The Annals of the University *Dunarea de Jos* of Galati
Fascicle VI – Food Technology, 34(1)

ORIGINAL ARTICLE

PHYSICO-CHEMICAL CHARACTERISTICS OF APPLES STORED IN CHILLING AND CONTROLLED ATMOSPHERE CONDITIONS*

MIRELA CALU, CAMELIA BONCIU, IOAN TOFAN

Bioengineering Department, "Dunarea de Jos" University,
111 Domneasca Street, 800201, Galati, Romania
mirelacalu@yahoo.com, cbonciu@ugal.ro

Received 10 July 2009
Revised 14 September 2009

Freshness represents one of the main characteristics of consumer choice of fruits and vegetables. Fruit quality characteristics such as color, firmness and storage potential have long been known to be related to the concentrations of certain fruit glucids (glucose) and vitamin C.
In this article, three types of apples stored in chilling industrial conditions have been characterized alongside other four types stored in controlled atmosphere conditions, assessing for 7 months, some physico-chemical parameters (extract content, pH, and firmness) and glucose and vitamin C content.

Keywords: refrigeration, controlled atmosphere, apple, firmness, glucose, vitamin C.

1. Introduction

Consumption of fresh fruits and fruit juices has substantially risen over the last years due to the increasing demand of low calories foods and fibers. (Raybaudi-Massilia *et al.* 2009) Moreover, it is scientific evidence that fresh fruit consumption helps prevent many degenerative diseases as cardiovascular problems and some cancers. (Rico *et al*., 2007)

Quality losses in fruits may occur as a consequence of microbiological, enzymatic, chemical or physical changes due to the natural physiological processes which are not stopped in chilling conditions. Fruit quality characteristics such as color, firmness and storage potential have long been known to be related to the concentrations of certain fruit minerals. Fruitlet analysis allows commercial fruit growing, packing and marketing operations to take advantage of these known relationships and increase profit margins by supplying information that can be used to increase fruit quality and reduce storage losses and market claims. (Wolk, 1997)

The apples must be harvested at the right time of their ripening cycle and stored in different conditions until they are marketed. During storage, fruits can lose some of their characteristics. Temperature and air humidity are major parameters affecting the apples quality. Apples are usually kept in cold storage rooms. Regular cold storage is less expensive than controlled atmosphere storage. The apple storage by chilling is a technique for fruit quality preservation using chilling temperatures (0.5-4°C). The softening of fruits during storage occurs because of the modification of their cell walls. Two major factors play a role in apple softening: water loss and enzymes causing cell wall breakdown. (Harsan, 2006, Johnstone, 2008). Refrigeration warehouses are widely used for fruit storage because of their less expensive costs and because this method requires a minimum of labor and handling. In the controlled atmosphere, storage temperatures are kept constant according to the apple variety, fruits chemical composition and fruit ripening level and avoiding chilling injury at the same time. Long time cooling may lead to losses in fruits quality caused by differential or inexistent activity of some enzymes. (Harsan, 2006, Berceanu, 2003) Refrigeration warehouses with controlled atmosphere, although need additional costs, are widely used for fruit storage because of the longer period of fruit storage in these storehouses. Fruit losses are lower and fruits have better quality as it will be further observed. (Jamba, 2002)

---

* Paper presented at the International Symposium *Euro - aliment 2009*, 9th – 10th of October 2009, Galati – ROMANIA

In this article, the physico-chemical parameters of 7 apple varieties, stored in chilling and controlled atmosphere conditions during winter were studied.

2. Materials and methods

Four varieties of apples harvested in Reghin territory were used for the experiment: Jonathan, Starkrimson, Gala and Golden and three apple varieties harvested in Insuratei territory: Fuji, Pinova and Golden. Reghin apples were stored in four different cells of the controlled atmosphere storehouse located in Reghin and the Insuratei apples were stored in chilled storehouses located in Insuratei. The temperature and air humidity in the storage room were continuously being recorded during storage and were specific for each apple variety. The conditions in controlled atmosphere storage houses were: for Jonathan apples - 2-3.5°C, 3% CO_2, 3.5% O_2, for Starkrimson - 1-2.5°, 3.5% CO_2, 3.5% O_2, for Gala apples - 1-2.5°C, 3.5% CO_2, 3.5% O_2, and for Golden Delicious from Reghin - 0.5-2°C, 2.5% CO_2, 2.5% O_2,. Air humidity in the storage room was continuously recorded and was maintained between 94.5 and 97%. The apples harvested from Insuratei were kept in chilled storage rooms with temperature 0.5-4°C. The apples samples were analyzed at monthly intervals for their quality characteristics. Reghin Apples (Jonathan, Starkrimson, Gala and Golden) were stored for 8 months, and the apples from Insuratei were stored in chilled conditions for 7 months.

