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Determination of tomato quality attributes using near infrared spectroscopy and reference analysis

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Abstract

The research objective was determination of ripening attributes of intact tomato (*Lycopersicon esculentum* Mill.) cv. 'Rutuliai' using near infrared (NIR) spectroscopy and reference analysis. Tomatoes were picked at six different ripening stages in order to evaluate the correlation between data obtained by near infrared spectra and physical-chemical analyses and how the quality parameters change during ripening. Primarily, spectroscopic measurements were followed by chemical analyses. NIR spectroscopy measurements and reference analyses showed that tomato fruit had lost skin and flesh firmness during the ripening processes and there were no big differences between the methods used for the determination of dry matter and soluble solids (°Brix) and the obtained results varied slightly. The obtained results of dry matter, soluble solids content (°Brix) and fruit skin and flesh firmness were presented as simple linear regression between NIR spectroscopy and reference analyses. A high correlation between NIR spectroscopy and reference analyses of dry matter was established and this correlation, expressed by regression coefficient, reached 0.9089. Regression coefficient between NIR spectroscopy and reference analyses of soluble solids was 0.815. Meanwhile, the highest correlation was detected for tomato fruit skin and flesh firmness and regression coefficient, respectively, reached 0.9119 and 0.9624. Hence the near infrared calibration has the potential to estimate the physical-chemical properties of tomato fruit according to their infrared spectra.

Key words: °Brix, dry matter, firmness, maturity, near infrared.

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular vegetables in the world. Tomato fruit consists of water and soluble and insoluble solids. Soluble solids are traditionally expressed as degrees Brix (°Brix) and mainly consist of sugars (sucrose and fructose) and salts (Salunkhe, Kadam, 1995; Beckles, 2011). Insoluble solids (4–8%) are mainly constituted of Salunkhe and Kadam (1995); therefore, tomato solids are very valuable at the factory processing. Higher amount of tomato solids need less amount of fruits to produce the same amount of tomato products (Beckles, 2011; Siddiqui, 2015). Total dry matter content in different tomato cultivars varies from 4% to 7.5% of fruit fresh mass. Soluble solids account for 75% of the total solids and are comprised primarily of the reducing sugars, which represent 55–65% of the total soluble solids content. Most of these organic compounds absorb near infrared (NIR) radiation due to the presence of functional groups (e.g., R-OH, R-NH_2, R-CH, R-CH_2 and R-CH_3) on the molecules. So, this makes it possible to develop an analytical technique based on NIR absorption spectrometry to determine soluble solids content of tomatoes non-destructively (Peiris et al., 1998).

Since its introduction in the early 1970's, the use of NIR spectroscopy has progressed rapidly in a number of fields. Its rapid adoption owes much to its distinct advantages: quick response time, simplicity of sample preparation, chemical free measurements and simultaneous measurement of multiple attributes. Food chemistry has greatly benefited from these developments, which allow the determination of a series of properties, such as soluble solid content, acidity and dry matter in different food matrixes (Chen et al., 2008; Zhu et al., 2015).

Consumers evaluate tomato fruit quality according to colour and firmness, probably these parameters are the most important attributes that determine overall fruit quality. Tomato maturity is traditionally classified into six ripening stages according to the colour change of the fruit from green to red (USDA Color Chart, 2011). Colour evolution during fruit ripening is mainly related to the breakdown of chlorophyll and synthesis of lycopene, which is responsible for the red colour and constitutes 75–83% of the total pigment content at full ripeness (Clement et al., 2008; Radzevičius et al., 2014; Schouten et al., 2014). During fruit ripening, cell wall hydrolytic enzymes contribute to tissue softening and lessening of intercellular adhesion and tomatoes lose their firmness (Brummel, 2006; Toivonen, Brummell, 2008). However, the ability of fruit flesh to resist compressive force is one of the most important characteristics to estimate fruit maturity and quality. Generally, firmness may be evaluated by touch or by penetrometer measurement. Both of these two methods are destructive and firmness value can vary greatly depending on the method used and the competence of an executor. Recently, measurement of the optical properties of fruits has been one of the most successful non-destructive techniques for quality assessment. Optical techniques, NIR spectroscopy for instance, have received considerable interest as a means for non-destructive evaluation of fruit firmness (Kusumiyati et al., 2008; Tiwari et al., 2013). Nevertheless, total soluble solids, dry matter and fruit firmness are very important internal quality attributes of vegetables (Karklelienė et al., 2014; Siddiqui, 2015). Most instrumental techniques to measure these properties are destructive and involve a considerable amount of manual work and money. So, researches have presently been focused on developing non-destructive techniques, e.g., visible/NIR spectroscopy, for measuring internal fruit quality attributes (Berra, 2012; Radzevičius et al., 2014).

