Thesis book

POSTHARVEST QUALITY CHANGE OF SWEET PEPPER

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1. INTRODUCTION

Nowadays, consumers' and retailers' demand for fresh horticultural products (fruits and vegetables) with excellent quality and prolonged shelf-life increases rapidly and significantly. According to this increasing demand, the quality preservation and shelf-life prolongation of horticultural products are among the major tasks of postharvest technology.

Horticultural products (fruits and vegetables) are complex living biological systems with continuous postharvest vital processes resulting in changes of the internal and external product properties. The storage among improper postharvest storage conditions (temperature, humidity, air composition, packaging, etc.) of fresh horticultural products can lead to fast quality and shelf-life decrease. The complex property of a product, called quality, depends on internal and external product properties and even on the consumer‘s experiences, preferences and expectations. For the precise, fast and reliable quality determination of quality, objective quality determination methods and systems are needed, especially non-destructive ones in case of horticultural products susceptible to rapid quality changes.

There are several objective destructive and non-destructive methods for quality determination of fruits and vegetables, but because of the great diversity (size, shape, internal structure, colour, texture, etc.) of these products, these methods are not for universal use. So in case of a new product, a new application, the methods already in use have to be tested and the suitability of new methods has to be analysed.

Sweet pepper (Capsicum annuum L.), called paprika, is a well-known and widespread vegetable in the whole world. It has a special role in the Hungarian diet; it is a so called 'hungaricum' product with significant produced average amount of 200.000 tons yearly sold and consumed in the domestic and foreign markets. Sweet pepper is originated in the New World, so the pepper plant needs warmth, water and light, and the pepper berry is a sensitive vegetable concerning postharvest storage, handling and marketing. The pepper pod, the berry has a special, a unique structure. It is a blown-up hollow berry, with thin and waxy exocarp (skin), variety dependent mesocarp (flesh) thickness, high water content, seeds located not in the middle of the berry, also variety dependent shape, size, colour, etc. Due to these special properties, sweet pepper is susceptible to relatively fast negative quality changes among improper postharvest storage conditions. In this case, the pepper berry rapidly looses its original freshness and firmness, inhomogeneous post-colouration may occur etc. resulting in rapid overall quality and shelf-life decrease. Furthermore, the overall quality and its decrease effecting consumers' perception and market value are really difficult or even impossible to determine objectively by the conventional quality measuring methods and even with the use of available, but not truly objective standards and regulations. Some of the difficulties concerning pepper quality determination are the followings. Harvest maturity and quality determination of paprika is mainly done at grower's side by the growers' subjective and empirical decision concerning texture, firmness, freshness, size, shape, colour, etc. Pepper texture and firmness are not easy to measure because of the unique structure, maturity and freshness are mainly subjective conditions really difficult to determine objectively, size and shape and colour are variety dependent properties. In near future, in case of postharvest operations product delivery and takeover according to quality should take over the place of currently used operation according to quantity. In order to achieve this goal, especially in case of sweet pepper, objective maturity, firmness, texture, colour, etc. determination methods and the exact knowledge about sweet pepper's postharvest behaviour are needed for the objective quality determination.

2. OBJECTIVES

According to the difficulties and problems mentioned above concerning sweet pepper's postharvest quality change and the need for objective quality determination, the goals of my experimental work were the examination and determination of postharvest pepper quality change together with the selection of suitable objective quality determination methods. The main objectives of my thesis work in detail were as follows:

- getting knowledge about the postharvest behaviour of different sweet pepper varieties at different storage temperatures considering the physiological changes and disorders caused by different storage temperatures, determination and identification of the symptoms of low temperature caused chilling injury together with the evaluation of the temperature threshold of chilling injury, determination of optimal storage conditions in order to increase shelf-life;
- as a main pepper quality criterion, quantitative and objective determination of sweet pepper firmness/stiffness, examination and determination of the role and effect of internal and external factors (maturity, colour, temperature, humidity, packaging, mass loss, etc.) effecting quality, evaluation of pepper quality categories according to the firmness/stiffness data gained by the objective texture analysis methods;
- examination of the suitability of mainly non-destructive and objective quality measuring methods for the determination of sweet pepper's postharvest quality change,

* examination of the suitability of measuring methods for the determination of maturity (membrane permeability measurement, surface colour measurement and chlorophyll fluorescence measurement),
* examination of pepper postharvest vital processes and behaviour by evaluation of respiratory activity considering internal and external factors effecting it (maturity, temperature, humidity, surface tissue damage, storage air composition, etc.);
* determination of transpiration properties and the connection between transpiration and mass/water loss;
* examination of the effect of modern postharvest storage conditions on pepper quality considering the prolongation of shelf-life.

