CORVINUS UNYVERSITY OF BUDAPEST

MODERN METHODS FOR PREDICTION OF VEGETABLE STORABILITY

Doctoral Theses

by Sándor Istella

Subject Leader:
Prof. emeritus Dr. Sándor Balázs

Subject associate:
Prof. Dr. József Felföldi

Department of Vegetable and Mushroom Growing
Corvinus University of Budapest

Budapest
2008

PhD School
Name: Doctoral School of Interdisciplinary Sciences and Agricultural Sciences and Plant Production and Horticultural Sciences

Field: Plant Production and Horticultural Sciences

Head of Ph.D. School: Prof. Dr. Magdolna Tóth
Doctor of the Hungarian Academy of Sciences
Head of Department of Fruit Sciences
CORVINUS UNIVERSITY OF BUDAPEST,
Faculty of Horticultural Sciences

Supervisor: Prof. Sándor Balázs, MHAS
Professor emeritus of the Hungarian Academy of Sciences
CORVINUS UNIVERSITY OF BUDAPEST,
Faculty of Horticultural Sciences

Associate supervisor: Prof. József Felföldi, PhD
Doctor of the Hungarian Academy of Sciences
Head of Department of Physics and Control
CORVINUS UNIVERSITY OF BUDAPEST
Faculty of Food Sciences

The applicant met the requirement of the PhD regulations of the Corvinus University of Budapest and the thesis is accepted for the defence process.

....
Head of Ph.D. School Supervisor

Background and Objectives

Formerly, the promotion of earliness and nowadays production stability and the aim to reach high yields all encourage the application of technologies that include, as a component, the raising of seedlings. The national seedling production has long traditions (such as the raising of melon seedlings in turf blocks) and earlier, everyone used to grow and produce the young plants on their own. More recently, seedling factories are seen to be making headway and growers tend to manage ever greater areas and they do not raise seedlings any more, but purchase them. This way, it is even more highlighted that seedlings, similarly to seeds, are an article of trust, therefore they should only be produced in high quality. For the initial self grown seedlings, the growers prepared the soil mixtures also themselves. These were generally mixed from cheap commodities of national origin, but of inadequate quality. Nowadays when the price of the seed may be as high as 100 HUF in the case of high value seedlings or one should only think of grafted seedlings, the soil mixture is only a fraction of the value of the seedling. Therefore one must not scrimp on the purchase of good quality medium.

It had long been customary to characterize a growing medium exclusively on the basis of its chemical properties, e.g. the pH value, the amount of available nutrients or the EC value. Still nowadays, the principal ingredient of seedling growing media is peat, owing to its favourable characteristics. Peats have low nutrient levels, plant requirements, however, can be met through controlled nutrient supply in the course of production. On the other hand, the medium should have optimal physical characteristics possibly already at the beginning of growing and these parameters are difficult to improve subsequently. A constant and high quality growing medium would be in great demand. A number of companies offer mixtures prepared according to their own recipes, the quality of these mixtures, however, are generally varying and the choice is complicated further by the use of several organic and inorganic materials which are offered for the substitution of peat, the major component.

Since only few investigations had been carried out before in Hungary into physical root media properties for my thesis I have set the objective to analyze the major physical properties and to determine the parameters of the media, as well as to study, in the light of these physical properties, the effect of the media made from different basic ingredients on the germination and early development of vegetables. Artificial soil mixes are very difficult to investigate in this direction, partly because of the scarcity of the national literature and partly because of the lack of exact analytical methods. It is a serious problem that the measurement methods elaborated for mineral soils cannot be fully adapted to the investigation of such media, besides reproducibility is hard to achieve, owing to the heterogeneity of the materials and the diversity of the measurement techniques.

In my work I grew the seedlings of 5 vegetable species with the tray method, containing species less susceptible to the physical properties of the root medium (tomato,

cabbage) and ones more susceptible (cucumber, pepper and lettuce). Trays are filled with peat based media in large scale production too. Fibrous raised bog peat has recently been getting more and more widely used. Many growers buy national fen peat still now, primarily for making soil mixes for their own use. In the trial, besides the Northern raised bog peats some Hungarian fen peats were also tested. Owing to the world's diminishing peat resources more and more attention is being directed towards the search for peat substitutes. Accordingly, in my seedling raising experiments I tested different mineral materials (bentonite, zeolite, perlite and expanded clay pellets) as medium constituents, as well as coconut coir which is getting ever more popular, determining the physical parameters and their effect on seedling development.