NIR spectroscopy technique has gained a great deal of attention in food quality analysis mainly due to its suitability for recording the spectra of solid and liquid samples at lowest cost and without any pretreatment. The main characteristics hindering NIR spectra expansion are broad, weak, non-specific, extensively overlapped bands. After multivariate calibration methods became widely available and accepted, NIR spectroscopy technique has been widely studied and applied (Chen et al., 2008; Tiwari et al., 2013; Deak et al., 2015). However, the potential use of visible NIR spectroscopy for tomato and tomato based products has been evaluated only by several researchers (Kusumiyati et al., 2008; Berra, 2012; Tiwari et al., 2013; Deak et al., 2015).

However, many researchers have proposed non-destructive methods for measuring internal quality of fruits and vegetables at fully ripen stage. For better explanation and accuracy, characteristics of NIR spectroscopy should be evaluated during all fruit ripening period, from green tomato ripening stage to fully ripen stage, because tomato fruit colour, flavour and texture change during ripening period.

The research objective was to determine ripening attributes (dry matter, °Brix, skin and flesh firmness) during tomato fruit ripening of intact tomato (*Lycopersicon esculentum* Mill.) cv. 'Rutuliai' using near infrared (NIR) spectroscopy and reference analyses and compare accuracy of the methods used.

Materials and methods

Investigation was carried out at the Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry in 2012–2013. Tomato cv. 'Rutuliai' was grown in the natural soil in a non-heated greenhouse, according to the tomato growing technology adopted by Institute of Horticulture (Jankauskienė, Survilienė, 2003). In the first year (2012) of experiment, samples (total number of samples reached 96) were used as calibration set and obtained data processed using software *Sacmi NCS Vers. 3.0 RC 1* (NIR calibration software). In the second year (2013), evaluation and comparisons of near infrared spectroscopy characteristics and reference analyses were made.

In order to evaluate the correlation between NIR spectra and physical-chemical analyses and the change of quality parameters during ripening, tomatoes were picked at six different ripening stages: 1 – ripeness stage means 100% green tomato fruit, 2 – ripeness stage means a definite "break" in colour from green to red (up to 10% coloured tomato fruit), 3 – ripeness stage shows a definite change in colour from green to red (10–30% coloured tomato fruit), 4 – ripeness stage shows 30–60% coloured tomato fruit, 5 – ripeness stage means that tomato fruit gained colour specific to nature (60–90% coloured tomato fruit) and 6 – ripeness stage, fully ripen tomato (over 90% coloured tomato fruit) (USDA Color Chart, 2011). Therefore, tomatoes were selected based on their colour uniformity (from 1 till 6 stages of ripeness). Each fruit was individually numbered. As the fruits were harvested from different plants, the experiment design was completely randomized with each fruit as an experimental unit.

The following fruit quality parameters at different ripening stages were evaluated: dry matter, soluble solids in fresh matter, fruit skin and flesh firmness. Tomato fruits at each ripening stage were harvested at random in four replications. Primarily, spectroscopic measurements using spectrophotometer NIR Case NCS001A (Sacmi Imola S. C., Italy) were made and afterwards physical-chemical analyses (texture measured using texture analyser, dry matter – gravimetrically, °Brix – using digital refractometer) were performed. Four tomato fruits were measured at each ripening stage four times; therefore total number of samples was 96.

Spectroscopic measurements were performed using NIR spectrophotometer NIR Case NCS001A. Measurement range was 600–1000 nm. The raw intensity spectrum of each fruit was taken around the tomato equator in four positions with approximately 90° between them. All physical-chemical analyses were performed immediately after NIR measurements.

