość odżywczą pomidora był zróżnicowany. Najwięcej suchej masy i kwasu askorbinowego zawierały pomidory uprawiane na mulczu ze słomy żytniej i gryczanej. Większą zawartość cukrów ogółem w owocach stwierdzono przy uprawie roślin na słomie kukurydzianej, a cukrów redukujących żytniej. Pomidory uprawiane na mulczu ze słomy gryczanej charakteryzowały się większą kwasowością miąższu.

Słowa kluczowe: sucha masa, kwas askorbinowy, cukry, kwasowość miąższu, włóknina polipropylenowa, słoma