3. MATERIALS AND METHODS

Experiments were carried out using the well-known and popular white paprika varieties Hó, HRF and the more and more popular Kárpia variety considering variety, maturity stage (according to a visual maturity colour scale from 1 to 8), packaging (LDPE, PP, PE+PA and without packaging), humidity, storage temperature (4 °C, 7 °C, 10 °C and 20-22 °C) and storage air composition (normal air, MAP, CA). Intact and sound paprika samples were harvested in maturity stage ready for harvest and consumption characterized by freshness and stiffness of the berry, glossy surface with variety dependent colour (Hó, HRF – yellowish-white, Kárpia – green, greenish-red or red) according to the general harvest practice based on the subjective decision of a professional grower.

The following examination methods were used and measurements were carried out during the experimental part of my thesis work.

For the description and characterization of variety characteristic postharvest behaviour, physiological changes and shelf-life of sweet pepper varieties Hó and HRF, storage experiments at different storage conditions (4 °C, 7 °C, 10 °C and 20-22 °C, in normal air and in MAP) were carried out, together with the identification and the determination of optimal postharvest storage conditions. Experiments were carried out at Dept. of Refrigeration and Livestock Product Technology, Faculty of Food Science, Corvinus University of Budapest (FFS-CUB).

In order to determine the postharvest texture changes of sweet pepper varieties Hó and Kárpia, computer aided universal texture analysers (SMS-TA-XT2i with Texture Expert for Windows - Dept. of Physics & Control, FFS-CUB and Zwicki 1120 with testXpert® - ATB-Potsdam, Germany) were used for the traditional destructive (Magness-Taylor firmness of pepper slices) and non-destructive texture analysis on intact peppers with Magness-Taylor probe (Ø=11 mm). The novel non-destructive acoustic and impact stiffness methods were used for the stiffness determination of intact peppers at the Dept. of Physics & Control, FFS-CUB.

For the determination of postharvest quality change concerning surface colour change, optical methods were used. Tristimulus surface colour measurements were carried out by Minolta CR-200 and CM-2600d at Dept. of Refrigeration and Livestock Product Technology, FFS-CUB and ATB-Potsdam, Germany, respectively. Digital image analysis of digital pictures of whole peppers were performed using the software SPOTS developed at Dept. of Physics & Control, FFS-CUB in order to determine the red to green surface colour ratio. Chlorophyll fluorescence measurements and data analysis were carried out by FluorCAM 690MF system and FluorCAM for Windows, respectively (ATB-Potsdam, Germany) in order to determine the change in photosynthetically active chlorophyll content related to colour change. Transpiration features (transpiration rate and transpiration resistance) of pepper were evaluated for body and stalk separately upon measured surface temperatures from thermal images taken by IR-thermal imaging system (VarioScan 2011 IR-camera and InfraTec IRBIS® thermal imaging software) in ATB-Potsdam, Germany.

In order to characterize the postharvest vitality of sweet pepper, respiratory intensity and respiration characteristics were evaluated considering temperature, storage time, humidity, variety, maturity, intactness and storage air composition (normal and CA-storage). Two custom made respiration measuring systems were used at the Dept. of Refrigeration and Livestock Product Technology. The PLC controlled system with continuous flow-through operation (‘open system’) was equipped with an ABB Advanced Optima IR CO_2-sensor and the ‘closed system’ with Ahlborn high sensitivity IR CO_2-sensors based upon the concentration dependent infrared absorption of CO_2.

Destructive measuring methods were also used for the evaluation of postharvest quality change of pepper. Membrane permeability (ion-leakage) of fresh and stored pepper samples in different maturity (from 1 to 8 according to a visual maturity colour scale) was evaluated. For the measurement of pepper tissue disks’ electric conductometry change until steady state in an isotonic mannitol solution, a PC-controlled LABVIG OE-420 electric conductometer was used. Measurements were carried out at the Dept. of Biochemistry and Food Technology at Budapest University of Technology and Economics. Water potential features (pressure, osmotic and water potential) of fresh and stored pepper samples were determined at ATB-

Potsdam, Germany using a computer aided WESCOR HR-33T microvolt meter and C-52 dew-point hygrometer chambers. Additionally, the water soluble content of sweet pepper samples was determined by the Zeiss-type optical refractometer and the ATAGO PR-1 digital refractometer using the pressed and filtered pepper juice.

For data conversion MS-Excel and for statistical analysis Statgraphics ver. 5.0 and SPSS ver. 11 programs were used at 95 % confidence level.

