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AN INFLUENCE OF QUARANTINE CONDITIONS ON ELASTICITY MODULUS IN APPLES STORED IN ULO AND REGULAR STORE

Tomasz Guz

Department of Food Engineering and Machinery, University of Life Sciences in Lublin

Summary. The paper presented an attempt to use thermal quarantine performed on apples cv. Gloster and cv. Ligol stored in ULO (1,5%O_2 + 2,4%CO_2) and regular cold store. The subject of the study was an analysis of influence of the time of storage, conditions of storage, shelf life and thermal quarantine on texture forming of the stored apples. These conditions are the key factors to judge the susceptibility of apples to bruising caused by the transportation and the market handling. The fruits were sampled gradually every 30 days from both chambers and then heated at 35ºC and 40ºC by the period of 96 h. The material was stored after the treatment at 6ºC by 17 days. The quarantine effect was compared to control sample. The quarantine conditions had a significant influence, on elasticity of Gala apples stored in regular store. Quarantine at 35ºC resulted in deterioration of apple flesh elasticity. Apples stored in ULO and subjected to thermal treatment resulted in higher flesh elasticity regardless of the temperature of heating. The storage conditions of Ligol cv. as well as quarantine temperature had no significant influence on fruits elasticity even when their stage of maturity was advanced (sampled from regular store).

Key words: apples, storage, thermal quarantine, elasticity.

INTRODUCTION

Apples are the fruit of great economic importance. Their world production is approx. 64 million tons, while acreage is approx. 4,800 million ha. [FAOSTAT 2006]. They are predominant in Poland, where their production is 2-2,5 million tons, but only 0,5 million tons of that figure are valuable desert varieties [Klimek 2001].

Apples are the fruit of great popularity among people in Poland [Babicz-Zielińska 1999], and all around the world [Jaeger i in. 1998, Harker 2002, Kühn i in 2001]. The harvest, the storage and transportation techniques are so sophisticated today that long-time storage is possible, maintaining high quality of the product. The consumption of fruit as a fresh and biologically active nutrition prevails during the season due to inadequate volume of modern ULO and CA storage chambers, while regular store and storage cellars are most common. The maintaining of optimum storage conditions is impossible without atmosphere and temperature control. The total number of CA and ULO chambers is insufficient for assuming the quality for all the stored fruit. The estimated value of fruits in CA or ULO chambers was 10% of the stored apples. According to the data collected by the author of this paper approximately 34% of apples were stored in CA and 5,5% in ULO chambers (Lublin region, 2007/08).

The most important feature of a product perceived by the consumer which is a key factor to acceptance or dislike is its appearance. This aspect according to apples is dependent on orchard conditions, climate influence [Nòe 1996, Reay 1999], storage and transportation conditions [Şumnu 1994, Şumnu 1995].

The other factors that influence the acceptance of the product is presentation and displaying of the product [Jaeger 2001] as well as consumer's preferences [Babicz-Zielińska 1999]. The judgment of fruit quality includes the presence of bruises that may occur during transportation and handling the product. The bruise susceptibility was studied by Lang [1994] by the arrangement of dynamic collisions where mass and energy for bruise development was estimated. This was done due to calculation of speed limit of fruit during handling.

The issue of utmost importance is to choose only those fruits whose harvest maturity and appearance is appropriate for long-time storage [Tomala 1995b]. Stored apples are susceptible for different diseases and storage disorders. There are three groups of storage disorders [Tomala 1995a]: fungi diseases, physiological diseases and fruit injuries: superficial scald and injuries caused by elevated carbon dioxide level.

Bauchot [1999] discovered that superficial scald may be developed by pure nitrogen ventilation at the final stage of storage. Apples harvested too early are susceptible to superficial scald [Tomala 1995b]. This disorder may occur after a long time of storage. Low O_2 concentration diminishes the risk of scald appearance [Lau et al.. 1998]. More effective was to spray the fruits surface by 1-MCP in all storage conditions [Zanella 2003]. The storage process of fruits is a complex phenomena and its final result is connected with several factors [Raybaudi et al. 2007]. The first group of factors is cultivar specifications, orchard conditions and climate, maturity stage at harvest etc [Konopacka, Plocharski, 2004].