In the world, several seedling raising technologies are known which utilize seedling trays. The major difference between them consists in the types of the trays used and the tray filling method. Therefore, I also carried out investigations to find out whether the choice between loose or compacted filling had any effect on the physical properties of the medium and on the development of the plants.

My aim was to select, taking into consideration the national commodities as well, the medium that suited best the vegetable species and the seedling raising techniques applied in the light of the most important physical properties.

Material and Method

In the experiments I used different vegetables in order to be able to study the range of applicability of the methods. Because of the detection of the cultivation technology effects and the applicability of the method the cultivation of the specimens used for the examination was conducted under different conditions.
In every case in the experiments I kept the vegetables examined in storage. I carried out storing for a shorter or longer period depending on the produce to be stored.

Storage conditions of paprika characterized by short storability

The samples were stored for two weeks at 10-15°C in a cool room without atmosphere control and without ventilation. Relative humidity changed between 80-90%. During this period I examined the varieties and measured the changes in firmness and losses in weight seven times. I used the same environment in each experiment.

Storage conditions of vegetables characterized by long storability

Storage conditions of beetroot

Storage was carried out in open polyethylene bags at a temperature of 1-4°C and at a humidity of 95%. I measured the varieties on three occasions: at harvest, after one and a half months of storage and after 4 months. The length of storage was 112 days.
In the variety comparison trials I dried the carrot roots for one day after harvest and did not wash them. The roots were put in storage at the optimal maturity of the varieties. The carrot roots were stored in unclosed polyethylene bags in a room without atmosphere control and without ventilation. The temperature was 4-10°C as characteristic of a cool cellar. The relative humidity ranged between 85-95%.
In the washed carrot storage experiment I placed the carrots after washing into polyethylene bags in a refrigerated room without atmosphere control. Conditions characteristic of the traditional refrigerator room of 4-5°C were maintained and the storage lasted for one month. The relative humidity ranged between 90-95%.

Onion storage conditions

Sound and healthy onions were stored in Raschel nets in a basement room without atmosphere control and without ventilation. The relative humidity ranged between 50-70% and the temperature between 5-9°C.
The harvest of the variety Makói bronz, grown using the fertilizer Perlka, a calcium cyanamide N fertilizer, was immediately followed by the measurement of firmness. Selected specimens were stored in paper bags at a basement room temperature for 45 days. The relative humidity ranged between 60-70%. The temperature changed between 15-18°C.

In my thesis I used methods that can be considered as modern in the field of research, that are fast and are able to provide information on the inner vegetable quality (acoustic method) or on the external one (impact stiffness method) in a completely non-destructive manner.

Up to the mid 1900s, firmness as a quality characteristic used to be determined using the experiences of the grower or intrusive methods. The assessment based on the experience of the grower can be regarded as very subjective. In the 21st century this is already considered to be an unacceptable method.

The greatest disadvantage of the invasive methods consists in permitting only a single measurement on the same fruit and in making the tested produce lose its value completely. Subsequently, these individuals can not be stored in the storage and the changes cannot be followed as the measurement has to be carried out always on another specimen. The reliability of the measurement will thus be diminished because of the variability of horticultural produces.

Nowadays, several non-destructive methods have been developed in order to eliminate these problems. These methods are already suitable for repeated measurements of the same specimen in a non-destructive manner, for the monitoring of the changes in firmness during storage. These methods are much more advantageous also from economical considerations as the produces tested can be processed or sold.

Acoustic stiffness method

The non-destructive acoustic test method (based on mechanical excitation of the sample and frequency-domain analysis of the acoustic response of the sample) is applied usually to spherical, mainly homogeneous and solid samples. The acoustic method gives relevant information about the overall stiffness of the sample (onion, tomato). According to new research this method can be applied for measuring the stiffness changes of elongated vegetables (carrot, cucumber, iceberg radish) as well in the case of mainly homogeneous samples.