4. RESULTS

Concerning the determination of the effect of internal (i.e. variety, maturity stage) and external factors (temperature, humidity and packaging, storage time, etc.) influencing postharvest quality change, the pepper varieties of Hó and HRF were found to be chilling sensitive to storage temperatures under 7 °C. The suggested optimal conditions for postharvest quality maintenance are storage temperatures not lower than 7-8 °C and stable relative humidity between 90-95 per cent provided by e.g. LDPE packaging. Under these storage conditions the keeping quality of sweet pepper is about 2-3 weeks and the shelf-life after cold storage at temperature not under 7-8 °C is about 5 to 7 days.

As a major pepper quality feature, the firmness/stiffness of pepper berry was determined using several texture analysis methods. It was proven by the use of methodological examinations that the postharvest stiffness and quality change of sweet pepper berry (softening and wilting) can not be measured and characterised objectively by the destructive Magness-Taylor penetration test. In contrast, the stiffness and quality change of sweet pepper can be characterized by the elasticity modulus (E), the impact stiffness coefficient (D) and the acoustic stiffness coefficient (S) evaluated by non-destructive texture analysis, impact stiffness and acoustic stiffness measurement, respectively (Figure 1.).

Serving as a base for a special decision-supporting expert system concerning postharvest pepper quality, the relationship between the objective non-destructive texture coefficients (E, D, S) and the empirically, organoleptically evaluated pepper stiffness was determined (Table 1.). This relationship can be used as a base also for the determination of objective pepper stiffness categories and therefore the determination of pepper quality.