The other factors are: time of storage, chamber temperature, humidity, CO_2 and O_2 levels and ethylene concentration [Saltveit 2003]. To preserve good quality of apples the conditions of shelf life plays a significant role. The first is humidity. Tomala et al. [2000] discovered that apples stored at 20ºC at three levels of humidity 30, 65 and 95% have a different quality characteristics. Those stored at low levels of air humidity showed the symptoms of searing while the others were suspected to manifest slight mark of mealiness.

Textural changes were studied by Johnston [2002] by the judgment of firmness and softening of Granny Smith and Pacific Rose after storage at 0,5ºC and 20ºC as a shelf-life. These are the model conditions for today's commodity market.

Thermal quarantine treatment of fresh fruits and vegetables was applied in the 30-ties of 20th century [Hallman 2000, Neven 2000, Lurie 1998] due to disinfestations by mortality of fungi, mildew and pests in fresh agricultural materials. Post-harvest heating is applied for disinfection of an increasingly large group of materials, including flowers, fruits and vegetables [Lurie 1998]. Among researches involved with such problems there is agreement that thermal treatment conducted at temperatures above 35˚C is conducive to retarded ripening of various fruit species [Lurie 1990]. Usually, thermal treatment is performed within temperature range of 35-46˚C, using air, humidified air or water as heat sources. The duration of treatment with warm air is 12-96 h.

One of the most important effects of thermal quarantine is high mortality rate of pathogens (fungi, mildew, larvae, fruit flies) subjected to the quarantine treatment [Conway i in. 2004]. Insects, as heterothermic organisms, are particularly sensitive to heat [Hansen i in., 2006]. .Studies on the metabolism of those organisms under various thermal conditions indicate a certain adaptation on their part to changing thermal conditions [Neven 2000].

The advantages resulting from the application of thermal quarantine are not limited to insect destruction, limitation of fruit softening or stoppage of ethylene production. Such treatment may help improve the firmness of fruits in storage, which is of enormous importance for transport and trade [Lurie 1995, Lurie 1996].

Application of thermal treatment of fruit material after the harvest is difficult from the technical point of view. Heating of large amounts of material within a short period of time (conditions during harvest) and at a suitable rate is not an easy task, considering that the use of warm air will extend the duration of the operation due to its low thermal capacity.

Of interest from the technological point of view is quarantine application to smaller batches of material already in storage and assessment of the effects of the treatment with relation to its physical properties before it reaches the market. Therefore, what is important from the practical point of view is extensive research that would take into account such factors as variable stage of ripeness of the material and industrial conditions of storage.

MATERIALS AND METHODS

The material used in the study was stored in the ULO chambers in the orchard where the stands of apple trees (Goster and Ligol cultivars) were located nearby from the place of their subsequent storage. The harvest of the apples was carried out on the1st and 2nd October, 2007. Apples for the tests were taken from the first batch that was meant for long-term storage. The apples were cooled gradually by placing them in refrigerated chambers immediately after harvest. A part of the fruits (approx. 50%) were stored in a conventional refrigerated storage shed, while the other fruits were stored under conditions of controlled atmosphere (ULO). After the chamber was closed and sealed, it was filled with nitrogen from a generator so as to reduce the level of oxygen to 5-6%. ULO conditions, i.e. O_2 concentration below 2%, got stabilised through the respiration of the fruits.

Fig. 1. The ULO chamber loaded with fruits before sealing

The level of O_2 was 1.4-1.5% at the initial period of storage and 1.6-1.7% at the final stage of storage. The gradual increase in concentration of O_2 was necessary to preserve a certain reserve of oxygen to prevent an occurrence of anaerobic processes. Anaerobic respiration begins for most apple cultivars at concentrations below 1% O_2 for fresh apples. The level of anaerobic respiration threshold (compensation point) is not constant and increases with extension in the time of storage. Concentration of CO_2 was stabilised at the level of 2.2 – 2.4%. Storage temperature in both chambers was 1.5-2ºC. In the ULO chamber the composition of the atmosphere was controlled.

