Effect of methyl jasmonate, salicylic acid and ascorbic acid on quality parameters of strawberry (*Fragaria x ananassa* Duch) fruit during cold storage

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Abstract

Introduction. The objective of this work was to investigate the combined solution effects of methyl jasmonate, salicylic acid and ascorbic acid on storability of strawberry fruits.

Materials and methods. The anthocyanins were quantified by the pH differential method. Total phenolic compounds were determined by method using Folin-Ciocalteau reagent. FRAP assay was applied in order to determine antioxidant activity. Determination of individual anthocyanins by HPLC was performed by a Varian- Prostar-500 series liquid chromatograph. The texture analyses of the strawberries were carried out using a Texture Analyser.

Results and discussion. Effect of combined solution of Methyl jasmonate (MJ), Salicylic acid (SA) and Ascorbic acid (AA) on storability of strawberry fruits (Victoria and Camarosa varieties) was investigated. Treatment with MJ, SA and AA positively influenced on the level of content of vitamin C in strawberries fruits during storage.Total anthocyanins in the control samples of Victoria gradually decreased from 21.35±1.06 to 13.35±0.66 mg100g^{-1} on the 13-th day of storage. As to the treated samples, anthocyanins content reduced to 15.49±0.77mg100g^{-1}. In the samples of Camarosa total anthocyanins reduced from 46.93±2.34 to 20.41 ±1.02 and to 34.59±1.72 mg per 100 g fruits in control and treated samples respectively.Total phenolic compounds (TPC) in the control samples of Victoria initially was equal to 129.86±6.49 mg100g^{-1} and at the end of experiment, it reduced to 111.15±5.55 mg100g^{-1}. Whereas, in the treated sample TPC was unchanged. TPC in Camarosa initially was by 40% more than in Victoria, i.e. 181.51±9.07 mg100g^{-1}. After 13 days of storage, TPC reduced to 131.00±6.55 and to150.02±7.50 mg100g^{-1} in the control and treated samples respectively. Effect of treatment was statistically and practically significant. During storage period, antioxidant activity of the fruits decreased gradually. Change in antioxidant activity of the treated samples was less significant than in untreated sample. i.e by 17.9 and 23.3 % for the fruits of Victoria and Camarosa varieties respectively. Main anthocyanin in the fruits of both varieties was Pelargonidin-3-O-glucoside. Its initial content in the fruits was 68.45±3.42 and 65.28±3.26 % of total anthocyanins for Victoria and Camarosa varieties respectively.

Conclusion Treatment of fruits of strawberry with combined solutions of methyl jasmonate, salicylic acid and ascorbic acid positively influenced on storability of the fruits. Maintenance of anthocyanins and total phenolics as well as antioxidant potential during storage period was statistically significantly increased. Treatment with combined solution resulted in improvement of texture of fruits during storage process.

Introduction

Strawberries (*Fragaria* x *ananassa* Duch) are one of the most popular berries in the world. The quality, chemical composition and sensory parameters of strawberries during fresh storage period have been studied intensively [1]. Strawberries are a good source of vitamins and minerals, and their quality and chemical composition vary among cultivars and with postharvest handling conditions [2]. Also, strawberry fruit is a rich source of natural antioxidants and phytochemicals, particularly anthocyanins, flavonoids, phenolic acids[3-8]. However, shelf life of strawberries is very limited. During fresh storage fruits undergo significant microbial decay, fruit softening, water loss, loss of red color, brown pigment formation, and flavor changes [1, 9–10].

Various chemical compounds have been used to treat the strawberry fruits in order to reduce such undesirable changes during storage period and to prolong shelf life of the fruits.

MJ and SA are endogenous plant hormones that play principal roles in regulating stress responses and plant development [11–12].

Methyl jasmonate (MJ)is a plant growth regulator and it very actively participates in many physiological processes [12, 13]. MJ serves as a signal molecule to initiate the defense mechanism in response to stress conditions [14]. According to Cardemil and co-authors, post-harvest treatments of fruits with jasmonate stimulates the production of such antioxidants as flavonoids, anthocyanins, phenolic acids; improvesthe fruits quality and prolongs their shelf life [15].