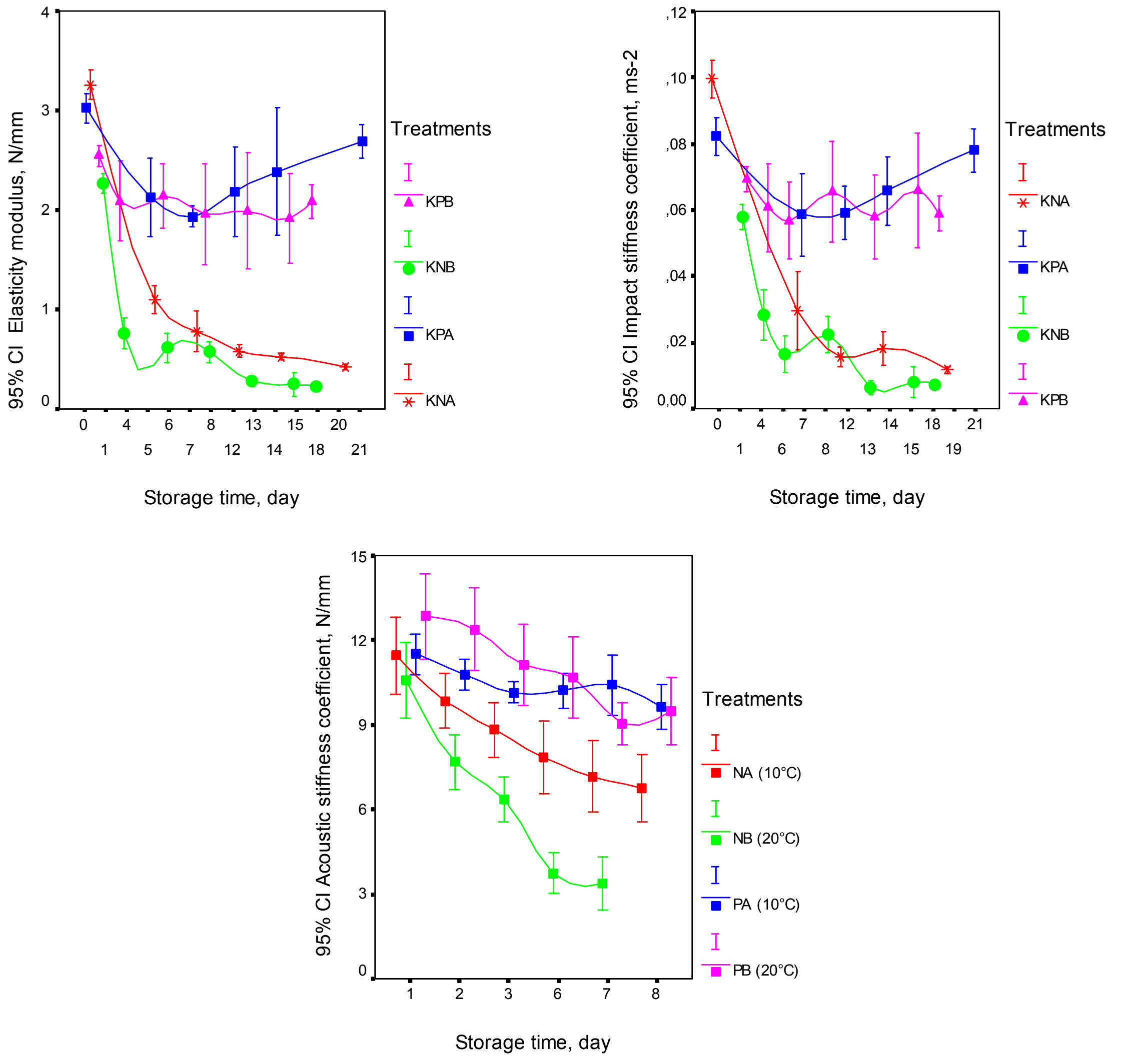

Figure 1. Change in elasticity modulus (E, N/mm), impact stiffness coefficient (D, m/s^2) and acoustic stiffness coefficient (S, N/mm) of Kárpia pepper stored at 10 °C and 20 °C (signed with A and B, respectively) and with and without LDPE-packaging (signed with P and N, respectively).

Table 1. Relationship between the stiffness data of Hó and Kárpia pepper determined by objective texture measuring methods and the subjective, organoleptically evaluated pepper firmness.

		Elasticity modulus (E, N/mm)		**Impakt stiffness coefficient (D, 1/ms^2)**		**Acoustic stiffness coefficient (S, N/mm)**
Judgement of firmness	**Point**	**Hó**	**Kárpia**	**Hó**	**Kárpia**	**Kárpia**
Fresh and firm berry by touch	5	4-5	3,2-4	0,65-0,85	0,85-1	10-11
Still fresh and firm berry by touch	4	3-3,9	2,5-3,1	0,55-0,64	0,7-0,84	7-9,9
Slightly softened berry	3	2-2,9	2-2,4	0,54-0,35	0,55-0,69	5-6,9
Hardly softened berry	2	1-1,9	1,9-1,1	0,34-0,3	0,35-0,54	3-4,9
Unacceptable soft berry	1	<1	<1	<0,3	<0,35	<3

The membrane permeability of fresh and stored sweet pepper determined by measuring the electric conductometry until steady state in an isotonic solution could be characterised by the change of parameters of the saturation function of ion-leakage (maximum ion-leakage, ion-leakage rate). The maturity of sweet pepper is characterised by the ion-leakage rate, so the membrane permeability of sweet pepper depends on the pepper's maturity stage. The ion-leakage rate of the mature red (maturity stage 8) Hó pepper is about 2,5-3 times higher than the one of mature yellow pepper (maturity stage 1) (Fig.2.).

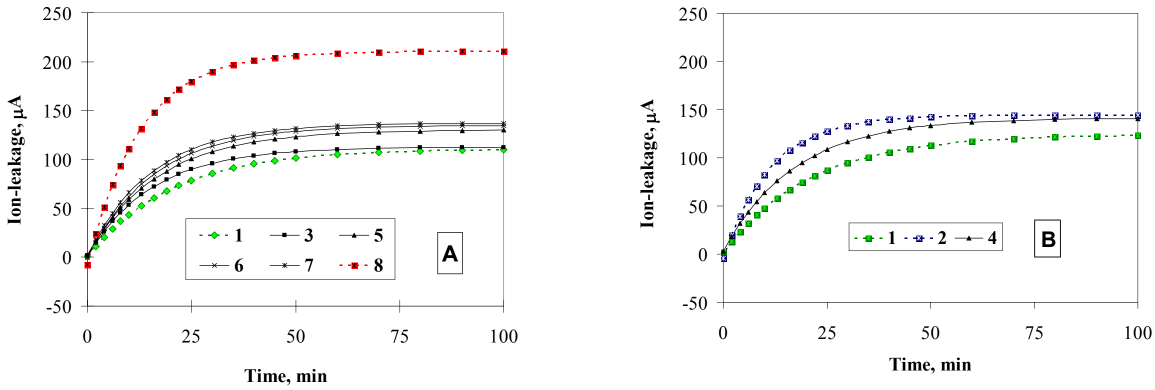

Figure 2. Average ion-leakage of fresh Hó peppers in 6 (1-8) different maturity stages (A) and the change in average ion-leakage of fresh Hó pepper samples (maturity stage 1) during postharvest storage at 20 °C (B) and post-colouration.

The postharvest respiratory intensity of sweet pepper shows a special pattern of change at normal atmosphere gas conditions. It increases up to a maximum in a relatively short time and later it decreases to a so called steady state level. The maturity stage, the physiological state, the variety and the temperature dependence of sweet pepper's respiratory intensity was determined and the respiratory intensity decreases with storage time at normal atmosphere gas conditions. Due to the textural changes of the pepper tissue (caused by mechanical injuries, physiological changes like aging, chilling injury, microbiological disorders, etc.) the respiratory intensity increases for a relatively short time and the steady state intensity is found to be higher than the one measured in the initial fresh state (Fig. 3.).