After acquiring NIR spectral data, skin and flesh firmness of the same tomato fruit were analysed. Tomato fruit texture was measured using a texture analyser TA.XTPlus (Stable Micro Systems, England). For each test, every single tomato was punctured on the specific positions around the equatorial area, with approximately 90° between them and the perpendicular to the stem-bottom axis. The obtained data was processed using software *Texture Exponent*. The firmness was expressed as the peak force and recorded in N. After the firmness measurements, dry matter and soluble solids of each fruit were analysed. Dry matter content was determined gravimetrically by drying tomatoes to a constant weight at 105°C. In order to determinate soluble solids, tomatoes were cut in small pieces immediately after firmness measurements and homogenized using a blender Bosch Easy Mixx, type CNHR6 (Robert Bosch GmbH, Germany) and measured by a digital refractometer ATAGO PR-32 (Atago Co. Ltd., Japan). Total soluble solids (sugars and salts) were expressed as % in fresh mass.

Data of each ripening stage was presented as an average of 16 measurements (16 measurements = 4 tomato fruits × 4 replications of each fruit). Significant differences were estimated by Fisher's least significant difference (LSD) test ($P \leq 0.05$) and standard deviation (SD); also coefficient of variation (CV) was calculated. Statistical software *STATISTICA 7.0*, *MS Excel* and *ANOVA* were used for data calculation and significance evaluation.

Results and discussion

The data of our study showed that the amount of dry matter and soluble solids (°Brix) varied during fruit ripening and depended on the ripeness stage of tomato (Table, Figs. 1–2). The highest values of these parameters were established in fully ripened fruits (6th ripeness stage), when predicted values of dry matter ranged from

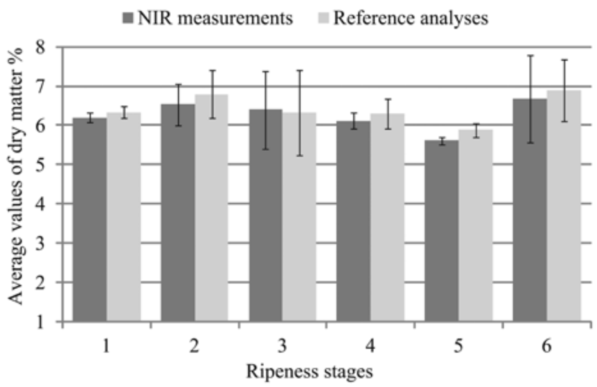
Table. Dry matter, soluble solids, skin and flesh firmness of tomatoes at different ripeness stages measured using near infrared (NIR) spectroscopy and reference analyses