The sample tapping lightly with a wooden stick and a microphone located under the cushioning sample holder sensed the sample's acoustic response.

The microphone's output recorded by the sound card in a PC-compatible computer. Custom Fast Fourier Transform software is using to analyze the recorded acoustic response. There is significant connection between the peak (characteristic) frequency of the acoustic signal and the sample's firmness. The characteristic frequency and the sample weight used to calculate the firmness coefficient:

$S= f^2*m$ [N/mm],

S – acoustic firmness coefficient

f – characteristic frequency of the sample

m – sample weight

The acoustic stiffness coefficient can be used for comperative examination or analysis.This method is suitable for following the changes in stiffness (softening) sensitively,

reproducibly and objectively. The sound response of the product hardly depends on position of the sample and the tapping location; it is independent on the person who taps the product and the hitting stick. The acoustic stiffness method can be used successfully for following the textural changes during storage.
This method more sensitively detecting the softening changes than the destructive penetrometer.

Impact method

The impact method characterizes the firmness of the surface. The impact method is based on the observation that the impact hammer's deceleration depends on the sample's firmness and elasticity. The measuring system consists of an impact hammer with a changeable weight, an electronic signal converter and a dynamic signal analyzer. A piezoelectric accelerometer is built into the hammer. The voltage signal of the accelerometer is recorded and displayed by the dynamic signal analyzer. This curve is analyzed by a special program. The time and voltage differences between the initial and the maximum point of the curve are determined by the program. The impact stiffness coefficient is used in order to characterize the sample's firmness :

$$\mathbf{D_d = 1/\Delta T^2 \ [ms^{-2}]}$$

where

D_d – impact stiffness coefficient

ΔT – time difference between the initial and the maximum point of the curve in milliseconds

Several trials were carried out in order to determine the surface stiffness of the horticultural samples by impact method. The main adventages of the method are: it can be automated, it can be easily built into the sorting or classifying and qualifying lines, so it can be used int he practice.This method is independent shape of the sample.

Lab analysis

For the lab analysis the samples were prepared as follows:

Ten of each different samples were choosen or the content analysis. The samples were suitable for sale on the market with tipical caracteristics of the variety.

The samples were grated after washed and cleaned of conteminations. This grated samples were used for the analysis

The following analysis were fulfill of the samples:

1. dry material contet
2. Beta-carotin content
3. sugar content
4. NO_3^- content from dry material content

Results

Of the vegetables selected the carrot and the paprika had not been mentioned by the literature as test plants suitable for use with the methods. Therefore, it was necessary to test the applicability of the methods to the two plants mentioned above (carrot and paprika) prior to the experiments.

In the pre-experiments I tested the paprika on one variety (Kaméleon). The results revealed that in the case of the test variety the acoustic method measuring the inner firmness followed the quality changes of the paprika right from the first day of storage.

The hitting on the pistil point (blossom end) of the fruit proved to be the best of the tested locations of hitting points which showed a good reproducibility during storage. It was the 8th day when the variety Kaméleon reached the point of quality deterioration that I could consider as the maximum of storability under the given conditions.

For the carrot experiment I used 5 industrial varieties, Krakkow, Katmandu, Karotán, Joba and Oldred, storing them for 6 months in a room without atmosphere control and ventilation. The five varieties showed different stiffness factor data, thus differences between the varieties were already observable at the beginning of storage. This was a demonstration of the applicability of the measurement for revealing the differences between the varieties. In the pre-experiment the variety Karotán proved to have the best storability among the varieties put in storage, even in spite of the high loss of weight. It reached the maximum of storability in December after 3.5 month storage. The other varieties started to show significant losses in quality already after 3 months.

My pre-experiments provided evidence for the suitability of the new acoustic non-destructive method for measurements in subsequent experiments. The stiffness factor obtained permits the characterisation of firmness and quality, as well as permitting to detect their changes over storage.

Results of storability comparison experiments of varieties using dynamic physical methods

In the literature, researchers describe a close relationship between variety, shelf life and fruit quality in *paprika* varieties. Each of the varieties used in my experiments differ from one another in an aspect of some kind. This way I had the possibility to study the sensitivity of the method and simultaneously the differences between the varieties.

