IMPACT OF THE DEGREE OF MATURITY ON APPLE QUALITY DURING THE SHELF LIFE

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Abstract

The main objective of this work was to determine optimum harvest date in apples, which were kept in long term as well as shelf-life storage (supermarket, T=18 °C). The effect of storage conditions and inhibitor of ethylene 1-methylcyclopropene (1-MCP) treatment on ethylene production and quality of apples stored in normal and controlled atmosphere conditions was evaluated during one successive season 2012/2013. Experiments were carried out at the Latvia State Institute of Fruit-Growing. Treated and untreated (control) apples were stored for six months in the cold storage rooms at 2±0.5 °C under normal atmosphere (NA) conditions or controlled atmosphere (CA) with 1.0% O_2, 2.0% CO_2, 97% N_2 and 1.5% O_2, 2.5% CO_2., 96% N_2. Directly after storage and after shelf-life (additionally 14 days at 18 °C) internal ethylene concentration was determined. For estimation of apple quality sensory evaluation and density were chosen. The obtained results give the possibility to conclude that almost all cultivars which are early harvested were suitable for storage in modified atmosphere. The apple storage in modified atmosphere gives the opportunity to extend the apple shelf-life period more than two weeks simultaneously without any qualitative changes.

Keywords: apples, quality, shelf-life, storage.

Introduction

Consumers mainly associate quality of apple with their firmness, juiciness, and sweetness. The softness of apples (mealiness) characterise a fruit on with low quality and suggest that fruits were stored too long (Galmarini et al., 2013). The shelf-life period of apples is determined by number of indicators. It has been reported by Gregersons from University of Illinois USA that apple expiration date mainly depends from chemical composition, especially from content of water and sugar (Gregersons, 2009), another authors suggested that it's depended from thickness of the wax layer and from the cultivars (Soliva-Fortuny et al., 2002). Winter cultivars which contain lower amount of water comparing with summer cultivars, always kept longer. There are a lot of factors which can affect the apples expiration date. Basically significant affect renders the ripeness of apples, for example 'Granny Smith' cultivar which was harvested slightly green and stored in controlled modified atmosphere for about a year, will be kept in shelf-life approximately 6–8 weeks, however the apple will not have a strong taste and aroma. According to Raffo and colleagues the apple storage in controlled modified atmosphere extend the expiration date up to 60 days, on the other hand it affect the sensory qualities of the products (Rafo et al., 2009). This type of storage not only delay the aging process, but also suppress the volatile organic compounds (esters, aldehydes, alcohols and terpenes), which is responsible for the fruit aroma development. Fruit quality on shelves is also dependent from the storage temperature and air relative humidity in the storage chamber. Traditionally the storage camera (refrigerator) can impair the texture of apples, as a result, during the expiration time these fruits can promptly become soft and mealy (Hui 2010). One of the most important indicators during the storage of apples is the placement in the shop. During the apple respiration processes the ethylene production increase, which accelerate the aging of the apple, and if they are stored near by the fruits which are also produce ethylene (pears, peaches, nectarines, plums, tomatoes, avocados, bananas, kiwi, mango and apricot), the ripening process become up to 10 times intensively, as a result maximal expiration date for this product will be 1–2 weeks. One of the possibility how can prolong the expiration date of fruit is 1-MCP treatment with the aim to delay the ethylene production. It gives the opportunity to extend the shelf-life period up to 4–6 weeks. However, there is still a risk that during the storage a receptor of ethylene will recovered and the cells will become susceptible to ethylene molecules (Abadi et al., 2009). Scientist from Spain Valera (2008) has determined the maximal shelf-life period for apples after storage in modified atmosphere. It has been reported that after 61 day storage of apples in a shop at 20 °C temperature, consumer evaluation showed that the quality did not changed significantly, while after 70 days of storage apples became softer. The aim of the work was determine optimal harvest date in apples, which are kept in long term as well as shelf-life storage (supermarket, T=18 °C).