Readouts of atmosphere parameters were taken automatically every 30 minutes. In the ULO chamber measurement equipment was employed for control of O_2 and CO_2 levels, operating in a coupled system. Control of the condition of the atmosphere consisted in taking samples of gas from the ULO chamber to a chamber containing the metering equipment and located on the outside of the ULO chamber, and performing the measurements. The measurements were taken with an accuracy of 0.01% by volume of the shares of particular components of the atmosphere.

The experiment was divided into post-harvest testing of the material and 5 in-storage stages. It was assumed that the duration of storage of the fruits in both the conventional storage shed and in the ULO chamber would be 150 days. The first stage of the experiment was conducted on fresh apples, the remaining stages – on apples taken from both storage chambers. Fruits from conventional storage were samples at 30-day intervals, counting from the date of their placement in storage. Material from the ULO chamber was sampled also every 30 days, counting from the date of stabilisation of ULO conditions in the chamber.

The fruits samples from the storage chambers were divided into 3 parts:

- apples for estimation of textural parameters after their removal from storage (variant A)
- material for storage at 6ºC after thermal quarantine in 35ºC (variant B35)
- material for storage at 6ºC after thermal quarantine in 40ºC (variant B40)

After removal from the storage chambers the fruits were placed in chambers previously heated to 35ºC and 40ºC. The fruits were stored for 17 days in 6ºC after thermal quarantine. Prior to the measurements, apples from the three groups were subjected to thermal stabilisation for 24 hours at 20ºC.

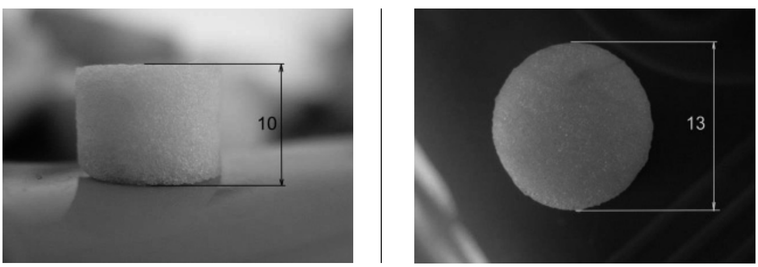

Fig. 2. Cylindrical core samples of apple flesh

From the central part of the apple a slice was cut, about 15 mm thick, so that the planes of cutting were perpendicular to the axis of the fruit. Next, using a cylindrical knife with a diameter of ϕ=13mm, cylindrical core samples with a height of h=10 mm were taken (Fig. 2).

Fig. 3. Compression test of core samples

The diameter of the core samples was determined on the basis of preliminary tests consisting in computer image analysis of slices cut from apples of each cultivar. The aim of the image analysis was determination of distribution, within the fruit structure, of seed pockets, bundles of vessels, and calculation of their distances from the fruit skin.

The height of the core samples was determined on the basis of literature data [Paoletti 1993, Alvarez et al. 2002] and on our own measurements of geometric features of experimental material conducted due to ensuring stability of the samples during compression tests.

Apple flesh core samples were subjected to compression using an Instron 4302 apparatus with Instron series IX software. Compression tests were conducted always at a constant rate of 50 mm/min. The coefficient of sample deformation was 50%

During the compression the following parameters were recorded:

- force required to destroy the sample,
- section inclination within the elastic range.

RESULTS AND DISCUSSION

The effect of thermal quarantine was judged in relation to textural changes after ripening in cold storage. The effect of quarantine was analysed in relationship to the studied apple cultivar. Time of storage and storage conditions chain were recorded from the harvest date to compression test. The data obtained from the experiment were analysed by the use of Statistica 6.0 software. Results were presented in Figs. 4 to 7.