The acoustic factor indicating inner firmness revealed the difference originating from the nature of the variety, i.e. higher dry matter content and more solid skin structure. Of the white fleshed varieties it was Danubia that proved to have the best storability.

In the paprika variety trial the non-destructive acoustic method (indicating inner firmness) and the dynamic impact method (indicating surface firmness) verified the effect of the variety on storability.

In the carrot variety trial I studied 4 varieties: Bolero has medium storability and is of Nanti type. The variety Nanti is similar to the former but has already better storability. Bangor can be stored for a longer period and is a hybrid of Berlikum/Nanti type. The variety Olympus has long storability and is of Flakker type. Based on the experiments, the optimal length of storage in storage facilities without atmosphere control and without ventilation is 2 months for the varieties Napa and Bolero and 3-3.5 months for the varieties Bangor and Olympus.

The beetroot variety trial contained 8 varieties in all. Two of them were cylindrical (Rocket and Forono) and 6 ones round (Pablo, Pronto, Bíborgömb, Bordó, Bonel and Bolivár). Based on the measurements performed the highest softening was observed in the variety Rocket. The greatest weight loss (27%) and the highest NO_3 content increase were found in the variety Bíborgömb. Based on the measurements of both the physical parameters and the weight and dry matter, the variety Bordó was found to be the one having the best storability.

Based on my experiment, the optimal storability, in perforated polyethylene bags, in a storing room of low temperature (1-4°C) without atmosphere control and without ventilation, is 2 months.

In the *onion* variety experiment I selected three varieties. The variety Piroska, as a Hungarian one with favourable dry matter levels, Daytona as one of good storability but relatively sensitive and a lilac type, Tétényi rubin with medium storability. The impact method indicating surface firmness did not reveal any significant difference between the varieties during storage. Because the outer bulb scales became less tight and were shed I do not recommend the surface test in the case of a longer storage, nevertheless the method is suitable for selection after harvest and cleaning. It is able to reveal eventual bruises and surface deformations. Of the varieties examined, Daytona had the hardest surface. During the 6 month storage Piroska proved to be the variety with the best storability and Tétényi rubin the one with the worst storability. The optimal length of storage in storage facilities without atmosphere control and without ventilation is 6 months for the variety Piroska, 5-6 months for the variety Daytona and 4 months for the variety Tétényi rubin.

The experiments confirmed the characterization included in the variety description. The acoustic non-destructive stiffness method managed to reveal the storability which was characteristic to the varieties. Therefore, the measuring method is suitable for the determination of storability and for the detection of differences between varieties.

Effect of changes in cultivation technology (fertilization, plant care) on storability

The effects occurring during cultivation, as factors influencing storability, have a very broad range.

In my experiments I studied the effect of the growing medium (soil, rockwool) and of the pruning system (1, 2, 3 and 4 stems) on *paprika fruit* storability. According to the literature, pruning has no significant influence on fruit firmness when the necessary technological discipline is observed. The tests described provide information only relative to the characteristics of the exterior appearance and to yield quantities. In the literature I did not find any measurement results relative to firmness data.

There was significant difference between the stiffness factors measured on soil and the ones obtained on rockwool. All three varieties had higher firmness on rockwool and the difference between the varieties was lower compared to that on soil. There was no significant difference in fruit firmness between the pruning methods.

The experiment was suitable for monitoring the differences in storability between the varieties, the changes in the growing media and in the firmness during storage.

In the *carrot* I studied the effect of different top dressings with selenium on storability. The dry matter contents differed over the two years which was strongly influenced by the different total rainfalls in the two years studied. The results suggested that the treatments had no effect on the carotene content.

Also the absorption of selenium produced interesting results. In the examination I concluded that the additional application of selenium had favourable influence on root selenium content which has strong impact on the beneficial role played in the antioxidant protection of carrot. This increased selenium content can be brought into relationship with the modified levels of the micro nutrients which jointly, together with other compositional values, form the protective mechanism which has its greatest role in prevention.

The selenium contents measured over the two years also showed differences. This confirms the fact that a heavier rainfall or irrigation promotes the absorption of selenium. In the two year experiment it was verified that the selenium level can be increased, but during cultivation it is necessary to determine the selenium level of the carrot via measurement, as the variety and the weather have clear influence on the absorption of selenium and a too high supply of selenium can cause problems in plant metabolism.

