THE INFLUENCE OF COLD CONVENTIONAL STORAGE ON FRUITS QUALITY

Oana – Viorela NISTOR[1], Mihai ŢÂMPĂU[1], Elisabeta BOTEZ[1]

[1]Bioingineering Department, Food Science and Engineering Faculty, „Dunarea de Jos" University, 111 Domneasca Street, 800201, Galati, Phone/Fax +40 236 460165, Oana.Nistor@ugal.ro

Abstract: *To determine the most suitable method of cold fruits preservation, we used three types of fruits: pome fruits (apples, pears and quinces), citrus (oranges) and exotic fruits (kiwi and bananas). The fruits were stored, using a household refrigerator, operating at refrigeration temperature (5˚C) and freezing temperature (-10˚C). The storage was made in two variants: bulk and packed fruits (using LDPE bags) for a total period of 14 days. Temperature measurements were made with a two day frequency, inside the storage space and in the fruits' core. To determine the water losses during evaporation, the fruits were weighted, before and after the storage.*
During the refrigeration of the bulk fruits, the quince, the orange and the banana registered a constant evolution, while the behaviour of the same packed fruits was irregular.
The evolution of bulk fruits represented by quince, orange and banana, during freezing period, was regular while for the packed ones such as banana, apple and orange we registered the best results.
The results lead to the conclusion that the refrigeration storage of the bulk pome fruits had a lower quantity of moisture losses (2.5-4.1%) comparing to the exotic fruits (6.5-21.3%). In packed fruits case the lowest quantities of moisture losses were registered in the pome fruits (0.6-1.1 %).
To draw a final conclusion, orange and apple presents the best evolution during the conventional cold preservation, while the behaviour of banana and kiwi is not proper for this kind of storage.

Key words: *fruits preservation, refrigeration, freezing, pome fruits, bulk, packed, LDPE bags*

1. Introduction

Deterioration of fruits and vegetables during storage depends largely on temperature. One way to slow down this change and so increase the length of time fruits and vegetables can be stored, is by lowering the temperature to an appropriate level. It must be remembered that if the temperature is too low the produce will be damaged and also that as soon as the produce leaves the cold store, deterioration starts again and often at a faster rate [1].

All fruits and vegetables have a "critical temperature" below which undesirable and irreversible reactions or "chill damage"' takes place. The storage temperature always has to be above this critical temperature. One has to be careful that even though the thermostat is set at a temperature above the critical temperature, the thermostatic oscillation in temperature does not result in storage temperature falling below the critical temperature. Even 0.5°C below the critical temperature can result in chill damage. Table 1 gives the critical temperatures for various fruits and vegetables. [1]

Table 1.

The critical temperatures for various fruits ([2])

Fruit type	Temperature, °C	Relative humidity, %	Maximum storage time recommended
Apple	0-4	90-95	2-6 month
Orange	0-4	85-90	3-4 month
Pear	0	90-95	2-5 month

The biological factors involved in postharvest deterioration of fruits are: respiration, ethylene production, transpiration or water loss, physiological disorders physical damage, pathological breakdown. [2-4]

Ethylene production rates, which depend on the fruit (Table 2), generally increase with maturity at harvest, physical injuries, disease incidence, increased temperatures up to 30°C, and water stress. On the other hand, ethylene production rates by fresh fruits are reduced by storage at low temperature and by reduced O_2 (less than 8%) and elevated CO_2 (above 1%) levels in the storage environment around the commodity.

Table 2.

Classification of Fruits According to Their Ethylene Production ([2-4])

Ethylene production rate	Fruits
Very low	Cherry, citrus fruits, grape, jujube, strawberry, pomegranate
Low	Blueberry, cranberry, olive, persimmon, pineapple, raspberry, tamarillo
Moderate	Banana, fig, guava, mango, plantain
High	Apple, apricot, avocado (ripe), nectarine, papaya, peach, pear, plum
Very high	Cherimoya, passion fruit

Temperature is the most important environmental factor that influences the deterioration rate of harvested fruits. For each increase of 10°C (18°F) above the optimum temperature, the rate of deterioration increases by two- or threefold. Exposure to undesirable temperatures results in many physiological disorders as mentioned above. Temperature also influences how ethylene, reduced oxygen, and elevated carbon dioxide levels affect the commodity. The growth rate of pathogens is greatly influenced by temperature and some pathogens, such as Rhizopus rot, are sensitive to low temperatures. Thus, cooling of commodities below 5°C immediately after harvest can greatly reduce Rhizopus rot incidence. [2-5].

Table 3.

