Thesis

Change of physical properties and taste attributes of carrot (*Daucus carota* subsp. *Sativus*) during non-ideal storage

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Introduction

The healthy diet is an essential part of the regular consumption of fruit and vegetables, help to get a substantial amount of micro-nutrients essential mineral elements, and especially to preserve the health of the organization, thus only the plants produced by endogenous compounds (Vandresen et al, 2009). Today, the market's increasing demand for these crops, where the price for the consumer is increasingly more important than quality, high vitamin and mineral content and nutritional value. Briefly, what aspects of the consumer decide what quality you expect? Quality is a complex concept, which is determinated by external (color, aroma, size, shape) and internal (taste, texture, ingredients, nutritional value) characteristics, consumer expectations, the market supply and earlier experience (Abbott, 1999).

Before entry into the market is the growing and harvesting conditions mainly affect the quality of the formation. After harvesting the properly selected storage conditions (eg. temperature, humidity) are important rules. Because of consumer demands for quality merchandise during all year, the long shelf-life and conversation of quality are main aspects as much as possible for seasonal crops.

However, the shelf-life of horticultural crops significantly affected by the fact, the long-term storage it is not solved, or these storing parameters are unavailable in households. Backyard farms and primary producers in much places in the basement is the only way by which the winter root vegetables, potatoes, onions and apples can be stored in inventory. In such cases, the chemical composition and physical characteristics of crops for short period of time can vary considerably, which reduces the pleasure of the crop. Of course, it is possible to vegetables by freezing, drying or heat treatment also for the preservation, thus the physical changes that occur during these many have been studied. However, because of home storage conditions are not ideal for long-term preservation of quality; it could destruct crops to unpalatable, uneatable raw materials. Carrot, this change can be occurring even for a short period of time. This delay, the shelf life may be extended as a carrot for the storage of sand. The storage of carrots under ideal conditions serves markets; our costumer needs after primeur period of time. However, the crop is on the shelf or within a short time after they are ready to go in quality. This is due to the low temperature and high humidity of physiological processes slow down, and then enters reservoir drier and warmer environment rapidly accelerated. However it is not sure, that the apparent loss of quality equal enjoyment impairment is present. The vegetables and fruits hardness testing of proven destructive and non-destructive methods are used. These studies provide information on the stock and quality of the crop. The consumption of eating habit of raw carrots and healthy lifestyles with the development of more and more organic part as nutritional value, as well as mineral and vitamin content is remarkable. The consumption of raw carrot, taste attributes, the firmness playing a role in the development of the entertainment experience. The question is, how to bear the carrots in the non-ideal storage conditions, and how the effect occur storage in the taste attributes.

OBJECTIVES

Objective of my research work was, to found relationship stored under non-ideal storage condition between mass loss, furthermore mechanical, optical and taste attributes. The aims to achieve the following projects were require.

Details:

1. **Determination of relationship** between the mechanical cutting test, compression creep-recovery test, optical measurements and taste attributes results, furthermore the mass loss. Details:

   Mechanical cutting test between:
   - cutting force/cutting deformation ratio,
   - decompression work/compression work ratio

   Compression creep-recovery test between:
   - loading force/deformation before creep ratio,
   - loading force/maximal deformation ratio,
   - elastic deformation/maximal deformation ratio,
   - plastic deformation/maximal deformation ratio,
   - plastic deformation/elastic deformation ratio, furthermore the mass loss

2. **Determination of relationship** between the optical measurements, the absorbance and color parameters and the mass loss
3. **Determination of relationship** between the sensory – „good odour”, „orange colour intensity”, „bite and chewing”, „sweet taste”, „bitter taste” and „global impression” – attributes and the mass loss
4. **Prediction of mass loss**
   - Prediction of mass loss by the determined mechanical parameters
   - Prediction of mass loss by the measured and determined optical parameters
   - Prediction of mass loss by the measured and determined taste attributes

MATERIALS AND METHODS

Material

Carrot

During my experiments Nanti kind of type, Nevis variety carrots were measured. The pre-experiments were in 2007, and the experiments carried out in three consecutive years, between 2008 and 2010 after harvest.

After the quality sorting of carrot the undamaged, straight carrots were used for the measurements.

Storage conditions

During the non-ideal storage conditions of the pre-experiments and experiments are different form the literary optimal temperature and relative humidity data.

The carrots were grouped at the beginning of storage. During the pre-experiment the samples of „EK1" and „EK2" measurement, furthermore the experiment of years in 2008 and 2009 were stored under „non-ideal" conditions in refrigerator, where the air flow were middle and top of the refrigerator. The measurements were performed at the beginning of storage and later once a week.

The samples of experiment in 2010 after the harvest were stored under long term („ideal") storage conditions in refrigerator as well, and in same time with this the last measured group was put into another chamber, where was short term, („non-ideal") condition. Each week a group was transferred into the non-ideal storage chamber, however the control group stayed under ideal ambience during the whole storage time. The storage period of the different carrot groups under non-ideal conditions was as follows: 4 weeks for group No. 4, 3 weeks for group No. 3, 2 weeks for group No. 2, 1 week for group No. 1.