Materials and Methods

The research has been conducted at the Latvia State Institute of Fruit-Growing (LSIFG) with the seven different commercial apple cultivars: 'Auksis', 'Orlik', 'Gita' (autumn), 'Antej', 'Belorusskoje Malinovoje', 'Sinap Orlovskij', 'Zarja Alatau' (winter). Apples were preserved in controlled modified atmosphere T=2±1 °C for six months, and two weeks stored in natural atmosphere (shelf-life) T=18±1 °C. The storage time was choosen accordingly with the report from Гудковский (2012). ULO1 chamber with gas content O_2=1.00%, CO_2=2.00%, and ULO2 chamber with gas content O_2=1.50%, CO_2=2.50% was used for preservation in controlled modified environment, and control samples were stored in cooling chamber at temperature 2±1 °C with relative humidity 85%. Treatment with 1-MCP was performed when fruit were ready for consumption. 1-MCP was obtained from Hangzhou Ruijiang Chemical Co., Ltd. 1-MCP was dissolved in warm water at ratio 1 : 30 in a sealed container. The container with 1-MCP was placed into a hermetically closed fruit processing cabinet; then the plug was opened and the treatment was performed for 24 h at 18±1 °C. The final concentration of 1-MCP in processing cabinet was 0.625 $\mu L \cdot L^{-1}$.

For optimal long term storage the apples with following parameters were chosen (Table 1 and 2).

Table 1

Suitable parameters of different type of storage for determination of optimal harvesting time

Cultivar	Concentration of ethylene, $\mu L\ h^{-1}\ L^{-1}\ kg^{-1}$	Firmness, kg cm^{-2}	The ration of soluble solids / titratable acidity, °Brix / %
‘Auksis’	0.174	9.400	18.177
‘Orlik’	0.181	8.490	13.301
‘Gita’	0.170	6.070	10.989
‘Antej’	0.221–0.252	6.320–6.440	16.879–17.530
‘Belorusskoje Malinovoje’	0.187–0.204	8.640–6.770	11.432–13.573
‘Sinap Orlovskij’	0.177–0.188	8.640–8.810	13.561–15.377
‘Zarja Alatau’	0.187–0.215	6.050–6.920	17.765–19.077

Data were obtained in our previous investigations.

Table 2

Suitable parameters of different type of storage for determination of optimal harvesting time

Cultivar	Iodine starch test (1–10)	Streif’s index	De Jager’s index	FARS index
‘Auksis’	5.0	0.167	5.004	0.103
‘Orlik’	4.0	0.192	5.383	0.160
‘Gita’	5.0	0.116	3.489	0.110
‘Antej’	4.5–5.0	0.109–0.128	3.27–3.758	0.072–0.085
‘Belorusskoje Malinovoje’	5.0	0.133–0.187	3.990–5.598	0.100–0.151
‘Sinap Orlovskij’	4.0–4.8	0.152–0.198	4.524–5.546	0.117–0.162
‘Zarja Alatau’	4.5–6.7	0.073–0.127	2.098–3.724	0.047–0.087

Data were obtained in our previous investigations

Determination of physicochemical parameters

Soluble solids content

The soluble solids content was determined according to LVS EN 12143:2001 standard.

Titratable acidity

The changes in acidity characterize the degree of apples ripeness. Titratable acid content is determined according to AOAC 942.15 standard.

Apple density

The changes in the fruit pulp density describe the degree of ripeness of apple. The density was measured with a digital penetrometer. Procedure and data collection was done according to LVS EN 1131:2001 standard.

Iodine-starch test

Iodine-starch test is based on the reaction of iodine with starch and expressed by specific blue colouring. During comparison, only the coloured field sizes and proportions were evaluated, but not the colouration intensity or colour tone. The standard scale range is 10 points where 1 point – clear blue, apple ripening has not started, 10 points – the starch is broken up and the apple remains untangled (Lopez Camelo, 2004).

The following indices were calculated:

TSS/TA ratio;

Streif’s index (SI) F/(R*S) (Streif, 1996);

De Jager’s index (PFW-1)F * (11 – S) / R (De Jager et al., 1996);

FARS index (F*A)/(R*S).

where: F – firmness, kg cm^{-2},

A – titratable acidity (TA), %,

R – soluble solids content (TSS), ºBrix,

S – starch index (on a scale from 1 to 10).

Determination of ethylene production

Ethylene production rate was determined with the Ethylene analyzer ICA 56 based on quantity of ethylene formed by the fruits during the postharvest storage (Barker, 2002).

For ethylene determination one apple from each treatment was enclosed in about 4 L airtight jar for 24 h at 20 °C, and then ethylene production rates were measured. Ethylene production was given as $\mu L\ h^{-1}\ L^{-1}\ kg^{-1}$ (Oz, Ergun, 2009).