In the storage experiments I concluded that the chemical Bioplasma (which is used in foliar fertilization in bioproduction) had favourable influence on the storability of the varieties Napa and Jaguár and the applied selenium was assimilated by the carrot root. Though the selenium treatments produced a higher selenium content they did not modify the storability of the carrot roots in a significant manner. The treatments improved carrot firmness in every case, compared to the control, as well as influencing storability. On the other hand, the final conclusion requires further experiments.

In the experiments with *onions* I studied the effect of nitrogen based calcium cyanamide fertilization. Calcium has proven influence on tissue structure and thereby on produce storability.

Based on the data of the measurements I found no statistically demonstrable difference between the onion specimens treated with the two fertilizers. Nonetheless, the stiffness factor of the onions treated with Perlka was higher than the one of those treated with the traditional fertilizer. Firmness began to change later in the treated specimens and its degree was lower. I obtained similar results relative to surface firmness, too.
By the end of the experiment the quality of the onions had not changed significantly, this way they preserve their storability for at least 45 days even under such conditions.

Effect of post harvest operations on carrot storability

The method and place of storage exert influence on storability, this is the reason why they were studied in my experiments. Cleaning and eventual washing as important influencing factors affect the produce to be stored and the storability of the latter.

Carrot storability under refrigerated and non refrigerated conditions without atmosphere control and without ventilation

In my experiment I studied the effect of washing and different storage temperatures on storability using a non-destructive stiffness method. I stored two varieties, Bangor and Olympus, for 4 months.
During this period I found no significant difference between the two varieties with the two types of storage, in the change of quality.
No significant difference occurred between the storage methods. In the case of root vegetables the method of storage is certainly determined by the ratio of costs and prices. It is not always reasonable to use refrigerated storage with carrot. Based on the results of the experiments, under the given conditions the variety Bangor can be stored for 3 months under refrigerated conditions (1-3°C) and for 2.5 months under non-refrigerated conditions. In the variety Olympus this is reduced to 2.5 and 2 months.

Effect of washing and cleaning on carrot storability
During washing carrots suffer surface injuries therefore their storability diminishes. In my experiment I studied the effect of this on two varieties (Bangor, Olympus).
In the first 8 days of storage the two varieties did not differ from one another in a significant manner. By the 12^{th} day however the differences were already observable.
No difference was seen between the varieties in weight loss. It was 10-11% by the end of the storage.
Based on my experiment, the two varieties could be stored optimally for 14 days in a washed state, put in perforated polyethylene bags, under refrigerated conditions. The weight loss was only 7-8% at this time.

New scientific results

Based on the results of the experiments carried out that the non-destructed physical experiments demonstrated (acoustic and impact) are suitable for predicting the storability of a variety and for the detection and characterisation of the results deriving from effects occurring during cultivation (different fertilizer effects, cultivation methods, varietal effects).

- The joint research on paprika and carrot samples carried out in collaboration with the Department of Physics and Automation of Corvinus University of Budapest provided a demonstration of the applicability of the non-destructive method in fields not considered probable by the literature. The new applicable method is the acoustic firmness measuring method. The experiments gave a demonstration that the effect of the factors influencing the difference between the paprika and carrot varieties, their shelf life and storability could be determined and changes could be monitored by monitoring the changes of the same individual during storage using the non-destructive method.
- I concluded that the difference in number of the stems per plant (1, 2, 3 and 4 stem pruning), depending on yield and average fruit size and on the costs of plant care operations, did not have any significant influence on the storability within the same variety in the case of the paprika having short storability. The varietal effect was already observable in the pruning methods.
- I found a relationship between the selenium treatment and the storability of carrot, being a vegetable with long storability and also a stored crop and a source of vitamins during winter, but the relationship was not significant, mainly because of the effect of the year therefore I recommend further experiments for a closer examination of the relationship.
- The effect of the fertilizers on storability could not be demonstrated in a significant manner, but in the case of onion a calcium cyanamide N fertilizer probably has positive effect on storability and the average of the acoustic stiffness of the onion bulbs than that of the onions treated with a fertilizers traditionally used. The softening of the onions begins later, i.e. the treatment retards the process. The real and statistically reliable effect needs further experiments.
- Among the post harvest operations, from the experiments on the washing of carrots I concluded that the interval of storability was diminished with the washing operation, this however did not mean the decline of quality. Based on my experiments I concluded that the two varieties could be stored, as an optimum, for 14 days in a washed state in perforated polyethylene bags under refrigerated conditions. The diminishment in weight occurring during this period will not cause the product to have a lower quality class.