Ripeness stage	Tomato number	Dry matter %		Soluble solids (°Brix) %		Skin firmness N cm^{-2}		Flesh firmness N cm^{-2}	
		NIR measurements	reference analyses	NIR measurements	reference analyses	NIR measurements	reference analyses	NIR measurements	reference analyses
1	1	6.245	6.432	3.18	3.40	443.5	455.3	101.3	89.4
	2	6.030	6.128	3.15	3.20	417.6	416.8	105.3	91.2
	3	6.210	6.314	3.11	3.70	418.2	421.8	104.9	96.2
	4	6.300	6.443	4.01	3.80	405.4	407.9	106.6	106.5
	LSD_{05}	0.157	0.181	0.57	0.49	39.4	48.8	7.5	8.7
	CV%	1.886	2.309	12.837	7.812	4.738	7.615	2.159	8.034
2	1	6.685	6.753	3.09	3.15	435.4	411.1	110.8	106.1
	2	7.190	7.627	3.27	3.30	398.9	356.4	99.8	101.2
	3	6.305	6.600	3.39	3.70	422.0	371.2	78.6	57.8
	4	5.965	6.183	2.85	3.30	393.9	346.9	93.6	77.5
	LSD_{05}	0.436	0.819	0.42	0.68	50.3	36.9	18.2	22.3
	CV%	8.044	8.943	7.494	7.014	3.799	4.867	14.061	26.164
3	1	7.860	7.919	4.98	4.80	387.0	328.3	45.8	44.8
	2	5.820	5.604	3.27	3.33	382.3	361.4	76.6	71.5
	3	6.085	6.154	3.58	3.80	379.8	395.9	60.8	62.3
	4	5.820	5.659	3.37	3.40	358.3	358.4	66.5	54.0
	LSD_{05}	1.390	1.752	1.13	0.91	15.3	47.0	17.9	20.4
	CV%	15.381	17.136	20.904	17.676	3.379	7.661	20.628	19.630
4	1	6.270	6.494	4.17	4.70	301.8	291.0	31.6	17.2
	2	6.280	6.719	4.84	4.50	344.6	313.5	46.3	45.9
	3	5.875	6.024	3.64	4.00	312.4	315.9	45.3	37.7
	4	6.025	5.940	4.05	4.40	277.8	289.6	21.4	21.4
	LSD_{05}	0.247	0.594	1.35	0.76	22.9	26.1	11.8	12.7
	CV%	3.230	5.938	11.972	6.691	8.963	4.668	32.865	44.262
5	1	5.695	5.840	3.49	3.70	309.0	260.7	46.7	44.9
	2	5.630	5.992	4.18	4.30	281.2	278.1	23.0	24.4
	3	5.645	6.056	5.09	5.00	251.2	231.6	21.0	21.7
	4	5.455	5.652	3.88	3.70	278.1	254.6	30.8	21.5
	LSD_{05}	0.316	0.519	1.58	1.24	32.4	25.7	12.4	5.1
	CV%	1.866	3.057	16.361	14.814	8.435	7.507	38.411	39.992
6	1	7.670	7.673	5.25	4.90	260.0	256.2	12.8	16.2
	2	7.620	7.479	4.19	4.70	234.7	215.9	8.8	16.5
	3	5.645	6.149	3.98	4.45	214.7	211.8	11.9	12.1
	4	5.785	6.268	4.08	4.70	223.2	174.5	6.9	12.0
	LSD_{05}	2.243	1.597	1.15	0.51	23.6	30.1	7.2	4.7
	CV%	16.706	11.532	13.516	3.931	8.440	15.557	27.019	17.438

CV % – coefficient of variation = standard deviation / average × 100

5.645% up to 7.670% (measured by NIR spectroscopy) and from 6.149% to 7.673% (measured by reference analyses). The highest amount of soluble solids in fully ripe tomatoes ranged from 3.98% to 5.25% (measured by NIR spectroscopy) and from 4.45% to 4.90% (measured by reference analyses). NIR spectroscopy measurements and reference analyses showed that tomato fruit had lost skin and flesh firmness during ripening processes. The data of our study agree with the data of other scientists. Batu (2004) reported that firmness values of two investigated tomato cultivars ('Liberto' and 'Criterium') decreased during ripening. Nour et al. (2014) stated that dry matter and soluble solids recorded a slight decrease during tomato growth, and the stage of ripening significantly influenced the content of all bioactive compounds. Nour et al. (2014) also admitted that the first stages of ripening were characterized by a slight decrease in the dry matter content, while this variation reversed in the last two stages of ripening.

The average data of dry matter measurements using NIR and reference methods are presented in Figure 1. The highest amount of dry matter was detected in fully ripe fruits and reached 6.680 according to NIR spectroscopy and 6.892% according to reference analyses, but NIR measurements showed the highest means of standard deviation (1.116) and coefficient of variation (16.706%) (Table, Fig. 1). Meanwhile, according to reference analyses, the highest means of standard deviation (1.085) and coefficient of variation (17.136%) of predicted values had been established in tomatoes at the 3rd ripeness stage. Comparison of two different measurements during tomato ripening showed, that there were no significant differences between them, and obtained results varied slightly.

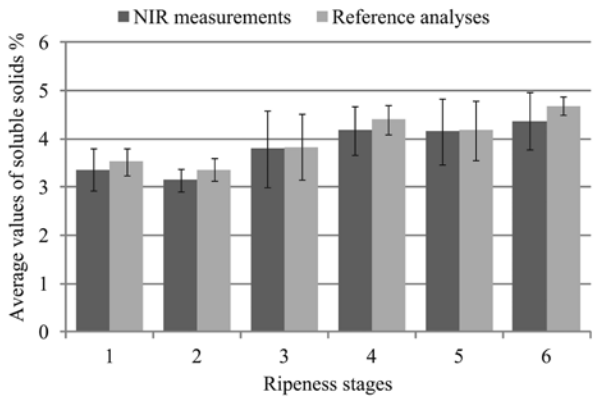


Note. Error bars show standard deviation (SD) value.