Salicylic acid (SA) is a hormonal substance, participating in regulation of numerous physiological processes [16]. SA can inhibit biosynthesis of ethylene in fruits and in such a way delay the ripening of fruits. SA reduces fruit deterioration caused by chill injury and fungal disease during fresh storage period[17].

Ascorbic acid (AA) is known to inhibit browning process in fruits. In addition, AA is cheap and safe for human consumption [18, 19–24].

The objective of our work was to investigate the combined solution effects of methyl jasmonate, salicylic acid and ascorbic acid on storability of strawberry fruits.

Material and methods

2.1 Chemicals

Ascorbic acid higher than 99.0% and potassium dihydrogen phosphate were purchased from Sigma-Aldrich (Steinheim, Germany); TPTZ – 2-4-6-tris (2-pyridyl)-s-triazine (Sigma-Aldrich, Switzerland), the Folin-Ciocalteau reagent (Appli Chem, Germany), hydrochloric acid, formic acid and phosphoric acid were provided by Merck (Darm-stadt, Germany); sodium carbonate was purchased from ChemCruz (ChemCruz Biochemicals, USA); ethyl acetate and methanol (Sigma-Aldrich, Steinheim, Germany) were HPLC grade. All other reagents were commercially available at the local market and were of analytical grade.

2.2. Sample collection

The strawberries (Camarosa and Victoria) were harvested in mid-summer in the eastern part of Georgia (GPS coordinates: Latitude: 41°57’59.99” N, Longitude: 44° 05’ 60.00” E). After harvesting, representative samples of the fruits were treated with combined solution (0.005% MJ, 0.15% SA, 1% AA) at 20±1 °C with an exposure time of 2.0 min. The treated

samples were stored in a refrigerator at 0±0.5 °C and 95±0.5% RH. Quality parameters such as vitamin C content, TPC and anthocyanin content, as well as the antioxidant potential were monitored at the start of sampling and after 4,7,10 and 13 days.

2.3. Sampling procedure

The samples were prepared for the ascorbic acid determination by HPLC (Varian-Prostar-500, USA, detector-UV varian Prostar, Australia, column- 250 mm × 4.6 mm, dp = 5 µm (Symmetry, Waters, Ireland) [25] as follows: briefly, the sample (10 g) was extracted in 10 mL water adjusted to pH 1.5 with 10 mL phosphoric acid-water (2%, v/v). The extracts were filtered through 45 µm filter paper (Whatman, UK) and 1.5 mL buffer (0.01 M KH2PO4, pH 8.0) then added to 1.5 mL of the sample extract. 1 mL aliquots (vitamin C) of each of the preferred mixtures were then loaded on to C 18 cartridges (Agilent, Bond Elut, USA) and 3 mL aliquots of water adjusted to pH 1.5 with 2 mL phosphoric acid-water (2%, v/v) passed through them.

The samples used for the antioxidant analysis were prepared according to Rodriguez-Saona and Wrolstad (2001) [26]. About 40 g of strawberries was cryogenically milled in liquid nitrogen. Chilled test tubes were filled with milled fruit powder and weighed (5 g), and the powder then extracted with acetone (200 mL).The acetone was removed under vacuum in a rotary evaporator at < 30 °C, and 250 mL of methanol (70%) then added to the powder. The total methanol extract was examined for antioxidant activity.

Samples for anthocyanin analyses by High performance liquid chromatography, HPLC (Varian – Prostar - 500, USA, detector - UV varian Prostar, Australia, column – S 250 x 4.6, Agilent, Microsorb – 100 - 5, The Netherlands) were prepared according to Prior et al. (2012) [27]. Berries (40 g) were homogenized in methanol/water/formic acid in a ratio of 60: 37: 3 (v/v/v), kept overnight (14 h) at 3 – 5ºC and later filtered by filter 45 µm (Whatman, UK) through a Buchner funnel under vacuum. The filtrates were centrifuged (4000 X g, 15min, 21ºC) The supernatant was concentrated under vacuum in a rotary evaporator at < 30°C to total evaporation of the methanol. An aliquot (2.0 mL) of the aqueous phase was carefully deposited onto a C - 18 cartridge (Agilent, Bond Elut, USA). sugars and more polar substances were removed by passing 2.0 mL of ultrapure water through the cartridge. polyphenols were removed by passing 2.0 mL of ethyl acetate and finally anthocyanin pigments were eluted with 10 mL of methanol. 10 mL deionized (DI) water was added to the methanol extract and then the methanol was removed under vacuum in a rotary evaporator at < 30ºC.