My conclusions confirming the research results already found in the literature

- The role of the variety in storability has been demonstrated in the literature by various authors (Blanpied et. al., 1978; Schuch et al., 1991; Sato et. al., 1997; Pálfi et al., 2004; Petroniene, 2005). In the case of the vegetable species used in my experiments I concluded that the variety had influence on the storability which I demonstrated using non-destructive acoustic and dynamic impact tests.
- The parameters of storage, as influencing factors, have effect on the storability and quality of the crop. The role of the temperature, as a factor influencing quality in the case of stored paprika and carrot, can be objectively demonstrated by acoustic stiffness measurement in a non-destructive manner. The impact stiffness test gave information on the effect of the changes in moisture content and temperature during storage.

Conclusions and Recommendations

After the evaluation and the analysis of the experiments I concluded that each vegetable species tested (paprika, carrot, red beet and onion) was suitable for the quality monitoring with the dynamic measurements. The acoustic stiffness method can be applied to each of the vegetables tested for the detection of varietal differences, for the examination of the varietal effect on storability and for the monitoring of firmness diminishment during storage.

During the experiments with carrots it was seen that also in the case of the long, cylindrical or conical vegetable shapes a characteristic acoustic response was observable which was changing during the storage. The results of my experiments also demonstrate the possibility to monitor this change.

For the purpose of storability tests, of the dynamic firmness measuring methods I recommend the acoustic stiffness method as the optimal non-destructive method for carrots and other crops of cylindrical shape (parsnip, celery root, white radish etc.).

In the case of the paprika, several of my experiments (variety trials of 2003 and 2004, 1, 2, 3 and 4 stem pruning) verified the applicability of the dynamic firmness measuring (acoustic stiffness method and dynamic impact tests). Both the dynamic impact test and the acoustic stiffness method were found to be suitable for monitoring shelf life, as well as for the detection of the effect of influencing factors (variety, pruning system).

I recommend the impact method for gathering information on quick surface changes while the acoustic method for the illustration of the changes in inner firmness.

The *onion* verified the applicability of both testing methods reported by the literature. Changes in the quality occurring within minutes can already be detected due to the sensitivity of the method, like the effect of influencing factors, which was also confirmed by my experiments.

For the detection of the changes occurring during long storage and for the detection of the inner structural changes of the onion bulb (sprout growth and inner quality defects) I recommend the acoustic measuring method.

For a quick surface test and for packaging I recommend the impact measuring system.

In the case of the *beetroot* I recommend the application of the methods as described for the carrot.

In the case of *paprika* and root vegetables (carrot in particular) and I recommend further research and that various experiments should be carried out, as well as the examination of further possibilities for applicability.

In the case of the *carrot* I carried out experiments on the effect of selenium content on storability in two years, but the data should be considered only as a rough indication because of the high standard deviation between the results of the measurements.

In view of the high standard deviation of the weights, in order to eliminate it, I recommend that the calculation use the length of carrot roots in the measurements. The pre-experiments in

this direction (2005-2006) give better results than with the acoustic factors measured with the weight.

In the case of the *paprika* I recommend further investigations focusing on varieties and on the effect of other influencing factors (foliar application of K and Ca as a quality improving effect, difference between harvest dates, effect of the stage of maturity).

I carried out my experiments in collaboration with the Department of Physics and Automation of Corvinus University of Budapest. The experiments carried out there aim at making the measuring method more accurate and are directed to its applicability and standardisation. In the light of this, my recommendation for the prospective application of the dynamic non-destructive methods in the practice:

- for use in variety qualification systems,
- for separation of varieties from the point of storage,
- for indication of optimal harvest state,
- for quality control before and during storage,
- as part of quality sorting system of automatic sorting lines.