Figure 1. Amount of dry matter at different ripeness stages measured using near infrared (NIR) spectroscopy and reference analyses

Travers and colleagues (2014) predicted dry matter and soluble solids content in apples using NIR spectroscopy and obtained that R^2 values range between 0.63 and 0.86 with residual predictive deviations between 1.7 and 2.7. These values were not high enough for general quantitative predictions and certain factors affected success, including changes in fruit physiology over time. Another study demonstrated that NIR spectroscopy is a suitable tool for quantification of dry matter in kiwifruit with small prediction errors over the entire range (Qiang et al., 2010).

Average data of soluble solids content determined by NIR spectroscopy and reference analyses during tomato ripening are presented in Figure 2. The data of our study showed that average means of soluble solids measured by NIR spectroscopy varied from 3.15% (2nd ripeness stage) up to 4.37% (6th ripeness stage) and measured by reference analyses had varied from 3.36% (2nd ripeness stage) up to 4.69% (6th ripeness stage).



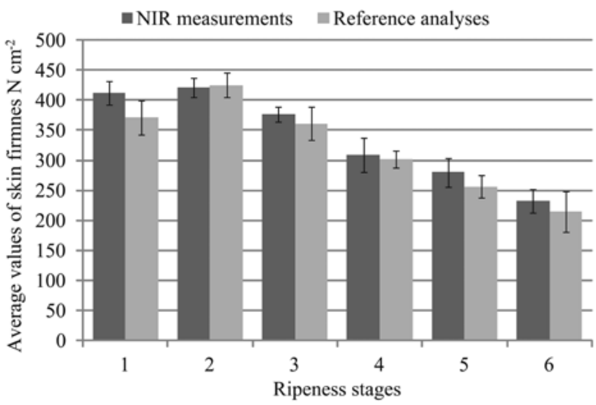
Note. Error bars show standard deviation (SD) value.

Figure 2. Amount of soluble solids (°Brix) at different ripeness stages measured using near infrared (NIR) spectroscopy and reference analyses

There were no significant differences between the data obtained using NIR spectroscopy and reference analyses, even means at the 3rd and 5th tomato ripeness stages were identical. The highest means of standard deviation (Fig. 2), coefficient of variation (Table) and data variation emerged at the 3rd ripeness stage using both detection methods. The lowest values of standard deviation (0.18) and coefficient of variation (3.931%) were obtained using reference analyses in fully ripen fruits. Previous studies related to determination of tomato fruit quality using NIR spectroscopy technique revealed (He et al., 2005) that calibration correlation coefficient between the NIR measurements and reference analyses of soluble solids (°Brix) content was high as 0.95, with the standard error of calibration 0.11. When the model was used to predict the other samples, the prediction results were also tolerable, with the correlation coefficient between the measured and the predicted (r) 0.90; the standard error of prediction was 0.19 (He et al., 2005). Equally, soluble solids were successfully predicted by VIS/NIR spectroscopic method in different fruits – apple, kiwi. In apples the highest correlation coefficient was 0.98, depending on the number of principal components and the pre-processing techniques (Liu, Zhou, 2013). Qiang et al. (2010) used NIR spectroscopy for dry matter determination in kiwifruit and reported that it could be determined non-destructively and dry matter can be predicted with very good accuracy and high correlation coefficient (r = 0.902). Peiris and colleagues (1998) demonstrated that there is a relationship between soluble solids content in tomatoes and NIR absorbance that can be exploited to estimate soluble solids of individual intact tomatoes. Pedro and Ferreira (2007) reported that standard error of soluble solids prediction in tomato was 1.14 and was similar to standard error of reference methods, and were comparable with results previously reported for NIR measurements. The data of our study revealed that the amount of soluble solids, determined by NIR spectroscopy and reference analyses, varied slightly and there were no significant differences between the methods used.