Fig. 4. Elasticity changes of Gloster fruits after regular store

Storage and thermal quarantine of Gloster cultivar caused considerable changes in the flesh elasticity. Heating of those fruits at 35°C resulted in significant elasticity loss after removal from the regular store. This process commenced rapidly after 60 days of storage (Fig. 4.).

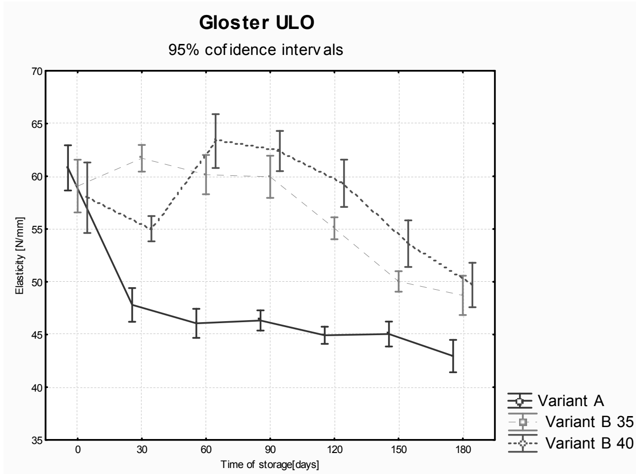

Fig. 5. Elasticity changes of Gloster fruits after ULO storage

The fruits of Gloster cultivar stored at ULO conditions exposed to different thermal conditions resulted in slow ripening and softening of the flesh. Quarantine performed at 35ºC and 40ºC resulted in significantly higher values of flesh elasticity compared to control group of fruits (without heating). Quarantine at 35ºC is regarded as the lowest acceptable temperature applied in the process. The Gloster cultivar is especially susceptible to mildew growth in the pocket seed. Softening of apple flesh occurred in the fruits heated at 35ºC after 60 days of storage at regular conditions. Heating the more ripened fruits reduced the flesh elasticity. Thus the heating initialized the process of ethylene production resulting in flesh decomposition.

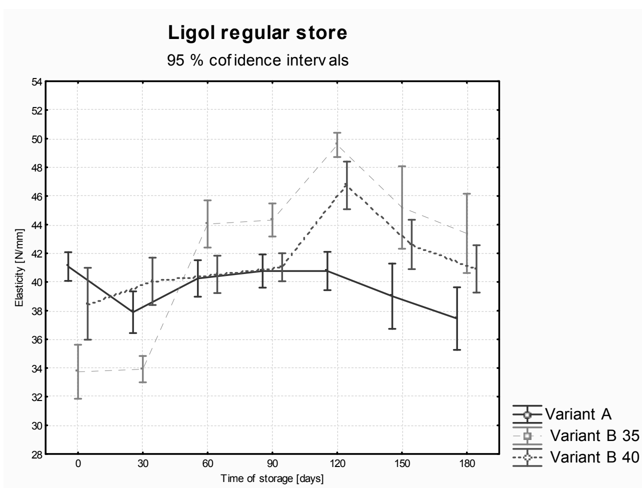

Fig. 6. Elasticity changes of Ligol fruits after regular store

The fruits of Ligol cultivar have a similar response to heating at 35ºC as at 40ºC. The diagram of elasticity changes resembles those received after storage in the regular store. Elasticity changes are irrelevant taking into account temperature as a variety factor. It was noticed after regular store and ULO. After 120 days of storage the elasticity modulus is at maximum both in ULO and regular store diagrams (6 and 7).