The storage conditions were as follows:

- Pre-experiment (EK1): temperature: 8.0±0.5°C; relative humidity: 86±1%
- Pre-experiment (EK2): temperature: 8.0±0.5°C and 15.0±0.5°C; relative humidity at both of temperature:87±1% and 84±1%
- Experiment (2008, 2009): temperature: 8.0±0.5°C; relative humidity: 84±2%
- Experiment (2010): „Ideal" storage: temperature: 2.0±0.5°C; relative humidity: 96±2%
  „Non-ideal" storage: temperature: 8.0±0.5°C; relative humidity: 84±2%

Measurement of respiration

The measurements were performed on the Department of Refrigeration and Livestocks' Products Technology, with a closed and big sensitivity (0-9999 ppm) respirometer (ALMEMO 3290, Ahlborn Mess- und Regelungstechnik GmbH, Germany) with infrared CO_2-sensor. The measurements were performed in usually two days interval, however on the first week the repetition was one day because of to monitor more precisely the processes. During the test the respiration was calculated from the time-unit change of CO_2 contamination of gas space. In the gas space of the closed respirometer were the known mass carrots.

The main part of the respiration meter (ALMEMO 3290) CO_2 analyzer and data acquisition unit, which is indicated in ppm CO2 concentration of the test atmosphere. The carrot samples were stored and measured under 8°C temperature. The results were calculated in ml/kg·h.

The AMR WinControl ver 4.1 (akrobit® Software GmbH., Germany) data-collector software was applied to the setting of the measuring parameter, such as measuring interval and time-period, furthermore visualization of the measured data and pre-evaluation. The sensors detect based on infrared absorption, which depend on the CO_2-concentration.

The carrot tissues were measured on Corvinus University of Budapest, Faculty of Horticultural Science, Department of Botany and Soroksar Botanical Garden. The engravings were prepared with Leitz type freezing microtome to the analysis, then the slide was preserved specimens of glycerol and water was 1:1. The photos were performed with Zeiss Axio Imager.A2 type microscope and Axio Cam HRc, Zeiss camera, where the zoom of object glass was 10x, and zoom of microscope were 2.5x, 5x, 10x, 20x, 40x, this means in reality the zoom 25x, 50x, 100x, 200x, 400x.

Carrot measurement by quasistatic and dynamic firmness methods

During my measurements the mass and the moisture content were determined on each measuring day. To the mass measurement the Voltcraft TS-500 type balance was used with the following parameters: 0-500g measuring range, 0,1g sensitivity. The moisture content was measured with Venticell Comfort Line drying chamber (MMM Medcenter Einrichtungen GmbH, Germany) where the parameters were as the follows: 105°C temperature, 100% airflow, 24 h time period (Aghbashlo et al, 2011). The moisture content was calculated to the dry basis and the wet basis.

During the pre-experiments (EK) cutting test was performed such as quasistatic method with SMS precision penetrometer. Furthermore, acoustic stiffness measurement and impact firmness measurement were performed such as dynamic firmness methods to the analyzing the samples. Based on the results of pre-experiments were performed the experiments, however the methods were completed with creep-recovery test, optical measurement in VIS and NIR range and measurement of taste attributes. The measurements were performed on each group on week interval.

Cutting test

The Stable Micro System TA-XT2 type precision penetrometer was performed to the traditional firmness measurement methods. Rheological behaviour can be measured by precision penetrometers. Several probe head and fixtures are the part of the instrument to analyze the foods. Two different measurements were performed with the device, such as cutting test and creep-recovery test. The samples were measured one week interval.

Destructive firmness tests were performed of each carrot group to determine the resistance when a blade penetrates the carrot. This instrument was fitted with a sharp blade of 3 mm thickness (from the SMS set). The motion of the blade was perpendicular to the surface of the 5 mm thick carrot disk. These disks were cut out of the carrots at the 1/3 of length from the top end. The disk was cut along its diameter with 0.1 mm s–1 cutting speed and the maximal deformation was 8 mm. Three cutting tests were performed on each carrot while the maximal cutting force and the maximal cutting deformation were determined. The cutting force/cutting diameter ratio was calculated from the mentioned parameters. Furthermore, decompression work/compression work ratio was determined from the following parameters: the ratio of work from zero force up to maximum cutting force (M_K) and the work from maximum cutting force up to maximum distance (M_{DK}) (Fig. 3). The decompression work/compression work ratio was calculated from the ratio of M_{DK} to M_K.

Acoustic firmness method

Non-destructive acoustic stiffness tests were performed to determine the acoustic stiffness coefficient of each carrot during its storage period. For the acoustic test, the carrot was fixed in vertical position into a foam sample holder that allowed the free vibrations of the sample (Felföldi, 1996a, 1996b). A microphone was fitted into the foam sample holder to record the acoustic response of the sample. The advantage of the acoustic response method is that it provides information on firmness of the whole carrot. The carrot was excited by hitting at its tip by a wooden hammer in vertical direction. Under the sample a microphone sensed the acoustic signal and transferred it to a PC via a sound processing card.

A special purpose software „Stiffness" was developed for recording and analyzing the signal at Corvinus University of Budapest, Faculty of Food Science, Department of Physics and Control. The software determines and displays the Fast Fourier Transform form of data from the recorded response, furthermore automatically searches the typical frequency in the selected frequency band.