The apples were analyzed for the following parameters: pH using a pH-meter HI 99181, extract content using a hand refractometer Mettler Toledo and texture using a digital firmness tester Penefel DFT 14.

The glucids content of the apples was determined using HPLC method. Analysis of glucose, fructose and sucrose using the liquid chromatography (LC) Agilent 1200 Series equipped with refractive index detector (RID). Extraction: the carbohydrates were extracted from 50 g fresh cut samples and boiled in 250 ml distilled water; the solution was filtered by 0.22 µm filter before HPLC analysis. Chromatography parameters were: column 250 x 4.6 mm Zorbax NH_2, 5 µm (Part No. 880952-708), mobile phase acetonitril 80%, flow rate 1.5 ml/min, injection volume 10 µl. Detector: Refractive Index Detector (RID). Fructose eluted between 7,5-7,8 min, glucose eluted between 8.00-8.3 min and sucrose eluted between 13.3-13.5 min.

The vitamin content was analyzed using the classical method with 2, 6-dichlor phenol indophenol and HPLC method. Analysis of vitamin C (ascorbic acid) in food using the liquid chromatography (LC) Agilent 1200 Series equipped with diode array detector (DAD). Extraction: 5 g fresh sample homogenized by grinding in a mojar and pestle with a little clean sand; the ascorbic acid was extracted with 50 ml 5% oxalic acid and the homogenate may be filtered by passing it through Miracloth. Chromatography parameters: column 50 x 4.6 mm Zorbax Eclipse XDB-C18, 1.8 mm (Part No. 927975-902) – Rapid Resolution HT, 600 bar, mobile phase water, pH 2.2 with H_2SO_4, flow rate 0.4 ml/min, injection volume 5 µl, detector parameters: DAD 254 nm. Ascorbic acid eluted between 1.77-2.12 min.

The results were analyzed using statistical control methods and the results presented represent the average media.

3. Results and discussion

The extract content of the samples is lower when the storage period is higher, as it can be observed in Figure 2. This is due to the consumption of the extract for fruit metabolism during storage. (Jamba *et al*., 2002).

The firmness of the apples was analysed using the penetrometer. It can be easily observed that apples stored in controlled atmosphere conditions have an average firmness higher than the apples stored in chilled storehouses (Figure 3)

The glucids content of the apples was also studied after the storage period. The glucose, fructose and sucrose content of the apples are presented in Figures 4, 5 and 6. During storage, the apples use glucids and organic acids as respiratory substrate. (Jamba, 2002)

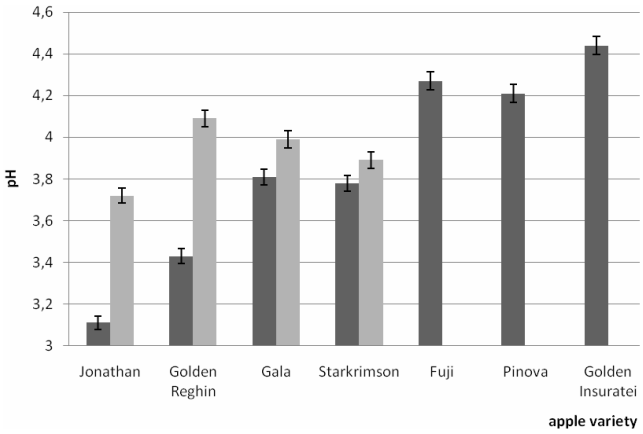

Figure 1. The pH variations after 7 (dark bars) and 8 (grey bars) months of storage of the tested apples. The Jonathan, Golden Delicious Reghin, Gala and Starkrimson apples were stored in controlled atmosphere conditions for 8 months and Fuji, Pinove and Golden Delicious Insuratei were stored in chilling conditions for 7 months

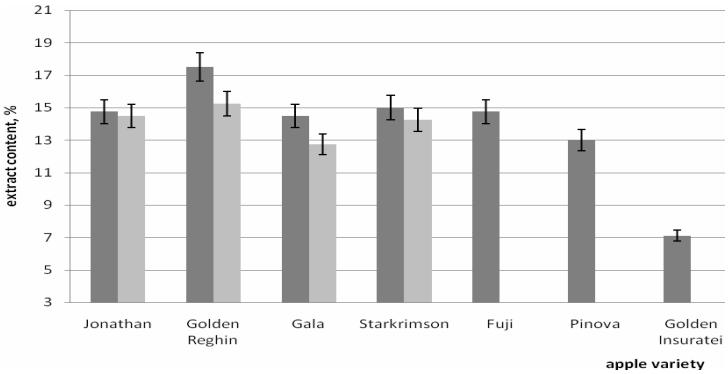

Figure 2. The extract content after 7 (dark bars) and 8 (grey bars) months of storage of the apples analyzed. The Jonathan, Golden Delicious Reghin, Gala and Starkrimson apples were stored in controlled atmosphere conditions for 8 months and Fuji, Pinove and Golden Delicious Insuratei were stored in chilling conditions for 7 months