2.4. Determination of pH

pH value of the berry fruits was measured using a pH-meter (EHS-320, China) at 20°C [28].

2.5. Determination of vitamin C

Vitamin C was determined by the HPLC method [25]. The columns used were 250 mm × 4.6 mm, dp = 5 µm (Symmetry, Waters, Ireland) and the mobile phase was water adjusted to pH 3 with phosphoric acid. The UV detector (Varian pro Star, Australia) was set at 215 nm and quantification was based on the peak area measurement. For HPLC (Varian-Prostar-500, USA), 20 µL of sample were injected.

2.6. Determination of total Anthocyanins

The anthocyanins were quantified by the pH differential method [29]. Samples were diluted 1:150 in pH 1.0 and pH 4.5 buffers, and the absorbance measured at 520 nm and 700 nm in a UV -Visible spectrophotometer (A & E Lab Co LTD, UK), based on a

cyanidin 3-glucoside molar extinction coefficient of 26,900 $\Delta Emol^{-1}$ and a molecular weight of 449.2 $gmol^{-1}$. The resulting values were expressed in terms of mg of anthocyanin per 100 g of fresh fruit.

2.7. Determination TPC

TPC was performed by Bond et al. (2003) [30]. As aliquot of 1.0 mL of diluted sample extract was vortexed with 10 mL DI water and 1.0 mL Folin-Ciocalteau reagent, and a 1.0 mL deionized water was used as control. After equilibration at room temperature for 8 min, the solutions were mixed with 4 mL of 7.5% (w/v) Na_2CO_3. The samples and standards (Gallic acid dilute working standard solutions: 10–50 μgmL^{-1}) were equilibrated at room temperature for 60 minutes. The absorbance of the samples and standards were measured spectrophotometrically (UV/Vis spectrophotometer, A&E Lab Co LTD, UK) at 765 nm, with a 10 mm path length cell. TPC was calculated as mg of gallic acid equivalents per 100 g fresh weight of sample.

2.8. Determination of individual anthocyanins by HPLC

Determination of Anthocyanins by HPLC Analyses was performed by a Varian – Prostar - 500 series liquid chromatograph. Separation was achieved on a C18, 150 mm x 4.6 mm column. Solvents used were: (A) Aqueous Trifluoroacetic acid (TFA) 0.1%, and (B) Methanol 100%, establishing the following gradient: isocratic 6% B for 5 min, 30% B over 10 min, isocratic 50% B for 15 min, 60% B over 5 min, and 6% B over 10 min, using a flow rate of 0.4 mL min-1, using 518 nm wavelength, and a mass spectrometer (MS, Varian-prostar-500, USA) connected to the HPLC system. The Mass Spectrometer (MS) was equipped with an Electro Spray Ionization (ESI) source and an ion trap mass analyzer. Spectra were recorded in positive ion mode 3500 volts. Quantification of anthocyanins content was carried out according to chromatographic peaks at 518 nm wavelength.

2.9. FRAP assay

The Ferric Reducing Ability of Plasma (FRAP) assay was carried out as previously described by Benzie and Strain (1996) [31]. The experiment was carried out at 37 °C and pH 3.6 with a blank sample in parallel. In the FRAP assay, the reductants ("antioxidants") in the sample reduce the Fe (III)/tripyridyltriazine complex to the blue ferrous form, with an increase in absorbance at 593 nm. The final results were expressed as micromole AA equivalents per 100 gram (mmol $AA100g^{-1}$).