Sensory evaluation

The line scale method, based on the ISO 4121:2003 (Sensory analysis – Guidelines for the use of quantitative response scales) was used for this study. The samples were evaluated for taste, aroma, acidity, sweetness, juiciness, and colour change.

Statistical analysis

Data was processed by SPSS software version 17.0. Data was analysed using descriptive statistics and processed by one-way analysis of variance ANOVA (one way ANOVA), as well as for comparing all apple samples depending from the storage of type two-way analysis of variance ANOVA were used (two-way ANOVA). Microsoft Excel software version 2007 was used to determine significant differences between the samples.

Results and Discussion

The most important aspect in consumer's choice of fruits and further inclusion in diet is sensory evaluation. The high quality apples were chosen to estimate fruit quality both after six months in different types of storage as well as after the shelves storage (shelf-life).

Sensory evaluation

Dramatic changes in apples quality have occurred during the storage in cooling chamber. From the seven of apple cultivars were retained only four of them. Analyzing data from sensory evaluation of apple colour (Figure 1a), which were stored in cooling chamber it was detected that highest assessment was for cultivar 'Sinap Orlovskij', while the lowest for 'Auksis' and 'Zarja Alatau'. Statistical evaluation of colour data showed that between the samples there were no significant differences ($p>0.05$). Similar results were obtained during the evaluation of aroma changes in apple samples. The highest intensity of aroma was recorded for cultivar 'Auksis', which corresponds to 6.87 points. On the other hand the lowest intensity of aroma was observed for cultivar 'Sinap Orlovskij', which corresponds to 4.21 points. Comparing the data statistically it is seen that there were significant differences ($p<0.05$).

Comparing the data obtained after sensory evaluation of taste the intensity had the greatest reduction similarly like previously in 'Sinap Orlovskij', which conform 4.32 points. On the other side the highest intensity of taste was found in 'Zarja Alatau' and this amount corresponds to 7.89 points. Analyzing data obtained after sensory evaluation of apple acidity, experts were concluded that the intensity of acidity of cultivar 'Sinap Orlovskij' was not expressed so well (3.09 points). Comparing the data of the sweetness of apples there were no significant differences between the cultivars. Evaluation of apple juiciness showed that maximal value was recorded for cultivar 'Belorusskoje Malinovoje' (9.46 points), while the minimal value was for cultivar 'Auksis' (4.82 points). Comparing the data of apples after six months of storage, which had been stored in cooling chamber as well as after storage on shelves (shelf-life) it was found that the colour of apples after shelf-life period became more intensive for all cultivars. On the other side analyzing the data of apple sweetness was recorded that it's became more intensive for cultivar 'Belarusskoje Malinovoje', while other attributes became less intensive (Figure 1b).

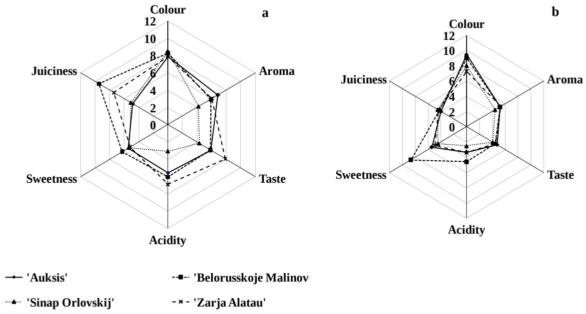

Figure 1. Diagram of apple sensory evaluation of control in cooling chamber: *a* – after six months of storage, *b* – shelf-life period

Obtained results suggest that apple storage in cooling chamber combination with 1-MCP treatment gives the possibility maintain and prolong the fruit expiration date till six months. Analyzing the obtained data after sensory evaluation (Figure 2a), it was found that the attributes like colour and aroma got significantly ($p<0.05$) lower assessments, while taste and juiciness has been more intensive comparing with control samples. The effectiveness of 1-MCP in decreasing the impact of aging on fruit physiology has been shown in a number of studies (Abdi et al., 1998; Golding et al., 1998; Fan, Mattheis 1999; Lurie et al., 2002; Defilippi et al., 2004; Kondo et al., 2005; Mattheis et al., 2005). On the other hand studies from Latvia (Juhnevica et al., 2013; Juhnevica-Radenkova et al., 2013) imply that 1-MCP treatment had a positive effect on apple sensory attributes.