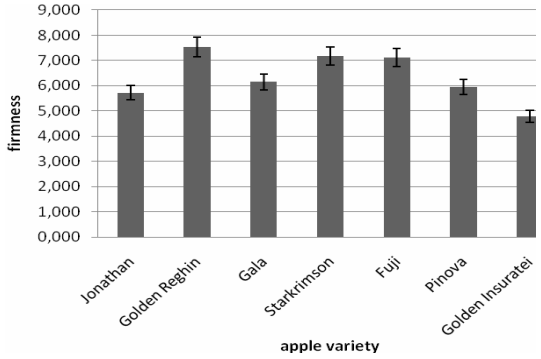

Figure 3. The apples firmness after 7 and 8 months of storage respectively. The Jonathan, Golden Delicious Reghin, Gala and Starkrimson apples were stored in controlled atmosphere conditions for 8 months and Fuji, Pinove and Golden Delicious Insuratei were stored in chilling conditions for 7 months

As it can be observed in Figure 4, the glucose content is higher for the apples stored in chilling conditions than for those stored in controlled atmosphere conditions. This may be due to the lower content of the Reghin apples in glucose.

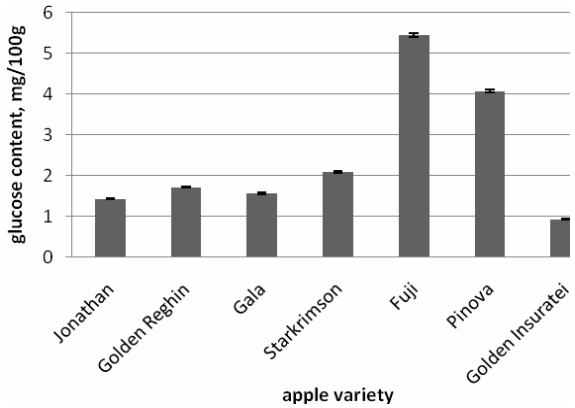

Figure 4. The glucose content of the apples after 7 months of storage in chilling conditions (Fuji, Pinova, Golden Delicious Insuratei) and controlled atmosphere conditions respectively (Ionathan, Golden Delicious Reghin, Gala, Starkrimson)

The fructose content of the apples is higher when the fruits are stored in controlled atmosphere conditions. This may be due to the lower respiration rate of the fruits kept in controlled atmosphere conditions. It is well known as CA (controlled atmosphere) in the industrial storage involves careful control of temperature, oxygen, carbon dioxide and relative humidity. Exact conditions in the storage room are set according to species, varieties, the fruit chemical composition and the ripening level (Harsan, 2006).

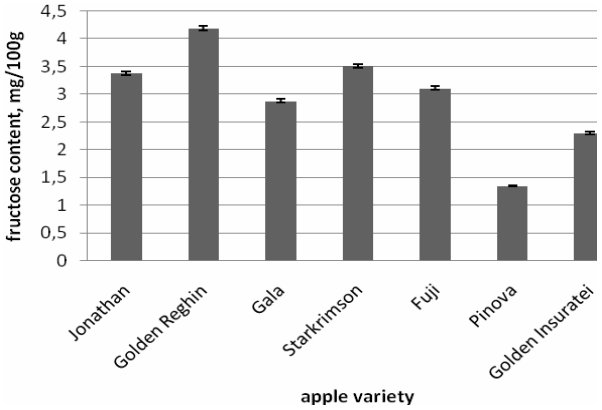

Figure 5. The fructose content of apples stored for 7 months in chilling conditions (Fuji, Pinova, Golden DeliciousInsuratei) and controlled atmosphere conditions respectively (Ionathan, Golden Delicious Reghin, Gala, Starkrimson)

The vitamin C content measured by HPLC method was not detected because of the low quantities of this vitamin in the apples stored for 7 months and 8 months respectively. The vitamin C was then determined using the classic method with 2, 6 dichlor phenol indophenol and the results are shown in Figure 7.