As the results of the test, the acoustic stiffness coefficient (S; m^2s^{-2}) was calculated (Zsom-Muha and Felföldi, 2007) from the resonance frequency and the length of the carrot, as follows:

$$S = f^2 \cdot l^2 \tag{1}$$

where: f – typical resonance frequency of the sample, Hz
l – length of the sample, m.

Methods for the analysis of carrot texture

Creep-recovery test

Creep recovery test was performed by SMS TA-XT2 type precision penetrometer. The measurement was repeated once a week, when 9x9x9 mm length cubes were cut from the both of carrot part xylem and phloem. The cubes were compressed with 75 mm diameter aluminum plate. The measuring parameters were as the follows: 60 N loading force, 60 s creeping time, 0.1 mm/s speed of measurement. One group was measured on each week with 2 repetitions at the xylem and phloem. Before the measurement pretest was performed to decide the direction of the compression. Therefore the cubes were measured parallel and perpendicularly to the axis; finally the parallel compression was used. The reason of decision is that the compression was similar with the direction of carrot disc cutting.

During the creep-recovery test the determined parameters were as the follows:

- Ratio of loading force and deformation before creep (F_t/D_{ke}), in the beginning point of creep
- Ratio of loading force and maximal deformation (F_t/D_{max}) in the final point of creep
- Ratio of elastic deformation and maximal deformation (E/D_{max})
- Ratio of plastic deformation and maximal deformation (P/D_{max})
- Ratio of plastic deformation and elastic deformation (P/E).

Impact method

The impact method is suitable to measure of the surface firmness of samples. Therefore this method was performed to analyzed the both of carrot parts xylem and phloem with one week interval. The impact test method is based on the principle of piezoelectric accelerometer hammer (hemispherical metal head), transducer electronic unit and an HP 35670A type signal analyzer.

During the „Impact" program was performed to collect the data (developed by Corvinus University of Budapest, Faculty of Food Science, Department of Physics and Control). The program saves the difference between the initial and maximum time of curve based on force sensor signal. The impact firmness coefficient was calculation to characterize the surface firmness from the difference between initial and maximum time of first wave of sinus curve (Felföldi and Fekete, 2000) (D, ms^{-2}):

$$D = \frac{1}{\Delta T^2} \tag{2}$$

where ΔT – the difference between the starting and maximum point of sinus curve, ms

The measurements were performed once a week on the both of carrot part xylem and phloem, and the parameter was measured on fresh cut carrot surface. The carrots were cut at the 1/3 of the length from the top end perpendicularly to the carrot axis. The xylem and phloem part was measured on 5-5 points and the average was calculated from the results to the evaluation.

Optical methods

Near infrared spectroscopy (NIR)

The important materials in the food industry has absorption maximum in near-infrared range. This parameter can be measured by Spectralyzer (PMC Spectralyzer 10-25 infrared spectrophotometer). The measuring range is 1000 – 2500 nm and the spectral resolution is 2 nm. Illumination and observation geometry is 0/45°. The holographic grating of instrument includes color filter two ranges (1000-1600 nm and 1600-2500 nm).

The instruments were performed once a week with the other measuring methods. The sample preparation is very important before the measurement. 2 cm thick discs were cut and 5 mm thick engraving was prepared from the both of carrot part xylem and phloem (figure 1). After the sample preparation we need to calibrate the instrument with the original standard.

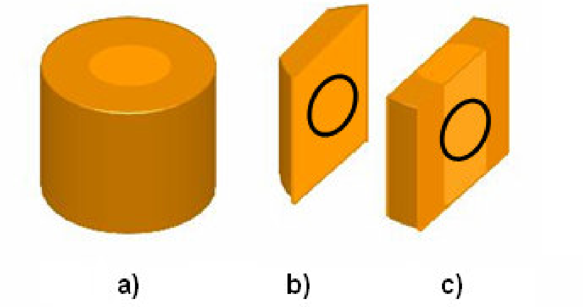


Figure 1 Sample preparation to NIR measurement a)whole disk, b)phloem sample, c)xylem sample

Colour measurement

Parameters of different colour system can be measured in VIS range between 400 and 700 nm by ColorLite sph850 (ColorLite GmbH, Katlenburg-Lindau, Germany). The instrument is suitable the measurements of solid materials, solutions and powders. The colour attributes of the fresh cut surface of each carrot were measured to determine CIE L*a*b* parameters. The carrots were cut at the 1/3 of the length from the top end perpendicularly to the carrot axis. The colour parameters were as the follows: lightness (L*), red-green colour coordinate (a*) and yellow-blue colour coordinate (b*). Both of parts xylem and phloem were measured on fresh cut carrot surface three times in case of each sample. From the results the average was calculated, finally I got one-one data for part of carrot in each sample.

Taste analysis methods

Electronic tongue

The measurements of carrots taste attributes were performed with electronic tongue. The potentiometric electronic tongue of Alpha ASTREE II (Alpha M.O.S., Toulouse, France) was fitted with an auto sampler unit. The electronic tongue has seven potentiometric chemical sensors, developed for food application, constructed of ion sensitive field effect transistors. Each chemical sensor has different organic membrane coating. Due to the coating type, the sensors are cross-selective and cross-sensitive to different taste attributes. An additional Ag/AgCl (Methrom) electrode was used as a reference sensor. The potential between each of the seven sensor electrodes and the reference electrode was measured and recorded.