Scientific studies from Michman and colleagues suggest that one of the most important negative aspects of 1-MCP is that, by eliminating sensitivity to ethylene, the production of volatile compounds is also reduced. These compounds contribute significantly to apple flavour and aroma (Michman et al., 2001). Our results coincide with the conclusions before, and unfortunately they are not recovered or partially recovering after two weeks of shelf-life (Figure 2b).

During the storage in ULO type cameras the colour and aroma of the samples (Figure 3a and Figure 4a) were partially developed. Statistically comparing the data it's seen that there were no significant differences between the ULO cameras ($p<0.05$). During the storage in ULO 1 camera it was observed one exception for cultivar 'Gita'. During the storage of this cultivar intensive weight loss was occurred, hence this cultivar had not appropriate quality.

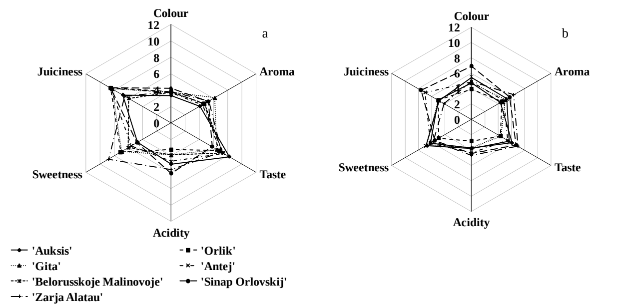

Figure 2. Diagram of apple sensory evaluation of control +1-MCP: *a* – after six months of storage, *b* – shelf-life period

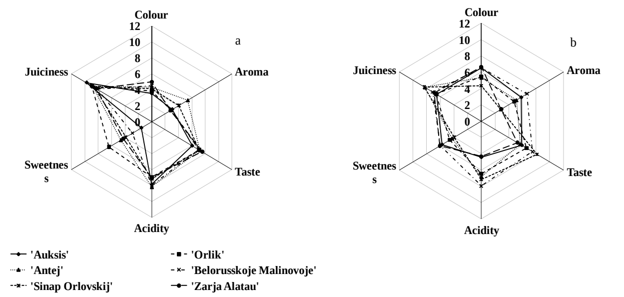

Figure 3. Diagram of apple sensory evaluation of ULO 1 chamber: *a* – after six months of storage, *b* – shelf-life period

The intensive weight loss can be explainable by the fact that this cultivar was harvested too early. Comparing the data of sensory attributes (taste, acidity and juiciness) it is seen that there were no significant differences between the cultivars in ULO cameras (ULO 1 and ULO 2).

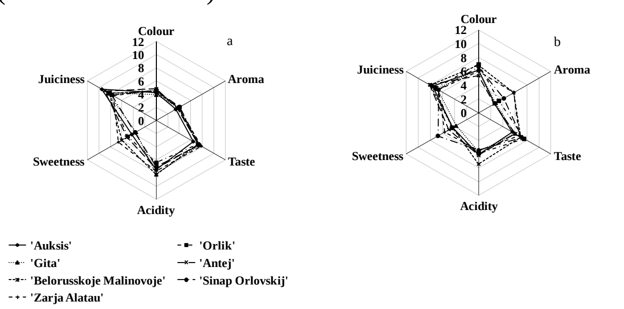

Figure 4. Diagram of apple sensory evaluation of ULO 2 chamber: *a* – after six months of storage, *b* – shelf-life period

Taken into account the evaluation of apple quality, it was recorded that apples, which were stored in ULO type cameras have a distinctive juiciness and fresh taste. Scientists from Poland were gained the similar results (Kruczyńska, Rutkowski, 2006). Mainly all apples which were stored in ULO type cameras can be characterized like green apples. One part of panellists noted, that the tastes of these apples are not so suitable for consumption like other apples, which were stored in cooling chamber in combination with 1-MCP treatment.

The results of this study showed that colour became more intense in all cultivars, while aroma was recovered in one part of cultivars (ULO 1: 'Orlik', 'Belorusskoje Malinovoje') and (ULO 2: 'Belorusskoje Malinovoje' and 'Zarja Alatau') (Figure 3b and Figure 4b). The evaluations of attributes like taste, acidity, sweetness and juiciness almost for all cultivars were much higher than for control samples and control, which was treated with 1-MCP. Obtained results can be explainable by the fact that during the storage in modified atmosphere decreased level of O_2 and increased level of CO_2 has a retarding effect on enzymatic activity and on morphological changes at a cellular level i.e. respiratory intensity, breakdown of membrane phospholipids and decrease of the volume of cytoplasma and mitochondria are all inhibited (Herregods, 1999).

