DETERMINATION OF THE POSTHARVEST QUALITY CHANGE OF SWEET PEPPER

T. Zsom
Department of Refrigeration and Livestock Products Technology,
Faculty of Food Science, Corvinus University of Budapest,
H-1118, Budapest, Ménesi út 43-45., Hungary,
tamas.zsom@uni-corvinus.hu

ABSTRACT

The aims of my work were the examination and determination of postharvest pepper quality change. The work focused on the determination of postharvest behaviour of sweet pepper varieties at different storage conditions, determination of optimal storage conditions, determination of the role and effect of quality effecting internal and external factors, evaluation of the applicability of non-destructive measuring methods for pepper quality determination. Hó and HRF varieties were found to be chilling sensitive, storage temperature threshold is 7 °C with stable RH 90-95 %. Stiffness and quality change 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. Surface colour related postharvest maturity change was characterized objectively by digital image analysis and chlorophyll fluorescence analysis. Maturity stage, physiological state, variety and temperature dependence of sweet pepper's respiratory intensity was determined.

INTRODUCTION

Excellent quality and prolonged shelf-life are the main criteria for fresh horticultural products in connection with the increasing demand of the fresh product market. 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 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 (Abbott, 1999; Tijskens, 2004). For the precise, fast and reliable quality determination, objective quality determination methods and systems are needed, especially non-destructive ones in case of horticultural products susceptible to rapid quality changes.

Several novel non-destructive methods are available nowadays for scientific research offering the possibility for the quantification and/or prediction of produce quality and the characterisation of fruit responses (maturation, physiological state, etc.) to different postharvest conditions and maintenance. Concerning textural and firmness changes the acoustic impulse-response method and the dynamic impact stiffness measuring methods are found to be suitable (e.g. De Keteleaere et al., 2006; Felföldi and Fekete, 2003; Gómez et al., 2005). For the characterization of fruit and vegetable responses to different external stress factors chlorophyll fluorescence analysis is frequently used (e.g. Bron et al. 2004; Kosson, 2003; Saquet and Streif, 2002).

Concerning the great diversity (size, shape, internal structure, colour, texture, etc.) of fruits and vegetables, the currently available objective destructive and non-destructive methods for quality determination are not for universal use. In case of sweet pepper (*Capsicum x annuum L.*) consistent quality (texture, colour, shape and size) and uniform maturity are the main criteria influencing consumer acceptance, purchase decisions and market value. Pepper is susceptible to relatively fast negative quality changes and shelf-life decrease among improper postharvest conditions (loss of freshness/firmness, water potential, post-colouration). These changes are really difficult to determine objectively by the conventional quality measuring methods. 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 case of perishable horticultural products, such as sweet pepper, objective quality determination methods and the exact knowledge about postharvest behaviour are needed.

The aims of my work were the examination and determination of postharvest pepper quality change together with the selection of suitable objective quality determination methods. The work focused on the determination of postharvest behaviour of sweet pepper varieties at different storage conditions considering the physiological changes, determination of optimal storage conditions, determination of the role and effect of quality effecting internal and external factors, evaluation of pepper quality categories, evaluation of the applicability of non-destructive measuring methods for pepper quality determination.

MATERIALS AND METHODS

Experiments were carried out using Hó, HRF and Kárpia varieties considering maturity stage, 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.

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.

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; Zwicki 1120 with testXpert®) were used for the non-destructive texture analysis on intact peppers with Magness-Taylor probe (Ø=11 mm). The novel non-destructive acoustic impulse-response and impact stiffness methods were used for the stiffness determination of intact peppers.

For the determination of postharvest quality change concerning surface colour change, tristimulus surface colour measurements were carried out by Minolta CR-200 and CM-2600d. Digital image analysis of digital pictures of whole peppers were performed using the software SPOTS in order to determine the change in red to green surface colour ratio. Chlorophyll fluorescence measurements and data analysis were carried out by FluorCAM 690MF system and FluorCAM for Windows, respectively in order to determine the change in photosynthetically active chlorophyll content related to colour change.

For the postharvest vitality characterization 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. 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.

For data conversion MS-Excel, for statistical evaluation at 95 % significance level and for the comparison of the dependent variables SPSS for Windows 10.0 (ANOVA function) were used.

RESULTS AND DISCUSSION

Concerning the determination of the effect of internal (variety, maturity stage) and external factors (temperature, humidity and packaging, storage time, etc.) influencing quality change, the pepper varieties of Hó and HRF varieties 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 % 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.