Carrot juice was prepared to the measurement from the carrot samples by fruit juicer (Philips Juicer HR 1851). The measurements were performed at the end of the storage periods from frozen juice samples. The 100% carrot juice were filtered and diluted to 5% (v/v) concentration. Sensor conditioning was performed before each sample measurement. Wetting and cleaning procedures were performed with cleaning solution (0.01M hydrogen chloride). Sensors were cleaned with distilled water between subsequent measurements until stable potentional was obtained.

Sensory analysis

The question was that significant sample sequence can be set up according to storage time based on sensory attributes during sensory classification.

The sensory analysis was performed by 16 panelists. The panelists got one (4 cm length) „carrot disc” from middle part of carrots in case of all of five groups, and tested it, according to the following attributes: „good odour”, „orange colour intensity”, „bite and chewing”, „sweet taste”, „bitter taste”, „global impression”. In such a case, the ranking test is supposed to the best evaluation method. This is a version of the „Paired comparison test” where panelist receive three or more coded samples and rank the samples according to the intensity of some specific attributes. The samples were coded with three digit random numbers and were given to them in randomized order together with the evaluation sheet. The results were evaluated by Page test, which is usually used to predict that the observations will have a particular order such as a definite sensory attribute of stored samples. The test considers the null hypotheses that, the central tendency of the groups are equal. While the alternative hypothesis is that the central tendencies of the groups provide an increasing order. The P value provided by the test shows that there are significant differences at last on cases.

RESULTS AND DISCUSSION

Relationship of cutting force/cutting diameter ratio and mass loss

The figure 2 shows the ratio of cutting force/cutting diameter in the function of the mass loss in experimental year 2008. Close linear correlation was found between the parameters, where the value of cutting force/cutting diameter ratio decreased with the mass loss increasing. This result was confirmed by results of 2009 and 2010 years. The change of tendency was similar in each of case. The common fitting of model for the all measuring years showed close correlation as well, that the figure 3 shows.

I determined that, the mass loss predictable from the cutting force/cutting diameter ratio (F_v/D_v) with close correlation (R^2 = 0.852) and small root mean squared error (RMSE = 2,684 N/mm). The common fitting for the all years showed similar results. We can declare by the results, the mass loss well predictable from the cutting force/cutting diameter ratio.

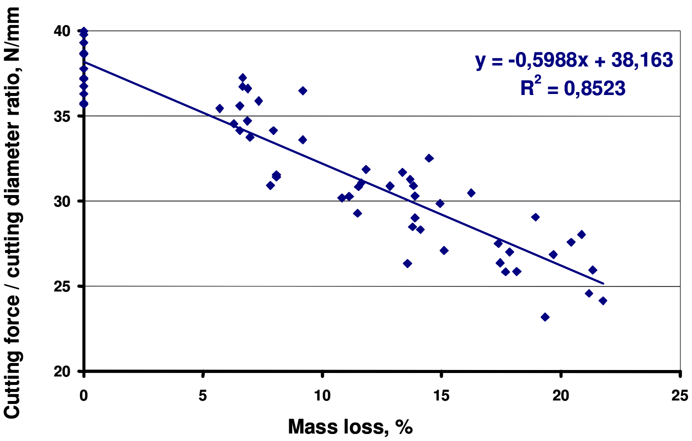


Figure 2 Cutting force/cutting diameter ratio (F_v/D_v) versus mass loss (experiment in 2008)

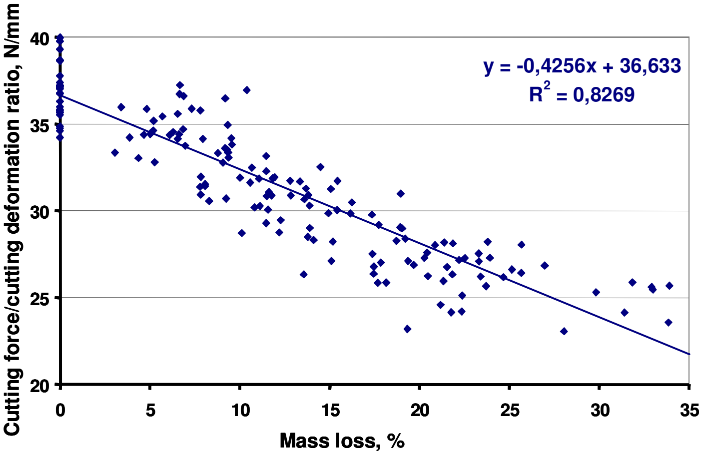


Figure 3 Cutting force/cutting diameter ratio (F_v/D_v) versus mass loss (common fitting to the all of experiment, 2008, 2009 and 2010)

Relationship of decompression work/compression work ratio and mass loss

The decompression work/compression work ratio was analyzed in the function of mass loss with linear model, but I experienced, that the linear model was not the best to describe the relationship between the parameters. Therefore, I analyzed the exponential model as well. Good correlation was found between the decompression work/compression work ratio and mass loss. The result was confirmed by experiments in 2009 and 2010. The figure 4 shows the result of experiment in 2008.