Traditionally, fruit firmness was estimated in a destructive manner by means of the Magness Taylor test. This test may be performed in the laboratory or using portable equipment and is based on the introduction of a cylindrical head into the flesh of a peeled fruit to measure the maximum penetration force. The development of sensors to measure fruit firmness features is one of the challenges of post-harvest technology. Fruit packing companies need to measure quality variables, but they need to do so in a non-destructive manner. Manufacturers and researchers are currently developing sensors with this aim (Garcia-Ramos et al., 2005; Sirisomboon et al., 2012).

It was established that coefficient of variation varied in small range from 3.379% up to 8.963% (Table), standard deviation – from 12.7% up to 27.7% (Fig. 3) according to the data on tomato skin firmness obtained using the non-destructive method. Meanwhile, data obtained using reference analyses varied a little greater: SD – from 14.1% up to 33.4% and CV – from 4.668% up to 15.557%.



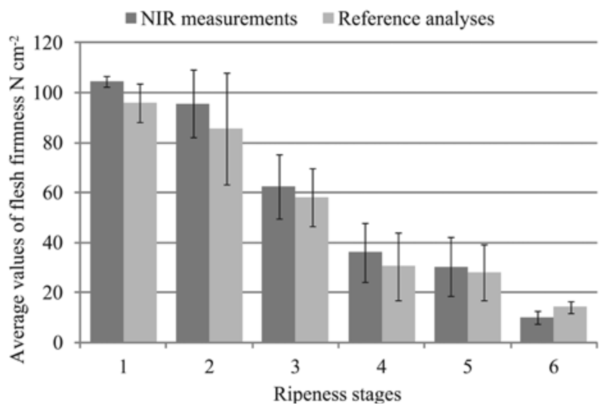
Note. Error bars show standard deviation (SD) value.

Figure 3. Tomato skin firmness at different ripeness stages measured using near infrared (NIR) spectroscopy and reference analyses

Comparison of tomato skin firmness determined using NIR spectroscopy and reference analyses revealed that detected values were similar and there were no significant differences between the methods used. This agrees with the data of other scientists. He with colleagues (2005) studied the use of NIR spectroscopy in measuring the quality characteristics of tomato cv. 'Heatwave' and established the relationship between NIR spectra and the major fruit physiological properties, including fruit firmness. The results showed excellent prediction performances with the standard error of prediction of compression force (r = 0.81) was 16.017 N; and that of puncture force (r = 0.83) was 1.18 N. Kusumiyati with co-workers (2008) investigated on-tree and after-harvest tomato firmness using portable NIR spectroscopy and established positive linear correlation. Results of our and other studies (He et al., 2005; Kusumiyati et al., 2008) of NIR measurements may contribute to the prediction of the optimal harvesting time of fruit on-tree when the desired levels of firmness and colour values are developed. On the other hand, the after-harvesting NIR measurement may be used as a fast and non-destructive technique for sorting or grading fruits based on desired quality attributes.

Various methods are used for efficient simplification and interpretation of many different variables simultaneously. The methods reveal the main structures and relationships in huge data tables, giving relatively simple output graphs and tables that have maximum information and minimal repetition and noise (Maindonald, Braun, 2010; Siddiqui, 2015). Simple linear regression is the most commonly used technique for determination of how one variable of interest (the response variable) responses to changes in another variable (the explanatory variable). The quantities that result from regression analyses may be written in many different forms that are mathematically equivalent but superficially distinct. Besides the regression variables, the third parameter of fundamental importance is the correlation coefficient r or the coefficient of determination R^2, which shows the ratio between the variance (Maindonald, Braun, 2010).

It was established that fruit lost flesh firmness during ripening processes (Fig. 4). The lowest predicted values of flesh firmness were established in the 6th ripeness stage and were 10.1 N cm^{-2} (measured by NIR spectroscopy) and 14.2 N cm^{-2} (measured by reference



Note. Error bars show standard deviation (SD) value.

Figure 4. Tomato flesh firmness at different ripeness stages measured using near infrared (NIR) spectroscopy and reference analyses

analyses). The strongest flesh firmness of tomato fruits detected in the 1st ripeness stage was 104.5 N cm^{-2} (measured by NIR spectroscopy) and 95.8 N cm^{-2} (measured by reference analyses). Comparison of values of tomato flesh firmness determined by NIR spectroscopy and reference analyses revealed that detected means were similar and there were no significant differences between the methods used.