The vitamin C content is lower after 8 months of storage than after 7 months of storage for Reghin apples. During fruit storage the vitamin C content is decreasing, but the losses are lower when the

storage temperature is lower. During storage in controlled atmosphere conditions the vitamin C content losses are of a rate of 10-20%. (Jamba, 2002)

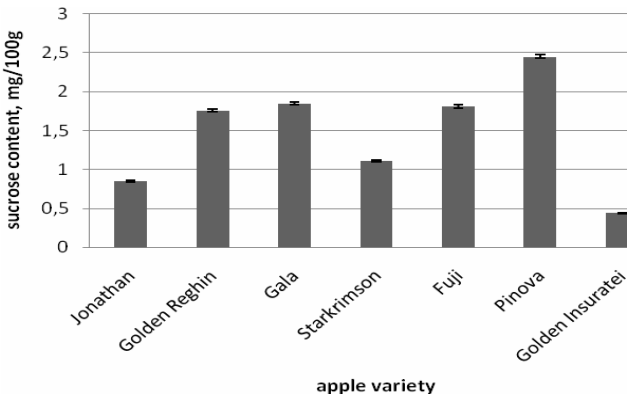

Figure 6. The sucrose content of the apples after 7 months of storage in chilling conditions (Fuji, Pinova, Golden Delicious Insuratei) and controlled atmosphere conditions respectively (Ionathan, Golden Delicious Reghin, Gala, Starkrimson)

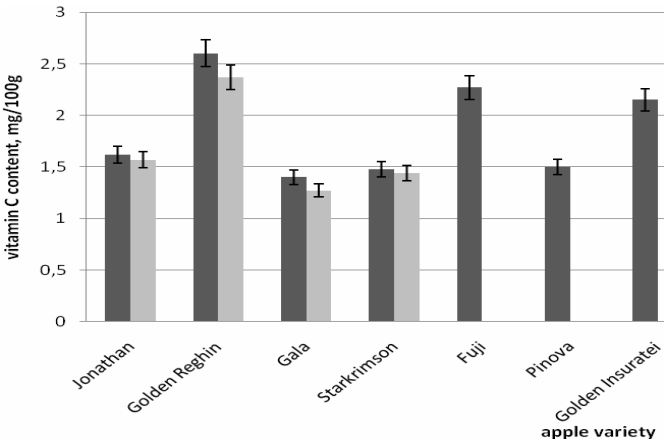

Figure 7. The vitamin C content of the apples after 7 (dark bars) and 8 (grey bars) months of storage respectively, in chilling conditions (Fuji, Pinova, Golden Delicious Insuratei) and controlled atmosphere conditions respectively (Ionathan, Golden Delicious Reghin, Gala, Starkrimson)

As other researchers showed, the vitamin C content in apples is not detectable after 3 months of cold storage. In our case, the vitamin C content is very low, but could be determined using the classical method.

4. Conclusions

Some physico-chemical indices of apples after 7 and 8 months of storage in chilling and controlled atmosphere conditions, respectively, were analyzed. During fruit storage important quality losses occur, no matter what storage method was used. Storage in controlled atmosphere conditions preserved better quality of the analyzed apples than in chilling conditions and for a longer period of time. The shelf life of apples from Insuratei, stored in chilled conditions was 7 months, while for the Reghin apples, stored in controlled atmosphere conditions was 8 months.

Fruit storage during winter is an important problem for cultivars all over the world. Freshness represents one of the main attributes of consumer choice of fruits. Fruit storage in controlled

atmosphere storerooms is one of the most known storage solutions because of the losses decreasing during storage mantaining a good quality of fruits and shelf life prolonging.

Acknowledgement

The authors are grateful to Institute of Food Bioresources and Prof. Burzo Ioan from USAMV Bucuresti for the support offered for this study.

References

Berceanu, D., Chira, A. 2003. *Tehnologia produselor horticole*, ed. Economica, Bucuresti

Harsan, E., Sestras, R., Somsai, P.A., Barbos, A., and Sestras, A. 2006. Research regarding the principal chemical component loss in the apple fruit during storage, *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, **34**, 106-114.

Jamba, A., Carabulea, B., 2002. *Tehnologia pastrarii si industrializarii produselor horticole*, ed. Cartea Moldovei, Chisinau.

Johnstone, J.W., Hewett, E.W., Hertog, M.L. 2002. Post harvest softening of apple fruit, *Journal of Crop and Horticultural Science*, **30**, 135-140.

Rasanu, N., Magearu, V., Matei, N., Soceanu, A. 2005. Determination of vitamin C in different stages of fruits growing, *Analele Universitatii din Bucuresti – Chimie*, 14(1), 167-172.

Raybaudi-Massilia, R.M., Mosqueda-Melgar, J., Soliva-Fortuny, R. and Martin-Belloso, O. 2009. Control of pathogenic and spoilage microorganisms in fresh-cut fruits and fruit juices by traditional and alternative natural antimicrobials, *Comprehensive reviews in food science and fruit safety*, **8**, 157-180(24).

Rico, D., Martin-Diana, A.B., Barat, J.M., Barry-Ryan, C. 2007. Extending and measuring the quality of fresh cut fruit and vegetables, *Trends in food science and technology*, **18**(7), 373-386.

Wolk, W. 1997. Practical application of fruitlet mineral analysis, 13th Annual Postharvest Conference

***, Natural food guide-Fruit vitamin C content of apple cultivars, http://www.naturalhub.com/natural_food_guide_fruit_vitamin_c_apple.htm