Classification of fruits according to their optimum storage temperatures and potential storage life

Potential storage life (weeks)	Optimum storage temperatures		
	0-2°C	**3-5°C**	**12-14°C**
<2	Apricot, bush berries, strawberry, fig	Cantaloupe, ripe avocado	Cherimoya, guava, pineapple
2-4	Cherry, nectarine, peach, plum	Tangerine and mandarin, carambola	Avocado, banana, mango
4-6	Grape, tamarillo	Orange, pomegranate, kumqut	Grapefruit, lime, pummelo
>6	Apple (nonchilling sensitive cultivars), pear, cranberry, kiwifruit	Apple (chilling sensitive cultivars)	Lemon

Relative humidity - the rate of water loss from fruits depends upon the vapor pressure deficit between the commodity and the surrounding ambient air, which is influenced by temperature and relative humidity. Air circulation rate and velocity can influence the uniformity of temperature and relative humidity in a given environment and consequently rate of the water loss from the commodity [2-5]. Produce is usually cooled to its long-term storage temperature in special facilities designed to rapidly remove produce heat. Forced-air cooling is the most widely adaptable method and is commonly used for many fruits, fruit-type vegetables and cut flowers [6-10]. Hydro-cooling uses water as the cooling medium and is less widely used than forced-air cooling because some products do not tolerate water contact, and it requires the use of water-resistant packaging. It is commonly used for root, stem and flower-type vegetables, melons and some tree fruits [6-10]. Vacuum- and water spray vacuum-cooling are usually reserved for crops, such as leafy vegetables, that release water vapor rapidly allowing them to be quickly cooled. Cooling times are at least 24 h and can be much longer if produce is not packaged correctly or no provision is made to allow airflow past boxes. It is used for a few commodities, such as citrus and CA-stored apples that can have acceptable, although not optimal, quality without use of rapid cooling.

Fruit are commonly classified by growing region as follows: temperate-zone (*pome fruits*: apple, Asian pear (nashi), European pear, quince, *stone fruits*: apricot, cherry, nectarine, peach, plum, *small fruits and berries*: grape (European and American types), strawberry, raspberry, blueberry, blackberry, cranberry), subtropical (*citrus fruits*: grapefruit, lemon, lime, orange, pummelo, tangerine, and mandarin, *noncitrus fruits*: avocado, cherimoya, fig, kiwifruit, olive, pomegranate), and tropical (*major tropical fruits*: banana, mango, papaya, pineapple, *minor tropical fruits*: carambola, cashew apple, durian, guava, longan, lychee, mangosteen, passion fruit, rambutan, sapota, tamarind). Growing region and environmental conditions specific to each region significantly affect fruit quality. [2-5]

The aim of the study was the chosen of the most suitable method of cold fruits preservation for three types of fruits: pome fruits (apples, pears and quinces), citrus (oranges) and exotic fruits (kiwi and bananas). The fruits were stored, using a home refrigerator, at refrigeration (5˚C) and freezing temperature (-10˚C). The storage was made in two variants: bulk and packed fruits (using LDPE bags) for a total period of 14 days.

2. Materials and methods

2.1. Raw materials: fruits (pome fruits - apples, pears and quinces, citrus - oranges and exotic fruits - kiwis and bananas), LDPE (Low Density Polyethylene) bags.

2.2. Apparatus/equipments: mercury thermometer, core product thermometer type AMPROBE TPP1-C1, refrigerator ZANUSSI A enery class, scale Owa Laborator.

2.3. Methods

The fruits were stored, using a home refrigerator, at refrigeration (5˚C) and freezing temperature (-10˚C). The storage was made in two variants: bulk and packed fruits (using LDPE bags) for a total period of 14 days.

As main analyses we studied: the temperature in fruits'core, the cooling rate, water losses and the final aspect of the fruits.

The temperature measurements were made with a two day frequency, inside the storage space and in the fruits' core. To determine the water losses during evaporation, the fruits were weighted, before and after the storage.

The water evaporation was calculated as a difference between the initial fruit's weight and the final one.

$$\mathbf{m_w = m_{if} - m_{ff}}$$

where, m_w – water mass;

m_{if} - initial mass of the fruit;

mff – final mass of the fruit.

Also it was determined the cooling rate for the refrigeration storage with a 3 hours frequency in a 15 hours interval.

To express the cooling rate it was used the Newton's Law of Cooling states that the rate of change of the temperature of an object is proportional to the difference between its own temperature and the ambient temperature.

$$\frac{dy}{dt} = ry.$$

This equation is of interest for either positive or negative values of the constant *r*. In fact *r*=*k*, and another case in which *r*=-*k*.