2.10. Texture Profile Analysis (TPA)

The texture analyses of the strawberries were carried out using a Texture Analyser (LLOYD, TA1, AMETEK Inc, USA).Cylindrical probe with 10 mm diameter was applied. Extension speed of the probe was 100 $mmmin^{-1}$. Work done by probe, which caused the sample to rupture, was calculated.

2.11. Statistical Analysis

The data represents the mean of three replicates ± standard deviation (SD). Data were subjected to the *t* - test. All calculations were performed with Microsoft Excel (Version 4, statistical functions, Microsoft Corp., Redmond, WA, USA).

Results and discussion

3.1. pH

During storage period, pH value of treated as well as untreated fruits did not change statistically significantly and was between 3.60–3.76 for Victoria (Table 1) and between 3.75–3.99 for Camarosa (Table 2). This fact indicates that there was no hydrolyses of proteins and no change in organic acids concentration during storage period, i.e. conditions for cold storage was chosen properly.

Table 1

Proximate chemical composition of Victoria

Storage period		pH	Vitamin C $mg100g^{-1}$	Total Anthocyanins $mg100g^{-1}$	TPC $mg100g^{-1}$	FRAP mg equivalents of vitamin C x $100g^{-1}$
Initial		3.60 ±0.18[a]	45.60 ±2.28[a]	21.35 ±1.06[a]	129.86 ±6.49[a]	206.46 ±10.32[a]
After 4 days	C	3.69 ±0.18[a]	56.40 ±2.82[b]	17.09 ±0.85[b]	134.23 ±6.71[a]	185.70 ±9.28[b]
	TS	3.79 ±0.19[a]	61.20 ±3.06[b]	20.21 ±1.01[a]	140.85 ±7.04[a]	202.12 ±10.10[a]
After 7 days	C	3.68 ±0.18[a]	52.80 ±2.64[b]	15.79 ±0.78[b]	130.92 ±5.23[a]	136.08 ±6.80[c]
	TS	3.80 ±0.19[a]	55.20 ±2.76[b]	19.50 ±0.97[c]	137.56 ±6.87[a]	177.25 ±8.86[b]
After 10 days	C	3.77 ±0.17[a]	41.00 ±2.05[c]	13.95 ±0.69[d]	126.57 ±6.32[a]	130.38 ±6.51[c]
	TS	3.82 ±0.20[a]	49.25± ±2.46[d]	18.91 ±0.94[c]	141.95 ±7.10[a]	169.14 ±8.45[b]
After 13 days	C	3.76 ±0.17[a]	22.55 ±1.12[e]	13.35 ±0.66[d]	111.15 ±5.55[b]	120.02 ±6.00[d]
	TS	3.95 ±0.20[b]	38.95 ±1.94[f]	15.49 ±0.77[b]	138.00 ±6.90[a]	157.61 ±7.88[e]

*C-control; **TS-treated samples

*-Values within a column with different letters are significantly different by ANOVA with Tukey's HSD tests at $p < 0.05$.

3.2. Content of vitamin C

Vitamin C content in the fruits of Victoria increased after treatment from 45.60±2.28 to 56.40±2.82 $mg100g^{-1}$ in control samples and up to 61.20±3.06 $mg100g^{-1}$ in treated samples, and stayed on this level until 7-th day. Increasing of vitamin C content was caused, probably, because of the prolonged ripening process in fruits during first storage days [25]. After 7-th day content of vitamin C declined due to destruction of vitamins caused by oxidation process [32-36]. On the 13-th day, it was 22.55 ±1.12 and 38.95±1.94 $mg100g^{-1}$ in control and treated samples respectively. Thus, treatment with MJ, SA and AA positively influenced on the level of content of vitamin C in Victoria strawberries fruits during storage.

As to the fruits of Camarosa, because of oxidation process again, vitamin C content decreased monotonically in the control and treated samples as well, and at the end of experiment it was about half of the initial level. There was no statistically significant difference between content of vitamin C in the control and treated samples (Table 2). So, in case of Camarosa fruits, no effect of treatment with MJ, SA and AA on the content of vitamin C was found.