Prediction results of dry matter, soluble solids content and fruit skin and flesh firmness are presented in Figures 5–8. In all figures, the ordinate and abscissa axes respectively represent the actual (measured by reference analyses) and predicted (measured by NIR spectroscopy) values. The simple linear regression implied between them for each characteristic. The correlation between the NIR spectroscopy and reference analyses of dry matter was high and was expressed by regression coefficient, which was 0.9089. Regression coefficient between NIR spectroscopy and reference analyses of soluble solids was 0.815. Meanwhile, the highest correlation was established for tomato fruit skin (regression coefficient was 0.9119) and flesh (regression coefficient was 0.9624) firmness.

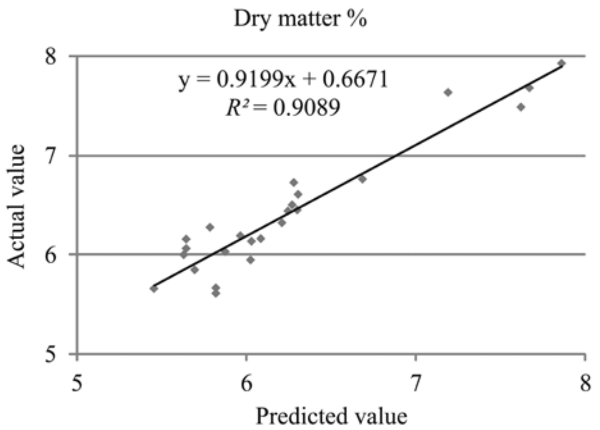


Figure 5. NIR prediction accuracy of dry matter

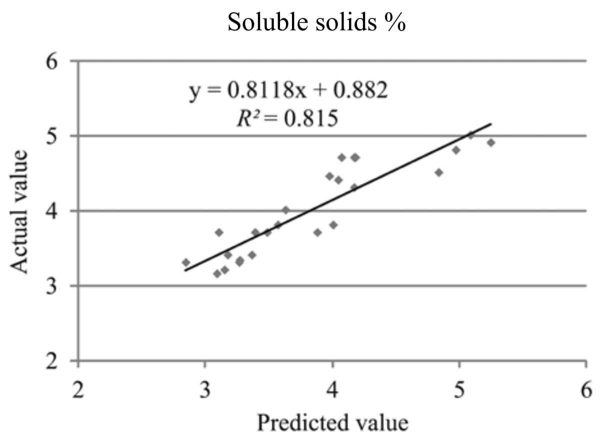


Figure 6. NIR prediction accuracy of soluble solids content (°Brix)

The advantages of NIR spectroscopy are obvious. It is a fast and non-destructive method for measuring the quality parameters; it provides a possibility to measure the same sample as many times as needed. Our data show that it is possible to employ this non-destructive technique for evaluation of the quality characteristics of tomato. For better NIR prediction accuracy more experiments with tomatoes remains to be done. The NIR calibration has the potential to estimate the component concentrations of the chemical and physical properties in the tomatoes according to their infrared spectra.