The increased respiratory activity, measured at room temperature and normal atmosphere of sweet peppers, which were CA-stored at 7 °C at low O_2 and high CO_2 concentrations and taken out from the CA-cabinets, suggests that the physiological injuries of pepper are caused by the unfavourable CA gas conditions but without the appearance of the visible symptoms of injury.

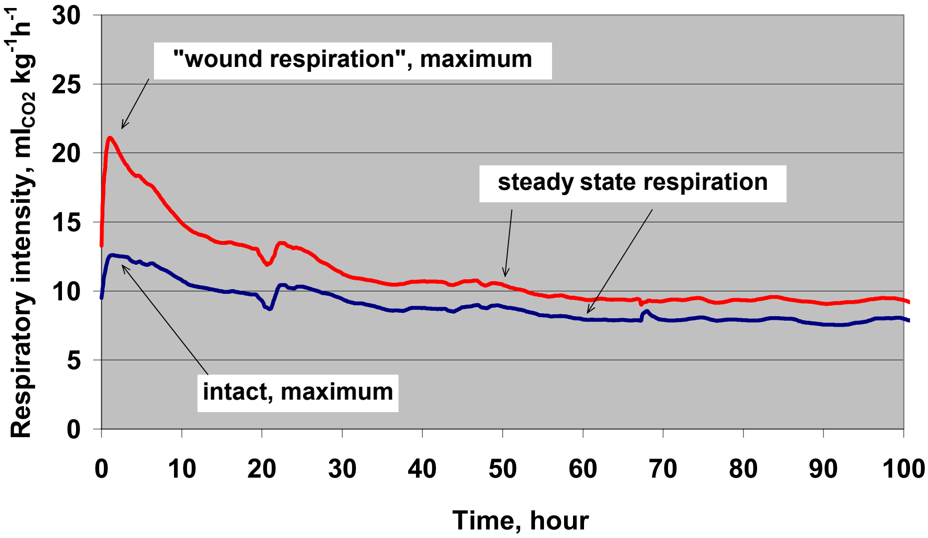

Figure 3. Characteristic change of respiratory intensity of fresh intact and slightly injured Hó pepper in maturity stage 1 (ready for fresh consumption) measured at room temperature.

The surface post-colouration with inhomogeneous distribution during sweet pepper's postharvest maturation follows the change in maturity. However, only local information can be obtained by the use of fast and easy to use tristimulus colorimeters about the change in maturity suggested by the surface colour change of sweet pepper. The maturity stage of pepper varieties undergo a green to red surface post-colouration (i.e. Kárpia) can be objectively characterised and the change in surface post-colouration can be quantified by the use of digital image analysis providing information about the pepper surface's colour change in percentages (red to green ratio).

By the use of chlorophyll fluorescence method, measuring the change in the visually not sensible chlorophyll fluorescence activity, the change in maturity stage and physiological state of sweet pepper can be determined. In case of the Kárpia pepper variety, undergo a green to red surface post-colouration, even before the final mature red maturity stage (8) chlorophyll fluorescence activity is measurable referring to photosynthetically active chlorophyll content. In contrast to the results found in literature, from the measured chlorophyll fluorescence parameters the variable fluorescence (F_v) and the maximum fluorescence (F_m) characterised more reliably the change in sweet pepper's maturity than the F_v/F_m, respectively (Fig.4.).