In the case of measuring point of all years the correlation was good as well, however the coefficient of determination was worse (R^2 = 0.7147) than the results in each years (figure 5). The results show that the exponential model suitable to describe the relationship between the decompression work/compression work ratio and mass loss, which was confirmed by Durbin-Watson statistic, value of Akaike criterion and prediction error as well.

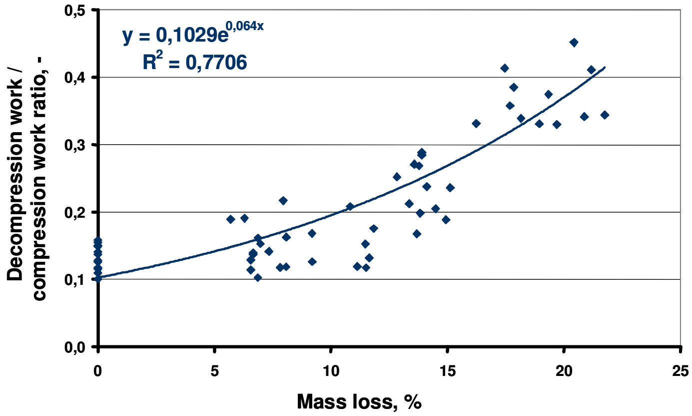


Figure 4 Decompression work and compression work ratio versus mass loss (experiment in 2008)

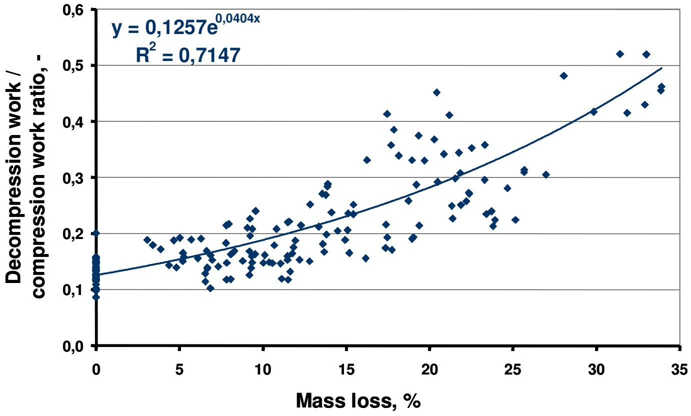


Figure 5 Decompression work and compression work ratio versus mass loss (common fitting to the all of experiment, 2008, 2009 and 2010)

Relationship of acoustic stiffness coefficient and mass loss

The change of acoustic stiffness coefficient was analyzed in the function of mass loss. Beside the linear model the exponential one was fitted to the measuring points as well. In the case of both of model was determined the DW statistic, the R^2, the AIC and RMSE values. These results confirmed that the relationship is exponential.

In case of linear model in 2010 the value

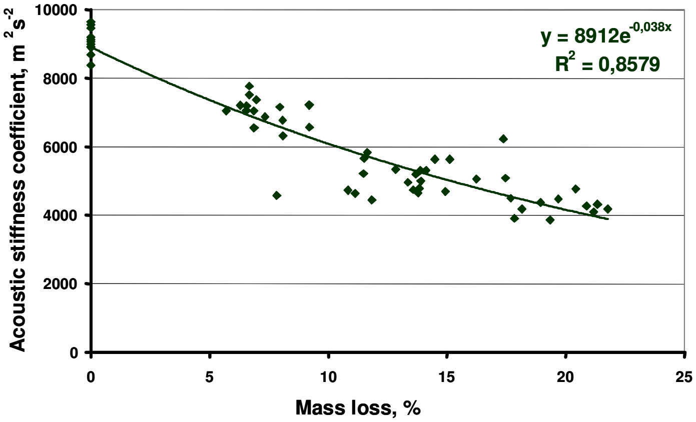


Figure 6 Acoustic stiffness coefficient versus mass loss (experiment in 2008)

of DW statistic was in the acceptable range and in 2008 and 2009 only uncertainty range. The exponential fitting showed better correlation at all of experiments. The figure 6 shows the results of year 2008, and it was confirmed by the other result of experiments. During the storage the firmness decreased exponentially.

Exponential relationship was found between the acoustic stiffness coefficient and mass loss in 2008 and 2009 and 2010. The each experiment showed close correlation between the parameters, however the common fitting showed weak result because of the high deviation.

Change of sensory attributes during storage

13 panelists were selected from 16 one by cluster analysis. The table 1 shows the results of sensory analysis, and Page-test by the selected panelists.

Table 1 Characterization of samples by sensory ranking (sums) and Page-test results (P)

Attributes	Week 0	Week 1	Week 2	Week 3	Week 4	P
„good odour”	38	39	42	30	46	-
„orange colour intensity”	42	28	33	47	45	-
„bite and chewing”	22	34	47	42	50	0.01
„sweet taste”	33	28	43	46	45	0.01
„bitter taste”	34	33	42	48	38	-
„global impression”	27	31	47	42	48	0.01
	0	1	2	3	4	

The Page-test results showed significant ranking in case of „bite and chewing”, „sweet taste” and „global impression” attributes. The figure 7 shows the ranking scores of sensory evaluation versus storage time for the „bite and chewing”, „sweet taste” and „global impression”.