Table 2

Proximate chemical composition of Camarosa

Storage period		pH	Vitamin C mg100g^{-1}	Total Anthocyanins mg100g^{-1}	TPC mg100g^{-1}	FRAP mg equivalents vitamin C x 100g^{-1}
Initial		3.75 ±0.15^{a}	56.40 ±2.82^{a}	46.93 ±2.34^{a}	181.51 ±9.07^{a}	370.23 ±18.51^{a}
After 4 days	C	3.78 ±0.15^{a}	58.80 ±2.94^{a}	35.03 ±1.75^{b}	188.10 ±9.40^{a}	352.30 ±17.61^{a}
	TS	3.82 ±0.19^{a}	62.40 ±3.12^{a}	48.43 ±2.42^{a}	197.80 ±9.89^{a}	368.45 ±18.42^{a}
After 7 days	C	3.87 ±0.18^{a}	43.20 ±2.16^{b}	30.15 ±1.50^{c}	162.83 ±8.14^{b}	281.60 ±14.08^{b}
	TS	3.80 ±0.18^{a}	45.60 ±2.28^{b}	42.20 ±2.11^{a}	184.81 ±9.24^{a}	319.99 ±15.99^{c}
After 10 days	C	3.90 ±0.19^{a}	28.70 ±1.43^{c}	26.28 ±1.31^{d}	160.32 ±8.01^{b}	216.30 ±10.81^{d}
	TS	3.84 ±0.19^{a}	30.75 ±1.53^{c}	38.17 ±1.90^{b}	180.11 ±9.00^{a}	277.98 ±13.89^{b}
After 13 days	C	3.99 ±0.20^{a}	23.40 ±1.17^{d}	20.41 ±1.02^{e}	131.00 ±6.55^{c}	201.14 ±10.05^{d}
	TS	3.83 ±0.18^{a}	25.42 ±2.27^{d}	34.59 ±1.72^{b}	150.02 ±7.50^{d}	248.25 ±12.41^{e}

*C-control; **TS-treated samples

*-Values within a column with different letters are significantly different by ANOVA with Tukey's HSD tests at $p < 0.05$.

3.3. Content of total anthocyanins

Total anthocyanins in the control samples of Victoria gradually decreased from 21.35±1.06 to13.35±0.66 mg100g^{-1} on the 13-th day of storage. The reason for reduction of anthocyanins quantity may be their oxidation process [37]. As to the treated samples, anthocyanins content reduced to 15.49±0.77mg100g^{-1}. Difference between control and treated samples at the end of experiment was statistically significant but practically insignificant (Table 1).

In the samples of Camarosa total anthocyanins reduced from 46.93±2.34 to 20.41 ±1.02 and to 34.59±1.72 mg per 100 g fruits in control and treated samples respectively. Difference between control and treated samples at the end of experiment was statistically and practically significant as well (Table 2). Thus, in case of Camarosa, application of combined solution of methyl jasmonate, salicylic acid and ascorbic acid positively influenced on storability of strawberry fruits.

3.4. TPC

Total phenolic compounds in the control samples of Victoria initially was equal to 129.86±6.49 mg100g^{-1} and at the end of experiment it reduced to 111.15±5.55, that is by 17%. Degradation of phenolic compounds was. Probably, caused by their oxidation [38.39]. Whereas, in the treated sample TPC was unchanged (Table 1), assumingly due to the treatment effect.

TPC in Camarosa initially was by 40% more than in Victoria, i.e. 181.51±9.07 mg100g^{-1}. After 13 days of storage, TPC reduced to 131.00±6.55 and to 150.02±7.50 mg100g^{-1} in the control and treated samples respectively (Table 2). Effect of treatment was statistically and practically significant. From these data, we can conclude, that combined solution of MJ, SA and AA effectively inhibited oxidation process of phenolic compounds in the fruits of strawberry of Victoria and Camarosa varieties.