Summing up the research work, the methods are suitable for:

- determination and monitoring of firmness as a quality parameter in variety trials,
- examination of the effect of factors influencing quality,
- of the effect of storage on product quality,
- of the effect of changes in composition (water content, carbohydrates, dry matter content etc.) on storability.

Publications belonging to present theses

Peer reviewed articles in journals:

1. Füstös Zs., Felföldi J. and **Istella S.** (1998): Objektivno merenje parametara kvaliteta luka (Objective measurement of quality parameters of onion - Journal on Processing and Energy in Agriculture,1998.(Volume 2):.62-67.
2. Füstös Zs., Felföldi J., Solberg S.O. és **Istella S**. (1999): A vöröshagyma tárolhatóságát meghatározó élettani tényezők és fizikai paraméterek. Kertgazdaság 31(4):114-117.
3. Tompos D., **Istella S**. and Ignáth T. (2003): Assessment of fruit firmness of pepper using non-destructive physical measurements, in response to different growing and pruning technologies. International Journal of Horticultural Science 9(1):59-62.
4. Muha V., **Istella S.** and Tompos D. (2005): Storability of paprika varieties measured by non-destructive acoustic method. International Journal of Horticultural Science 11(2):49-53.
5. **Istella S.,** Muha V. and Terbe I**.** (2006): Storage ability and differences of carrot varieties defined by firmness changes measured with new non-destructive acoustic method. International Journal of Horticultural Science 12(1) 37-40.
6. **Istella S.,** Muha V. és Tompos D. (2006): A paprika tárolás során bekövetkező állományváltozásának vizsgálata roncsolásmentes impact módszerrel. Kertgazdaság 38(2):70-73.

Other scientific articles:

1. **Istella S.** és Felföldi., J. (2003): Sárgarépa állományváltozásának vizsgálata roncsolásmentes akusztikus módszerrel tárolás során. Hajtatás Korai Termesztés 34(4):24-26.
2. **Istella S.,** Muha, V. és Molnár, K. (2005): Szelénes kezelés hatása a sárgarépa tárolhatóságára. Hajtatás Korai Termesztés 36(4):23-26.

Conference publications (Hungarian, full papers):

1. **Istella S.** és Ignáth, T. (2003): A paprika keménységének vizsgálata roncsolásmentes fizikai módszerrel, termesztési és metszési módoknál. MTA XXVII. Kutatási és Fejlesztési Tanácskozás, Gödöllő, 130-134.
2. **Istella S.** és Muha, V.(2004): A sárgarépa beltartalmi értékeinek és állományváltozásának vizsgálat tároláskor, Proceedings of the 11th Symposium on Analytical and Environmental Problems, Szeged, 27 September 2004. 247-251.

3. **Istella S.** és Muha V. és Molnár K. (2004): Szelénes és bioplazmás kezelés hatása a sárgarépa beltartami értékeire és tárolhatóságára. Proceedings of „The 12th Symposium on Analytical and Environmental Problems" Szeged, 27 September 2004. 186-190.

Conference publications (Hungarian, abstracts):

1. **Istella S.,** Muha V. és Ignát T. (2003): Cékla fajták tárolhatóságának vizsgálata roncsolásmentes módszerekkel, Lippay János - Ormos Imre - Vas Károly Tudományos Ülésszak. Budapesti Közgazdaságtudományi és Államigazgatási Egyetem Budai Campus, 2003. november 6-7. Budapest, 644-645.

International conferences (English, full papers):

1. Füstös Zs., Felföldi J. and **Istella S.** (1998): Non-Destrictive measurement of quality parameters of stored onion. Proceedings of the 1998 National Onion (and other Allium) Research Conference. Sacramento, California USA, 281-284.
2. Ignát T., **Istella S.,** Zsivánovics G., Muha V., Némethy-U., H. and Tóth K. (2003): Non-destructive texture measurement of beets varieties, Celostátny odborny seminár zeleninárov Slovenska, Nitra. 22-24.
3. **Istella S.** and Muha V. (2005): Washed carrot's storability measured by non-destructive method, Zbornik Radova Proceedings of, XL Croatian Symposium on Agriculture.15-18. February 2005. Opatija, Croatia, 339-340.