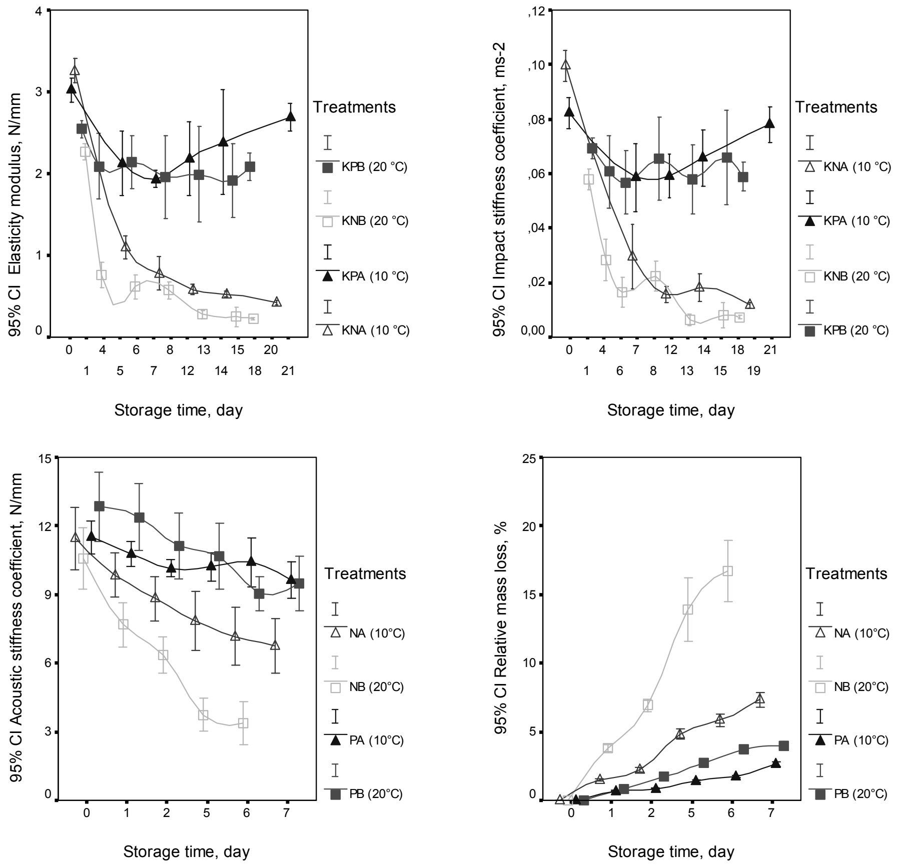


Figure 1
Change in elasticity modulus (E, N/mm), impact stiffness coefficient (D, m/s^2), acoustic stiffness coefficient (S, N/mm) and relative mass loss (%) of Kárpia pepper stored at 10 °C and 20 °C (signed with A and B, respectively) and with and without LDPE-packaging (signed with P and N, respectively).

As a major pepper quality feature, the firmness/stiffness of pepper berry was determined using nondestructive texture analysis methods. It was proven by the use of methodological examinations that 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 (Fig. 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 objective determination of pepper quality.

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)	
Judgement of firmness	**Point**	**Hó**	**Kárpia**
Fresh and firm berry by touch	5	4-5	3,2-4
Still fresh and firm berry by touch	4	3-3,9	2,5-3,1
Slightly softened berry	3	2-2,9	2-2,4
Hardly softened berry	2	1-1,9	1,9-1,1
Unacceptable soft berry	1	<1	<1

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

The postharvest respiratory intensity of sweet pepper shows a special pattern of change at normal atmosphere gas conditions increasing up to a maximum in a relatively short time and later decreasing 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. 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.