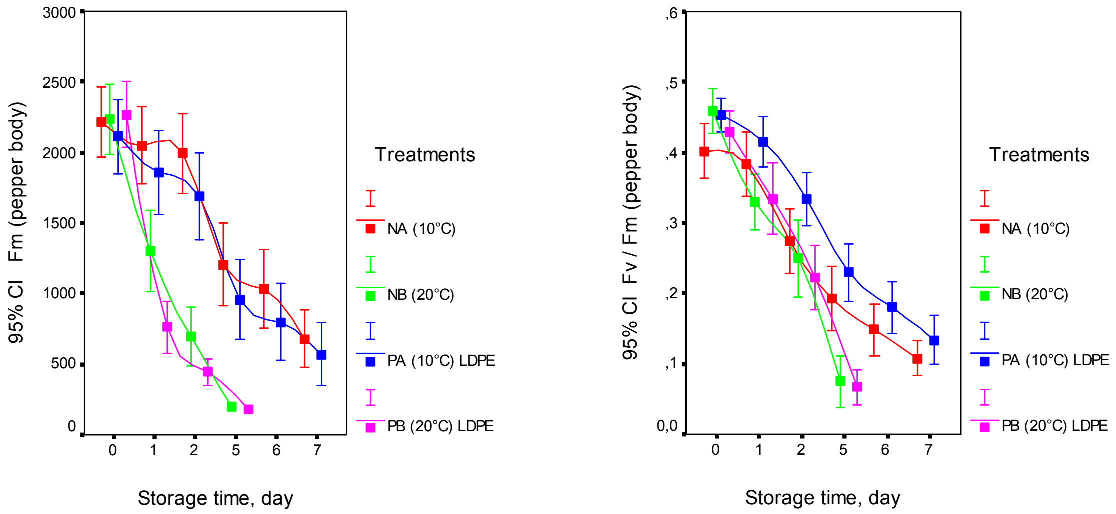

Figure 4. The change in maximum chlorophyll fluorescence (F_m) and maximum photochemical efficiency (F_v/F_m) of Kárpia pepper stored at 10 °C, 20 °C (signed with A and B, respectively) and with and without LDPE-packaging (P and N, respectively).

The transpiration properties, the surface water evaporation of sweet pepper were evaluated by the use of thermography, by the analysis of the thermographic images. According to the results, temperature difference was determined between the pepper surface and the pepper's environment in case of the pepper body and the pepper stalk too due to the surface transpiration, the water evaporation from the pepper surface. The transpiration of the pepper body and the stalk was different, because the pepper body's transpiration was found to be about 2,5-3 times higher than the one of the stalk. The postharvest transpiration properties of sweet pepper showed temperature and packing method dependence during storage.

According to the results of controlled atmosphere storage at 7 °C of Hó and Kárpia sweet peppers under different O_2 and CO_2 concentrations and ultra low oxygen (ULO) concentration the gas composition of 1-1,5 % O_2 and 0-1 % CO_2 provided suitable conditions for shelf-life prolongation for up to 4 weeks in case of Hó variety in contrast to the conventional cold storage. The effect of controlled atmosphere storage of Kárpia peppers under different storage gas concentrations was not found to be significant to the keeping quality of this variety.

NEW SCIENTIFIC RESULTS

- The pepper varieties of Hó and HRF were found to be chilling sensitive to storage temperatures under 7 °C. The storage temperature threshold for pepper varieties of Hó and HRF is 7 °C. Chilling injury symptoms may have occurred during cold storage, but the secondary symptoms develop during disposal and marketing at room temperature storage. The conditions for postharvest quality maintenance are the storage temperatures not lower than 7-8 °C and the stable relative humidity between 90-95 per cent for example by packing the pepper in LDPE. Under these storage conditions the keeping quality of sweet pepper is about 2-3 weeks and the shelf-life after cold storage at not under 7-8 °C is about 5 to 7 days. The mass(water) loss of sweet pepper does not depend on maturity, the major cause of mass loss is the water pressure difference between the product and its environment.

- The postharvest quality change of sweet pepper can not be measured and characterised objectively by the destructive Magness-Taylor penetration test. In contrast, it was proven by the use of methodological examinations that the stiffness change of sweet pepper can be characterized by the elasticity modulus (E), the impact stiffness coefficient (D) and the acoustic stiffness coefficient (S) evaluated by non-destructive texture analysis, impact stiffness and acoustic stiffness measurement, respectively. The stiffness and the textural change of sweet pepper depends on relative humidity and not on maturity.

  Serving as a base for a special decision-supporting expert system concerning postharvest pepper quality, the relationship between the objective non-destructive texture coefficients (E, D, S) and the empirically, organoleptically evaluated pepper stiffness was determined. This relationship can be used as a base also for the determination of objective pepper stiffness categories and therefore the objective determination of pepper quality.

- The membrane permeability of fresh and stored sweet pepper determined by measuring the electric conductometry until steady state in an isotonic solution could be characterised by the change of parameters of the saturation function of ion-leakage (maximum ion-leakage, ion-leakage rate). The maturity of sweet pepper is characterised by the ion-leakage rate, so the membrane permeability of sweet pepper depends on the pepper's maturity stage. The ion-leakage rate of the mature red (maturity stage of 8 according to a visual maturity scale from 1 to 8) Hó pepper is about 2,5-3 times higher than the one of mature yellow pepper (maturity stage of 1).

- The postharvest respiratory intensity of sweet pepper shows a special pattern of change at normal atmosphere gas conditions. It increases up to a maximum in a relatively short time and later it decreases to a so called steady state level. The maturity stage, the physiological state, the variety and the temperature dependence of sweet pepper's respiratory intensity was determined and the respiratory intensity decreases with storage time at normal atmosphere gas conditions. Due to the textural changes of the pepper tissue (caused by mechanical injuries, physiological changes like aging, chilling injury, microbiological disorders, etc.) the respiratory intensity increases for a relatively short time and the steady state intensity is found to be higher than the one measured in the initial fresh state.