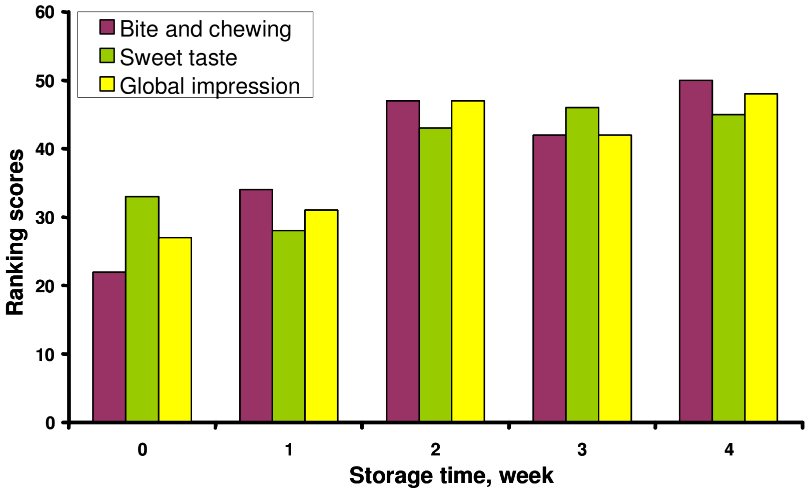
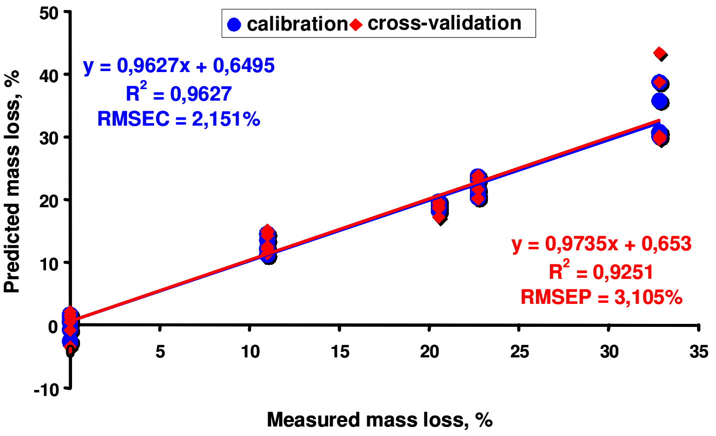


Figure 7 Significant sensory attributes in the function of storage time by Page-test (experiment in 2010)

Prediction of mass loss by electronic tongue results

The mass loss was predicted by PLS-regression from the electronic tongue results (figure 8). The figure shows the model, calibration and LOO-cross-validation. Very close correlation was found between the parameters with small root mean squared error of prediction.



8. ábra Prediction of mass loss with PLS- regression from the electronic tongue results (experiment in 2010)

The table 2 shows the results of prediction at mass loss. Close correlation was found in 2010, and good correlation was found in 2008 and 2009.

Table 2 PLS-calibration and cross-validation for the mass loss based on the electronic tongue results

Measured experiments	LV	calibration				cross-validation				
		r^1	SEC^2	$RMSEC^3$	$Bias^4$	r^1	R^2	SEP^5	$RMSEP^6$	$Bias^4$
2008	3	0.8613	3.757	3.681	-2.956e-6	0.8097	0.6556	4.342	4.256	-0.125
2009	5	0.8994	4.731	4.635	2.056e-5	0.8147	0.6637	6.362	6.235	-0.1428
2010	**4**	**0.9812**	**2.188**	**2.151**	**5.245e-6**	**0.9618**	**0.9250**	**3.152**	**3.105**	**0.1909**

[1]Correlation coefficient; [2]standard error of calibration; [3]mean-squared error of calibration; [4]systematic difference between predicted and measured values; [5]standard error of prediction; [6]mean-squared error of prediction; LV: latent variable

The results show that the mass loss predictable from the electronic tongue results.

The Page-test results showed significant ranking for the „bite and chewing”, „sweet taste” and „global impression” sensory attributes. Therefore these parameters were applied for prediction. The table 3 shows the calibration and cross-validation for the sensory attributes of carrot samples based on mechanical analysis and electronic tongue measurement. The sensory attributes were predicted with PLS-regression by mechanical methods and electronic tongue results.

The „bite and chewing” was predicted from results of the acoustic stiffness coefficient, cutting force/cutting deformation ratio (F_v/D_v), loading force/deformation before creep ratio (F_t/D_{ke}) and elastic deformation/maximal deformation ratio (E/D_{max}). The coefficient of determination (R^2 = 0.9500) means that there is a close relationship between the predicted and measured variables.

The „sweet taste" was predicted from the electronic tongue measurement results. This prediction is confirmed by close correlation of cross-validation (R^2 = 0.9025) and good root mean squared error of prediction (RMSEP = 2.32).

The „global impression" was predicted from results of the acoustic stiffness coefficient, cutting force/cutting deformation ratio (F_v/D_v), loading force/deformation before creep ratio (F_t/D_{ke}) and elastic deformation/maximal deformation ratio (E/D_{max}) and the electronic tongue results. The coefficient of determination (R^2 = 0.8668) and the mean squared error of prediction (RMSEP = 3.185) of cross-validation confirmed the goodness of this prediction.