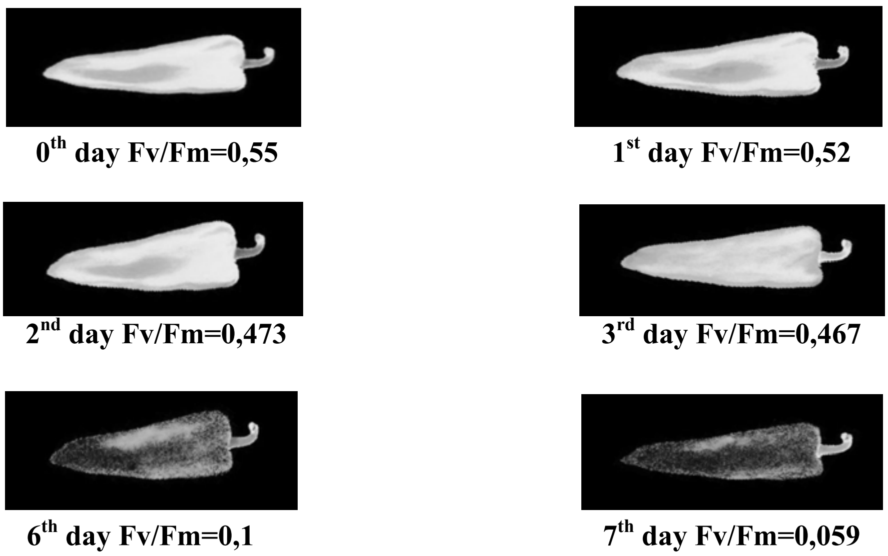
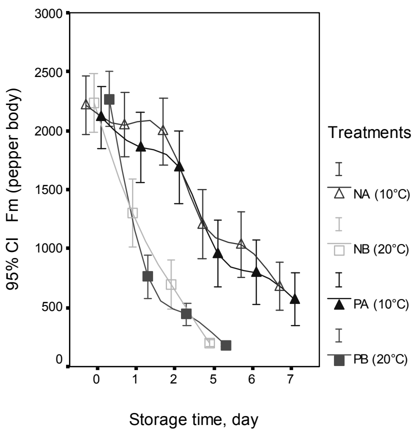
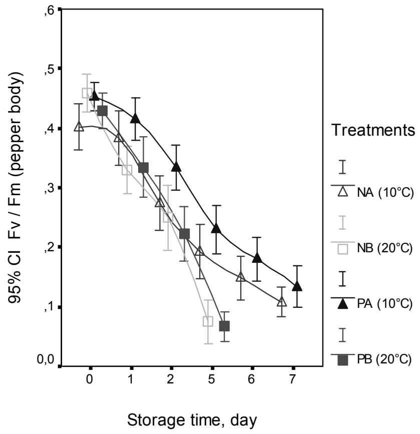


Figure 2
Chlorophyll fluorescence images of the LDPE-packed samples stored at 20 °C (PB). The false-colour fluorescence images show the spatial and the temporal variation of the F_v/F_m. Bright colour indicates high and dark colour low photosynthetically active chlorophyll content.

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. 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).



a)



b)

Figure 3
The change in F_m (a) and F_v/F_m (b) of Kárpia pepper stored at 10 °C, 20 °C (signed with A and B, respectively), with and without LDPE-packaging (P and N, respectively).

Chlorophyll activity and photosynthetically active chlorophyll content decreased with progressive ripening (dark colour) only in the fruit bodies, while the stalks clearly retain a high (bright colour) photosynthetic potential (Fig. 2). All fluorescence parameters (F_0, F_m, F_v and F_v/F_m) showed significant decrease versus storage time. The chlorophyll fluorescence change referred to and characterized well the temperature effect on post-ripening. In case of the Kárpia samples, 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, 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.3).

Controlled atmosphere storage at 7 °C of Hó and Kárpia peppers under different O_2 and CO_2 concentrations and ultra low oxygen (ULO) concentration resulted that 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. Controlled atmosphere storage of Kárpia peppers under different storage gas concentrations was not found to have significant effect to the keeping quality.

Conclusions

The pepper varieties of Hó and HRF were found to be chilling sensitive and the storage temperature threshold is 7 °C. The conditions for postharvest quality maintenance are the storage temperatures not lower than 7-8 °C and the stable RH 90-95 %. The mass loss does not depend on maturity, but on water pressure difference between the product and its environment.
Concerning the stiffness/firmness related change in postharvest quality, the stiffness change can be characterized by the elasticity modulus (E), the impact stiffness coefficient (D) and the acoustic stiffness coefficient (S). The stiffness and the textural change of pepper depends on relative humidity and not on maturity. Serving as a base for a special decision-supporting expert system, the relationship between the objective non-destructive texture coefficients (E, D, S) and the empirically, organoleptically evaluated pepper stiffness was determined.
The postharvest respiratory characteristics of sweet pepper were determined by the measurement of respiratory intensity. The respiratory intensity of sweet pepper shows a special pattern of change at normal atmosphere gas conditions and it depends on maturity stage, physiological state, variety, temperature.
The post-colouration of sweet pepper during postharvest maturation follows the change in maturity, but with inhomogeneous surface colour distribution. Digital image analysis provides objective information about the colouration of the whole pepper surface, related to the change in maturity. An algorithm was developed for the determination of the red to green surface colour ratio for pepper varieties undergo a green to red surface colour change. The maturity stage of peppers can be objectively characterised and the change in surface colour referring to the change in maturity can be quantified.
The chlorophyll fluorescence method was found to be suitable for the determination and characterization of the change in maturity stage and physiological state of Kárpia sweet pepper. 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.

Digital image analysis and chlorophyll-fluorescence method offer great opportunity for their practical application in the postharvest chain after having the automatizated the processes for measurement and analysis.

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