At CA-storage of sweet pepper with low O_2 and high CO_2 concentrations the increased respiratory activity of peppers taken out from the CA-cabinets measured at room temperature and normal atmosphere suggests that the physiological injuries of pepper are caused by the unfavourable CA gas conditions but without the appearance of the visible symptoms of injury.

- The post-colouration of sweet pepper during postharvest maturation follows the change in maturity, but the surface colour distribution is inhomogeneous. However, only local, but not really characteristic information about the pepper maturity can be obtained by the fast and easy to use tristimulus colorimeters determining the CIEL*a*b* coordinates of individual surfaces.
- An algorithm was developed for the determination of the ratio of pepper surface colour change concerning pepper varieties undergo a green to red surface post-colouration (i.e. variety Kárpia) using the software SPOTS developed at the Department of Physics and Control, Faculty of Food Science, Corvinus University of Budapest. By the use of this digital image analysis method providing information about the colouration of the whole pepper surface as red to green ratio, the maturity stage of Kárpia peppers and Kárpia alike peppers (with green to red surface colour change) can be objectively characterised and the change in surface post-colouration referring to the change in maturity can be quantified.
- The chlorophyll fluorescence method measuring the change in the visually not sensible chlorophyll fluorescence activity was found to be suitable for the determination and characterization of the change in maturity stage and physiological state of Kárpia sweet pepper with green to red colouration. In case of the Kárpia pepper variety, even before the final mature red maturity stage (8, according to a visual maturity scale from 1 to 8) chlorophyll fluorescence activity is measurable referring to photosynthetically active chlorophyll content. The maximum (F_m), the variable chlorophyll fluorescence (F_v) and the maximum photochemical efficiency (F_v/F_m) were found to be suitable for the characterization of maturity, and their change sensibly referred to the change of photosynthetically active chlorophyll content. In contrast to literature, F_v and F_m characterized more reliably the change in sweet pepper's maturity than the F_v/F_m, respectively.

The digital image analysis and the chlorophyll-fluorescence method offer great opportunity for their application in practice in the postharvest chain. There is the possibility to industrial application of these novel methods after the automatizaton of the processes for measurement and analysis, because of their suitability for product sorting according to colour, maturity and physiological state, for product classification.

- The transpiration properties, the surface water evaporation of sweet pepper were evaluated by the use of thermography, by the analysis of the thermographic images. According to the results, temperature difference was determined between the pepper surface and the pepper's environment in case of the pepper body and the pepper stalk too due to the surface transpiration, the water evaporation from the pepper surface. The transpiration of the pepper body and the stalk was different, because the pepper body's transpiration was found to be about 2,5-3 times higher than the one of the stalk (body: 2,5-3 $mg_{water}\ cm^{-2}h^{-1}$, stalk 0,5-1,2 $mg_{water}\ cm^{-2}h^{-1}$ in fresh state) both in case of fresh and stored samples.
- According to the results of controlled atmosphere storage at 7 °C of Hó and Kárpia sweet peppers under different O_2 and CO_2 concentrations and ultra low oxygen (ULO) concentration the gas composition of 1-1,5 % O_2 and 0-1 % CO_2 provided suitable conditions for shelf-life prolongation for up to 4 weeks in case of Hó variety in contrast to the conventional cold storage. The effect of controlled atmosphere storage of Kárpia peppers under different storage gas concentrations was not found to be significant to the keeping quality of this variety.

5. CONCLUSIONS AND SUGGESTIONS

For the objective postharvest quality determination of sweet pepper, the applicability and suitability of several measuring methods were investigated. Postharvest behaviour and characteristics of three sweet pepper varieties, Hó, HRF and Kárpia, were evaluated considering storage time, temperature, storage method and shelf-life. The examined sweet pepper varieties were found to be chilling sensitive and susceptible to chilling injury under the temperature of 7 °C. Optimal postharvest storage conditions were evaluated. For quality maintenance and shelf-life prolongation I do suggest storage temperature not lower than 7-8 °C and high relative humidity offered by the preferably use of LDPE-packaging.

The non-destructive texture analysis, the impact stiffness and acoustic stiffness measurement were found to be suitable for the reliable and objective measurement of textural changes and for the characterization of postharvest quality change. The relationship between the objective non-destructive texture coefficients and the empirically, organoleptically evaluated pepper stiffness was determined, which could be used as a base for a special decision-supporting expert system for the determination of objective pepper stiffness categories and therefore the objective determination of pepper quality.