Table 3 PLS-calibrations and cross-validation for the sensory attributes of carrot samples based on acoustic stiffness coefficient, cutting force/cutting diameter ratio, loading force/deformation before creep ratio, elastic deformation/maximal deformation ratio and the electronic tongue results

Sensory attributes	LV (No)	calibration				cross-validation				
		r[1]	SEC[2]	RMSEC[3]	Bias[4]	r[1]	R^2	SEP[5]	RMSEP[6]	Bias[4]
Bite and chewing [A]	6	0.96	2.88	2.84	0.08447	0.97	0.95	2.29	2.25	-2.098e-6
Sweet taste [B]	4	0.97	1.82	1.78	-5.37e-5	0.95	0.90	2.36	2.32	-0.067
Global impression [C]	13	0.98	1.69	1.66	4.62e-6	0.93	0.86	3.19	3.14	-0.215

[1]Correlation coefficient; [2]standard error of calibration; [3]mean-squared error of calibration; [4]systematic difference between predicted and measured values; [5]standard error of prediction; [6]mean-squared error of prediction. [A]prediction based on acoustic stiffness coefficient, cutting force/cutting diameter ratio, loading force/deformation before creep ratio and elastic deformation/maximal deformation ratio [B]prediction based on electronic tongue results. [C]prediction based on acoustic stiffness coefficient, cutting force/cutting diameter ratio, loading force/deformation before creep ratio, elastic deformation/maximal deformation ratio and the electronic tongue results. LV: latent variable

The figure 9, 10 and 11 show the prediction of „bite and chewing", „sweet taste" and „global impression" such as the different sensory attributes.

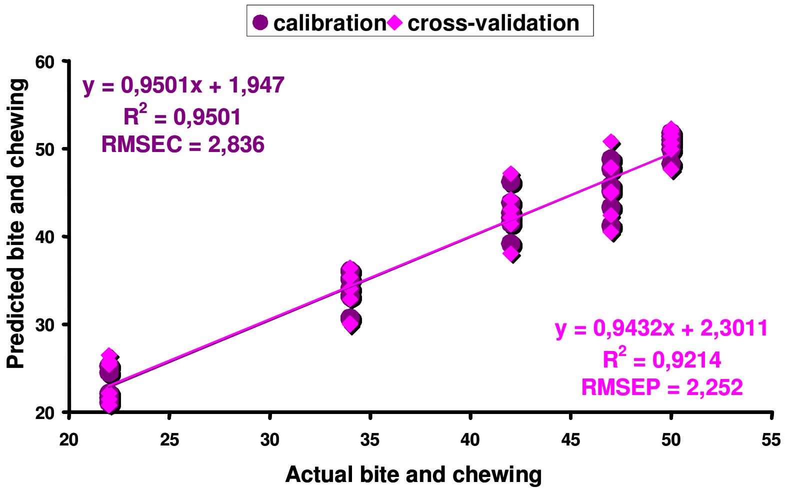


Figure 9 Prediction of „bite and chewing" attribute with PLS regression based on acoustic stiffness coefficient, the cutting force/cutting diameter ratio (F_v/D_v), loading force/deformation before creep ratio (F_t/D_{ke}) and elastic deformation/maximal deformation ratio (E/D_{max}) results

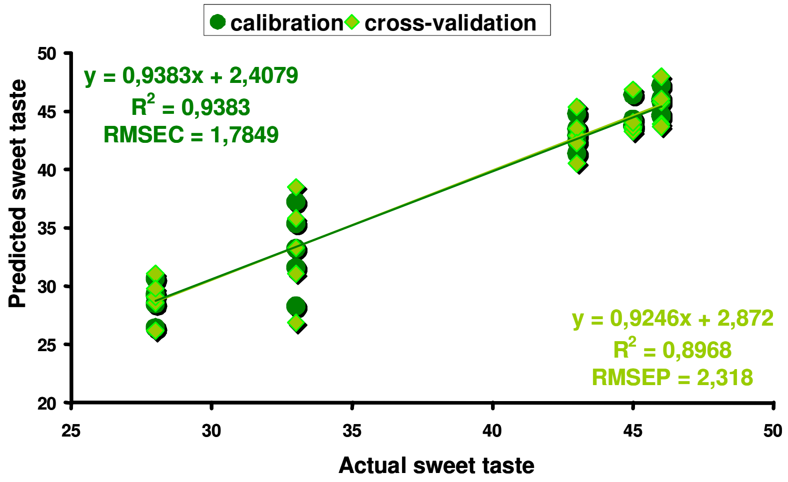


Figure 10 Prediction of „sweet taste” attribute with PLS regression based on electronic tongue results