Apple firmness

In connection with reports from Poland scientists (Rutkowski et al., 2008) and scientists from Latvia (Juhnevica et al., 2009) another important indicator of fruit quality is tissue firmness, which play an important role in fruits choosing by consumers.

The softening and cell separation in many fruits is associated with the increased proportion of readily soluble pectins. There are stages of cell wall breakdown during the ripening of apples. In the first stage fruit firmness declines slowly and wall galactans decrease. In the second stage, firmness decreases more rapidly and soluble polyuronides increase (Herregods, 1999). Reduction of the oxygen concentration to O_2 2%, give the possibility significantly delay the second stage of fruit ripening (Knee, 1974). At the moment the standards for estimating the firmness of apple tissue, which characterize the quality of these fruits does not exist in Latvia. Based on the scientist from Poland (Rutkowski) and his unpublished works, apples can be considered like qualitative, when the firmness of the tissue not lower than 4.0 kg cm^{-2}, while the another scientist from America submits that firmness of qualitative apple should be not lower than 4.4 kg cm^{-2} (Kupferman, 1992).

Taken into account the works from Poland scientists as well as after estimating the obtained data it is seen that our obtained results partially similar with Polish standards. Obtained results from ULO 1 type camera (Figure 5) showed that firmness of cultivar 'Auksis' is (4.7 kg cm^{-2}) and 'Sinap Orlovskij' (4.6 kg cm^{-2}).

Comparing the data obtained in ULO 2 type camera practically all cultivars are comply with the Polish standards, except of cultivar 'Orlik' (2.9 kg cm^{-2}). Although after two weeks of apple storage on shelves (shelf-life) comparing with after six months of storage there were no found significant differences ($p>0.05$) between ULO cameras, and these results were no complying with Polish standards.

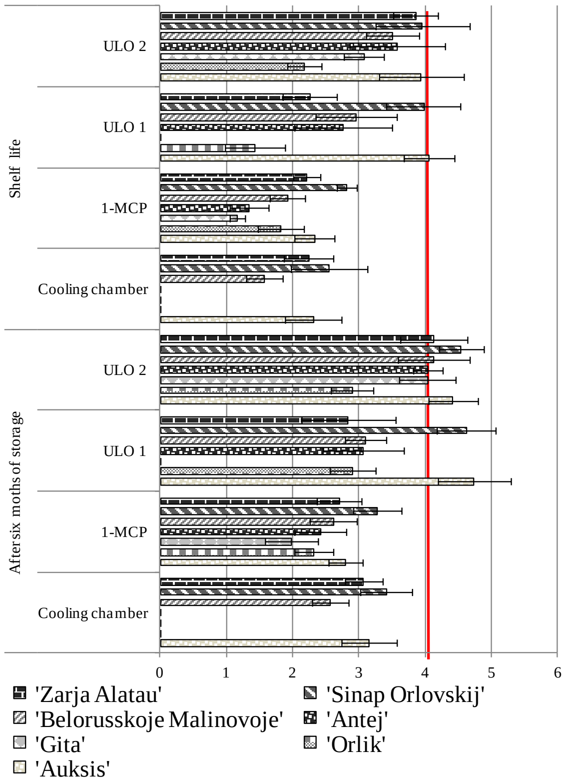

Figure 5. Firmness, kg cm^{-2}, depending on storage conditions

Detected only one exception for cultivar 'Auksis', which was stored in ULO 1 and the firmness corresponds with the standards (4.0 kg cm^{-2}).

Conclusions

Obtained results indicate that fruits, which were stored in modified atmosphere, as well as were treated with 1-MCP have less intensive aroma, flavour and colour. One of the possibilities how recover partially these attributes by storing the fruits for a short time (two weeks) on shelves (shelf-life).

Taken into account the evaluation of apple quality was recorded that apples which were stored in ULO type cameras have a distinctive juiciness and fresh taste.

After six months of apple storage was detected that more appropriate storage for maintaining of apple firmness was ULO 2 type camera. All of these results comply with quality standards.

On the other hand after two weeks of apple storage only one cultivar 'Auksis' (ULO 1 type) showed a positive value of firmness, while the other cultivars are not complying with the quality standards.

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