3.5. FRAP assay

It is well known that antioxidant activity of fruits is proportional to the phenolic compounds content [40.41]. Therefore, it was not surprising that antioxidant activity monotonically decreased in the control samples of Victoria from 206.46±10.32 at the first day to 120.02±6.00 mg equivalents of vitamin-C per 100g fruits at the end of the experiment. Change in antioxidant activity of the treated samples of Victoria was less significant: from 206.46±10.32 to 157.61±7.88 units, that is by 17.9% less than in the case of control samples.

Antioxidant activity of fruits of Camarosa initially was by 80% more than that of Victoria fruits. During storage period, antioxidant activity of the fruits of Camarosa decreased gradually. After 13 days of storage, it was equal to 201.14±10.05 and 248.25±12.41 units for untreated and treated samples respectively (Table 2). Thus, the effect of treatment was statistically and practically significant, i.e. 23.3%.

3.6. Individual anthocyanins

Main anthocyanin in the fruits of both varieties was Pelargonidin-3-O-glucoside. This is a common case for strawberry fruits [42]. Its initial content in the fruits was 68.45±3.42 and 65.28 ±3.26 % of total anthocyanins for Victoria and Camarosa varieties respectively. Though total anthocyanins content gradually decreased during storage period, percentage of this anthocyanin did not change during storage days (Table 3). This indicates on the fact, that Pelargonidin-3-O-glucoside remained the main anthocyanin during whole period of storage. In Victoria variety Pelargonidin-3-acetyl-glucoside was the second anthocyanin by quantity – its percentage in the treated and untreated samples was about 10% and did not changed during storage. Percentage of this anthocyanin in the Camarosa variety varied non-monotonically during storage time. Non-monotonical changes of percentage of individual anthocyanins, assumingly, was a result of the fact that quantity of various anthocyanins were changing differently during storage period. In Camarosa Cyanidin-3-O-glucoside was the second anthocyanin by quantity, its percentage changed during storage period from 10.25±0.51 to 9.41±0.47 and 8.10±0.40% for untreated and treated fruit samples respectively. Pelargonidin-3-O- rutinoside was one more anthocyanins detected in both varieties of strawberry. Its initial percentage was equal to 6.14±0.30 and 8.23±0.41% in Victoria and Camarosa varieties respectively. Cyanidin-3-O-rutinoside was presented in the smallest quantity in both varieties. Its percentage was less than 1% and did not change practically during storage time.

Table 3

Individual Anthocyanins in Strawberry cultivars (%)

Cultivars	Storage period		1	2	3	4	5
Victoria	Initial		5.44 ±0.27[a]	0.17 ±0.008[a]	68.45 ±3.42[a]	6.14 ±0.30[a]	10.03 ±0.50[a]
	After 4 days	C	5.39 ±0.26[a]	0.21 ±0.01[b]	69.04 ±3.45[a]	7.65 ±0.38[b]	9.83 ±0.49[a]
		TS	6.30 ±0.31[b]	0.19 ±0.009[c]	69.19 ±3.46[a]	6.45 ±0.32[a]	9.13 ±0.45[a]
	After 7 days	C	7.71 ±0.38[c]	0.23 ±0.01[d]	65.95 ±3.29[a]	7.44 ±0.37[b]	10.33 ±0.51[a]
		TS	6.76 ±0.33[b]	0.22 ±0.01[bd]	66.87 ±3.34[a]	6.59 ±0.32[a]	10.06 ±0.50[a]
	After 10 days	C	5.23 ±0.26[a]	0.20 ±0.02[bd]	69.45 ±3.47[a]	6.12 ±0.30[a]	8.09 ±0.40[b]
		TS	6.19 ±0.38[a]	0.24 ±0.01[d]	68.01 ±3.40[a]	7.33 ±0.36[b]	9.38 ±0.47[a]
	After 13 days	C	8.27 ±0.41[c]	0.23 ±0.01[bd]	66.29 ±3.31[a]	6.02 ±0.30[b]	8.22 ±0.41[b]
		TS	8.69 ±0.43[c]	0.35 ±0.02[e]	64.84 ±3.24[a]	5.47 ±0.27[c]	9.10 ±0.45[a]
Camarosa	Initial		9.28 ±0.46[a]	0.48 ±0.02[a]	65.28 ±3.26[a]	8.23 ±0.41[a]	7.01 ±0.35[a]
	After 4 days	C	10.25 ±0.51[a]	0.63 ±0.03[b]	65.40 ±3.27[a]	11.71 ±0.58[b]	3.13 ±0.15[b]
		TS	7.81 ±0.39[b]	0.46 ±0.02[a]	68.68 ±3.43[a]	8.72 ±0.43[a]	4.12 ±0.20[c]
	After 7 days	C	9.29 ±0.46[a]	0.70 ±0.03[c]	65.50 ±3.27[a]	13.93 ±0.69[c]	1.57 ±0.07[d]
		TS	10.58 ±0.52[a]	0.59 ±0.03[b]	64.00 ±3.20[a]	10.67 ±0.53[b]	4.62 ±0.23[e]
	After 10 days	C	11.41 ±0.57[a]	0.65 ±0.03[b]	65.81 ±3.29[a]	10.08 ±0.50[b]	2.23 ±0.11[f]
		TS	9.12 ±0.45[a]	0.31 ±0.01[d]	62.73 ±3.13[a]	4.11 ±0.20[d]	12.26 ±0.61[g]
	After 13 days	C	9.41 ±0.47[a]	0.62 ±0.03[b]	67.81 ±3.39[a]	10.16 ±0.50[b]	2.02 ±0.10[f]
		TS	8.10 ±0.40[b]	0.32 ±0.01[d]	63.73 ±3.18[a]	4.00 ±0.20[d]	11.30 ±0.56[g]