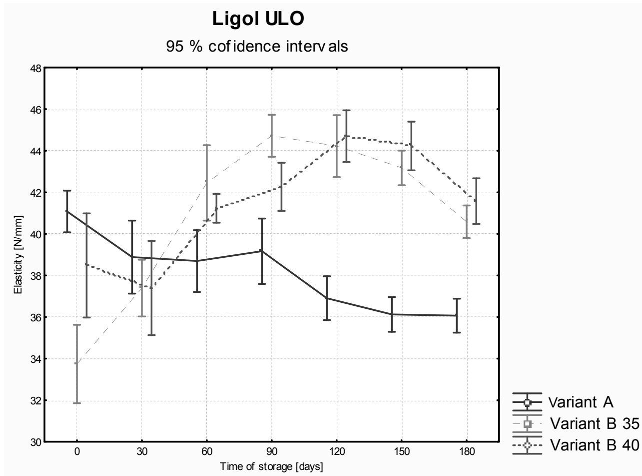

Fig. 4. Elasticity changes of Ligol fruits after ULO storage

Thermal quarantine has a significant influence on the retention of higher elasticity modulus in the apple flesh. The values of this parameter are slightly higher after 35ºC quarantine. The temperature of the process had no significant influence on elasticity changes during storage period (Fig.7). The parameters of apple flesh in the fruits of Ligol cultivar is not influenced by the storage conditions.

CONCLUSIONS

Contemporary storage techniques controlled by precise and modern control equipment, as well as different and conditioned shelf life are sophisticated and non-chemical methods of protection of the commodity from pests. These are useful tools of forming its texture parameters for today's needs of the market. However, it ought to be born in mind that different species and cultivars of the commodity subjected to different treatment have specific responses to heat stress and storage conditions. The apples of Gloster cultivar are very sensible to storage conditions as well as heat treatment conditions. Heating these fruits, stored at regular store at 35ºC resulted in the lowest values of elasticity module. In this case the temperature of heating played a significant role in texture forming of these fruits.

There were no significant differences of storage conditions (ULO or regular store) on texture changes of Ligol apples. Storage conditions as well as heat treatment had no significant influence on the final result of thermal quarantine performed both in 35ºC and 40ºC.

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WARUNKI KWARANTANNY TERMICZNEJ A ELASTYCZNOŚĆ MIĄŻSZU JABŁEK PODCZAS ICH SKŁADOWANIA W KOMORZE ULO ORAZ CHŁODNI

Streszczenie. W prezentowanej pracy wykonano próbę zastosowania zabiegu termicznego (kwarantanny) prowadzonego dla jabłek odmiany Gloster oraz Ligol przechowywanych w chłodni oraz w komorze ULO (1,5%O_2 + 2,4%CO_2). Przedmiotem analiz był wpływ takich czynników jak czas składowania, zmiana warunków przechowywania oraz kwarantanny termicznej na kształtowanie właściwości sprężystych miąższu jabłek, które są ważnym parametrem pozwalającym ocenić podatność na uszkodzenia w owocach podczas składowania oraz obrotu towarowego. Owoce podczas składowania pobierano sukcesywnie z obu komór, (co 30 dni) a następnie ogrzewano przez 96h w temperaturze 35ºC, oraz 40ºC. Surowiec składowano po tym zabiegu przez 17 dni w temp. 6ºC. Efekt kwarantanny porównywano z próbą kontrolną. Warunki kwarantanny wpływały istotnie na cechy sprężyste miąższu jabłek Gloster z chłodni. Niska temperatura procesu (35ºC) skutkowała pogorszeniem jego cech sprężystych. Kwarantanna przeprowadzona w tych warunkach (35ºC oraz 40ºC) powodowała utrzymanie wyższej sprężystości oraz spoistości próbek miąższu owoców świeżych oraz przechowywanych komorze ULO. Warunki przechowywania jak i kwarantanny nie zmieniało istotnie sprężystości owoców Ligol znajdującego się w stanie bardziej zaawansowanej dojrzałości (pobieranego z chłodni zwykłej). Owoce odmiany Ligol z komory ULO zachowywały wyższą sprężystość miąższu niezależnie od warunków prowadzenia kwarantanny.

Słowa kluczowe: jabłka, przechowywanie, kwarantanna termiczna, elastyczność.