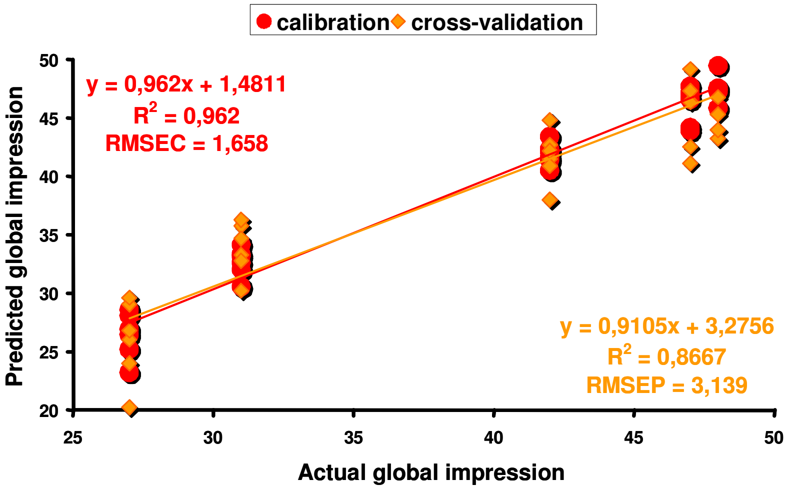


Figure 11 Prediction of „global impression” attribute with PLS regression based on acoustic stiffness coefficient, the cutting force/cutting diameter ratio (F_v/D_v), loading force/deformation before creep ratio (F_t/D_{ke}), elastic deformation/maximal deformation ratio (E/D_{max}) and the electronic tongue results

During the sensory analysis from the sensory attributes the „bite and chewing”, the „sweet taste” and the „global impression” showed significant similarity with the storage ranking, which was unknown for the panelists. Consequently, the selected mechanical parameters and electronic tongue were suitable for prediction of the changes in definite sensory attributes.

NEW SCIENTIFIC FINDINGS

In 2008, 2009 and 2010 Nanti kind of type and Nevis variety carrot was harvested and stored under non-ideal storage condition (8,0±0,5°C-on and 84±2%) for 4 weeks. The change of mechanical, optical and taste attributes were measured during this condition. The following new scientific findings were determined:

1. Close linear correlation was found between cutting force/cutting diameter ratio and the mass loss, where the coefficient of determination $R^2_{2008} = 0.852$, the value of root mean square error $RMSE_{2008} = 2.684$ N/mm. In case of the fitted model for the all years: the coefficient of determination $R^2 = 0.827$, the root mean squared error $RMSE = 2.140$ N/mm.
2. Good exponential correlation was found between the decompression work/compression work ratio and mass loss, which were characterized by the following values: coefficient of determination $R^2_{2008} = 0.771$, the root mean square error $RMSE_{2008} = 0.046$. In the case of the fitted model for the all years: the coefficient of determination $R^2 = 0.715$, the root mean squared error $RMSE = 0.045$.
3. Close exponential correlation was found between acoustic stiffness coefficient and mass loss, where the coefficient of determination was: $R^2_{2008} = 0.858$, and the root mean squared error was $RMSE_{2008} = 618.9\ m^2s^{-2}$.
4. During the sensory analysis, the Page-test scores than the "bite and chewing", "sweet" and "overall impression" attributes a 99% significance level, in the function of storage time showed a declining trend.
5. Electronic tongue measurements with the results of PLS method successfully was estimated the mass loss. The individual measurement's coefficient of determinations $R^2_{2008} = 0.656$, $R^2_{2009} = 0.664$, $R^2_{2010} = 0.925$; the root mean squared errors $RMSE_{2008} = 4.256$, $RMSE_{2009} = 6.235$, $RMSE_{2010} = 3.105$.

6. The „bite and chewing” sensory attribute was predicted with close correlation by PLS-regression from the follow measured parameters: properties of electronic tongue, the acoustic stiffness coefficient, the cutting force/cutting diameter ratio (F_v/D_v), the loading force/deformation before creep ratio (F_t/D_{ke}) and the elastic deformation/maximal deformation (E/D_{max}) ratio. The coefficient of determination was ($R^2 = 0.921$), and the root mean squared error of prediction was (RMSEP = 2.252).
7. The „sweet taste” attributes was predicted with close correlation by PLS-method from the measured properties of electronic tongue, where the statistical parameters were as the follows: coefficient of determination ($R^2 = 0.897$) and root mean squared error of prediction (RMSEP = 2.318).
8. The „global impression” sensory attribute was predicted from the acoustic stiffness coefficient, cutting force/cutting diameter ratio (F_v/D_v), the loading force/deformation before creep ratio (F_t/D_{ke}), the elastic deformation/maximal deformation (E/D_{max}) ratio, and from the electronic tongue measurement results. This prediction is confirmed by close correlation of cross-validation ($R^2 = 0.867$) and good root mean squared error of prediction (RMSEP = 3.139) according to the cross-validation.

RECOMMENDATION FOR FURTHER RESEARCH

I established during the research that the carrot has a vey inhomogeneous texture, and its firmness depend on the effects of several parameters. The recommendations are as follows:

- To measure of respiration during storage
- To analyze the effect of change of storage temperature and humidity for mechanical and taste attributes of both of carrot parts xylem and phloem in the function of storage time
- To analyze the change of mass loss during non-ideal storage
- To predict the mechanical properties from mass loss
- To predict the taste attributes from mass loss
- To analyze the effect of non-ideal storage for mechanical and taste attributes change of different carrot varieties.

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