The postharvest respiratory intensity and the respiratory patterns of pepper were evaluated considering variety, maturity, storage time, temperature and storage method. Maturity stage, physiological state, variety and temperature dependence of sweet pepper's respiratory intensity was determined.

According to the results of surface colour measurements by the use of classical tristimulus colorimeters and digital image analysis, both methods could be used for the objective quality determination concerning surface colour related maturity. By the use of automated digital image analysis, determining the red to green ratio of the whole pepper surface, the maturity related surface colour determination could be used as a part of the on-line objective pepper quality evaluation in the postharvest practice. Additionally, chlorophyll fluorescence measurement of pepper was found to be an informative and objective method for giving information about the physiological state and the maturity of pepper. So, in the postharvest practice again, the automated determination of on-line chlorophyll fluorescence could be used for objective quality determination.

6. PRESENTATIONS AND PUBLICATIONS APPEARED IN THE SUBJECT OF DISSERTATION

Articles with impact factor

T. Zsom, W.B. Herppich, Cs. Balla, A. Fekete, J. Felföldi, M. Linke. Study of water transpiration features of sweet pepper using a thermal imaging system and non-destructive quality monitoring during post-harvest storage. Journal of Thermal Analysis and Calorimetry vol. 82 (2005), p. 239-243.(IF = 1,430)

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Zsom-Muha Viktória, **Tamás Zsom**, József Felföldi (2007): In-vivo measurement of tomato firmness. Acta Horticulturae (publisment is in progress).

Zsom Tamás, Muha Viktória Werner B. Herppich, Balla Csaba (2005). Paprika pulton tarthatóságának meghosszabbítása (Prolongation of shelf-life of paprika). Kertgazdaság, 2005. 37. évfolyam 1. 101-104.

Muha Viktória, **Zsom Tamás**, Werner B. Herppich, Balla Csaba (2005). Étkezési paprika (Capsicum annuum cv. Kárpia) postharvest időszak alatti minőségváltozásának vizsgálata roncsolásmentes állománymérési módszerekkel. Hajtatás Korai Termesztés XXXVI. évf./2., 2005, 22-26.

Full conference publications

T. Zsom, Cs. Balla (2002): Examination of post-harvest factors influencing the texture of Hungarian type sweet pepper during storage. Proceedings of The 5th International Conference on Food Physics, Brno, Czech Republic, May 30 - June 1, 2002, p.138-142.

Zsom Tamás, Balla Csaba (2000): Külső tényezők hatása az étkezési fehérpaprika hűtőtárolás alatti minőségváltozására, MÉTE XIII. Országos Tudományos Diákköri Konferenciája előadásainak tartalmi kivonatai, 328-331.

Conference publications with summary

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T. Zsom, V.Muha, Cs. Balla, J. Felfoldi, W. B. Herppich (2005): Evaluation of local transpiration features and acoustic stiffness of sweet pepper during post-harvest storage (Étkezési paprika transpirációs jellemzőinek és állományának meghatározása). Abstracts of the 17th "Lippay János – Ormos Imre – Vas Károly Scientific Conference, Budapest, Hungary, October 19-20, 2005, p. 112-113.

T. Zsom, V. Muha, J. Felfoldi, Cs. Balla (2005): Classification of apricots in different maturity stages by non-destructive methods (Kajszibarack érettségi állapot alapján történő osztályozása roncsolásmentes módszerekkel). Abstracts of the 17th "Lippay János – Ormos Imre – Vas Károly Scientific Conference, Budapest, Hungary, October 19-20, 2005, p. 282-283.

T. Zsom, Cs. Balla, P. Merész (2002): Change of membrane permeability of Hungarian type sweet pepper during maturation. Postharvest Unlimited – Book of Abstracts, Poster Presentation PH5 June 11-14, 2002, Leuven, Belgium

T. Zsom, A. Szepes, W. B. Herppich, Cs. Balla (2003): Technical adaptation of quality monitoring methods of sweet pepper. Book of Abstracts of The 1st International Symposium on Recent Advances in Food Analysis, Prague, Czech Republic, November 5 - 7, 2003, pp. 97.

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T. Zsom, W.B. Herppich, Cs. Balla, A. Szepes, A. Fekete, J. Felföldi, M. Geyer, B. Herold, M. Linke (2004). Investigation of sweet pepper samples' water transpiration features using a thermal imaging system and non-destructive quality monitoring methods during post-harvest storage. Book of Abstracts of the 6th International Congress on Food Physics and Diary Sciences held in Pécs, Hungary, 22-26 May, 2004, p. 74-75.