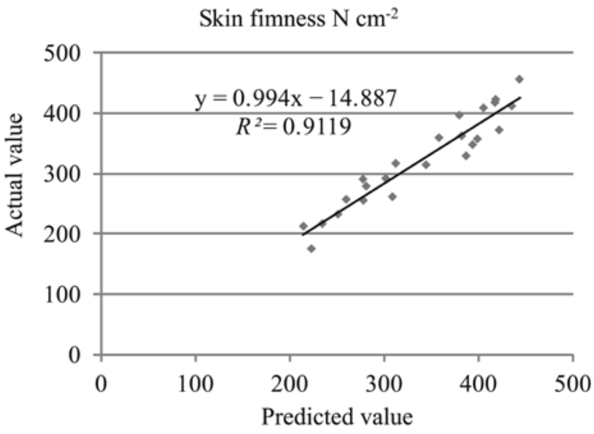


Figure 7. NIR prediction accuracy of tomato skin firmness

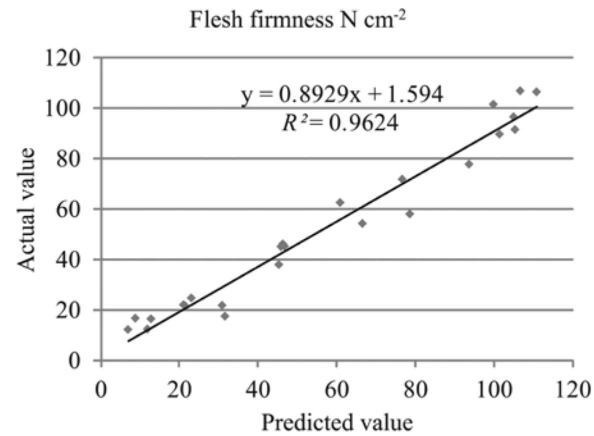


Figure 8. NIR prediction accuracy of tomato flesh firmness

Conclusions

1. The highest values of dry matter and soluble solids (°Brix) parameters were established in fully ripe tomato fruits (6th ripeness stage), when predicted values of dry matter ranged from 5.645% to 7.670% (measured by NIR spectroscopy) and from 6.149% to 7.673% (measured by reference analyses). The highest amount of soluble solids in fully ripened tomatoes ranged from 3.98% to 5.25% (measured by NIR spectroscopy) and from 4.45% to 4.90% (measured by reference analyses).

2. Comparison of near infrared (NIR) measurements and reference analyses for dry matter and soluble solids (°Brix) determination showed that obtained results varied slightly.

3. NIR spectroscopy measurements and reference analyses showed that tomato fruits lost skin and flesh firmness during ripening processes.

4. The NIR calibration has the potential to estimate the physical-chemical properties of tomato fruits according to their infrared spectra.

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Kokybinių rodiklių nustatymas nepažeidžiant pomidorų vaisiaus, taikant artimąją infraraudonąją spektroskopiją

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Santrauka

Tyrimų tikslas – nustatyti kokybinius pomidorų (veislė 'Rutuliai') rodiklius nepažeidžiant vaisiaus, taikant artimąją infraraudonąją (AIR) spektroskopiją ir įprastinius metodus. Siekiant tiksliau įvertinti ryšį tarp AIR spektroskopijos ir fizikinių bei cheminių analizių ir stebėti kokybės rodiklių pokyčius vaisių nokimo metu, bandymams buvo naudoti šešių skirtingų sunokimo lygių pomidorai. Pirmiausia buvo atlikti spektroskopiniai matavimai, po to vykdytos fizikinės ir cheminės analizės. AIR spektroskopijos ir įprastinės analizės parodė, kad veikiant nokimo procesams pomidorų vaisiai prarado odelės bei minkštimo tvirtumą ir tarp taikytų metodų nustatant sausųjų medžiagų bei tirpių sausųjų medžiagų kiekį nebuvo didelių skirtumų, o gauti rezultatai įvairavo nedaug. Sausųjų medžiagų, tirpių sausųjų medžiagų kiekio ir vaisiaus minkštimo bei odelės tvirtumo duomenys apdoroti panaudojus paprastąją tiesinę regresijos lygtį. Nustatyta stipri koreliacija tarp AIR spektroskopijos ir įprastinės analizės metodų matuojant sausąsias medžiagas, kai regresijos koeficientas siekė 0,9089. Matuojant tirpias sausąsias medžiagas regresijos koeficientas tarp AIR spektroskopijos ir įprastinės analizės buvo 0,815. Didžiausia koreliacija buvo nustatyta matuojant pomidorų minkštimo ir odelės tvirtumą – regresijos koeficiento reikšmė siekė atitinkamai 0,9119 ir 0,9624. Taigi, AIR spektroskopija sudaro galimybes įvertinti pomidorų vaisių fizikines ir chemines savybes atsižvelgiant į jų infraraudonųjų spindulių spektrą.

Reikšminiai žodžiai: artimoji infraraudonoji spektroskopija, sausosios medžiagos, sunokimas, tirpios sausosios medžiagos, tvirtumas.

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