*C-control; **TS-Treated samples

1.Cyanidin-3-O-glucoside

2.Cyanidin-3-O-rutinoside

3.Pelargonidin-3-O-glucoside

4.Pelargonidin-3-O- rutinoside

5.Pelargonidin-3-acetyl-glucoside

* Values within a column with different letters are significantly different by ANOVA with Tukey's HSD tests at $p < 0.05$

3.7. Texture analysis

The curve showing load resulting from deformation of fruit was linear for all samples (Fig.1).At the start of experiment for control samples of Victoria fruits, work required for rupture of fruits was equal to 20.6±4.7 Nmm, and at the end of the experiment, it was equal to10.8±4.8 Nmm. For the treated samples of Victoria this parameter changed from 25.1±9.8 to 17.8±4.5 Nmm. Camarosa fruits were more resistant against load force. Work to rupture untreated samples of Camarosa was equal 46.5±13.2 Nmm at the start of experiment and reduced to 30.4±5.5 Nmm after 13 days of storage. As to the treated samples of Camarosa, this parameter was 43.2±6.3 Nmm on the first day of experiment, and 32.6±5.5 Nmm on the 13-th day of storage. Thus, treatment with combined solution resulted in improvement of texture of fruits during storage process.

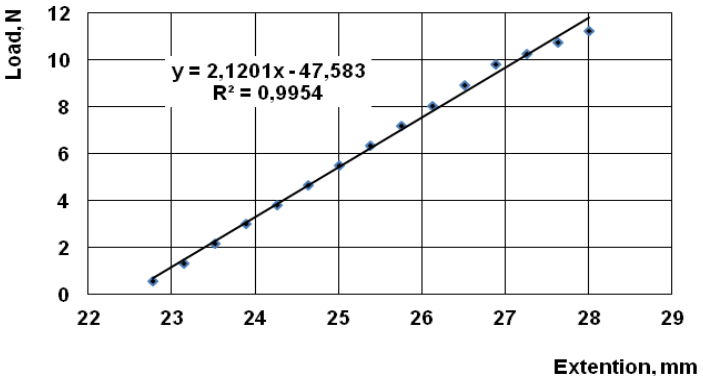

Figure 1. Load dependance on extention in camarosa fruits, control samples, first day

Conclusions

Treatment of fruits of strawberry with combined solutions of methyl jasmonate, salicylic acid and ascorbic acid positively influenced on storability of the fruits. Maintenance of anthocyanins and total phenolics as well as antioxidant potential during storage period was statistically significantly increased. Treatment with combined solution resulted in improvement of texture of fruits during storage process.

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