This is a differential equation which describes cooling slope.

3. Results and discussion

To determine the rate of cooling is directly related to the temperature difference between the cooling medium and the product. So the medium temperature was 5°C and the time interval was 15 hours fragmented into 3 hours sections.

In the Figure 1. is represented the cooling rate of the studied fruits at refrigeration temperature.

First, when the temperature of the fruit is the same with the room temperature, the temperatures drops rapidly, after the point of cooling shock (registered after 9 hours of refrigeration 4.5°C, an almost similar temperature for all the fruits being under the medium temperature 5°C).

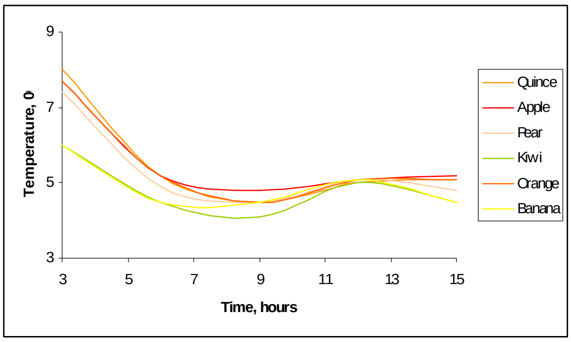

Figure 1. The cooling rate of the bulk fruits at refrigeration

For the core temperature determinations there were obtained the variation of each fruit variety as a particularity depending on the chemical composition and anatomical structure [11-15].

The core temperature variation of each studied fruit is presented in Figure 2.

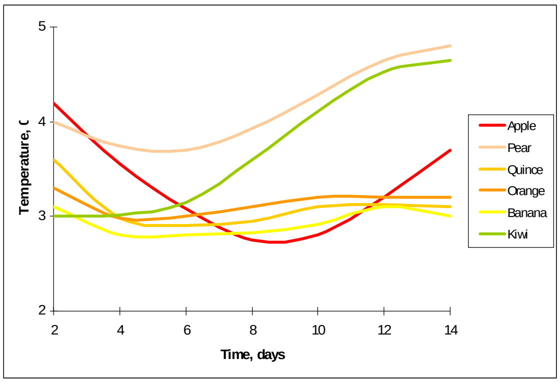

Figure 2. The variation of bulk fruits' core temperature at refrigeration

From this graphic it can be drawn that the orange, the quince and the banana had a constant variation, even if their anatomical structure is not similar. This can be explained as a relation between the peel presence for the citric and for the exotic fruit. Referring to quince structure, the core temperature variation can be constant as an influence of the rich fiber structure, pectic substances and sugar (8,5%) against the water natural contain which is the main responsible for the temperature variation.

The bigger temperature variation was observed for the apple (decreasing temperature reaching 2.9°C) and kiwi (increasing after reaching the 3.0°C).

The water losses variation during the refrigeration storage of the bulk fruits were centralized in the following graphic.

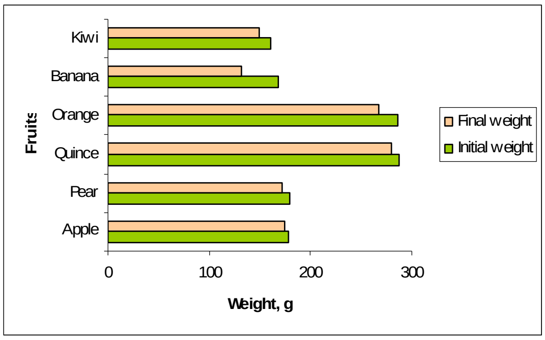

Figure 3. The water losses variation during refrigeration of bulk fruits

The water losses produced by the storage at refrigeration temperature preservation are lower for the pome fruits (2.5-4.1%) than for the citric and exotics (6.5-21.3%). Correlating these technological aspects with the final aspect of the products, the exotic fruits represented by kiwi and banana had become unfit for consumption. The lowest quantity of moisture which was lost by the pome fruits can be justified by the homogeneous structure of these fruits.
In Figure 4 is presented the core temperature variation of the packed fruits in LDPE bags.
It had been chose the LDPE bags because the material is considered an excellent barrier for steam and water, but not so good for gases. Also because is a very used material in food industry and also for economic criteria being cheaper comparing to other types of packages.
The allure of the temperatures curves is more similar than the other from the bulk fruits, but it can be seemed that during the refrigeration of the bulk fruits, the quince, the orange and the banana registered a constant evolution, while the behavior of the same packed fruits was irregular.

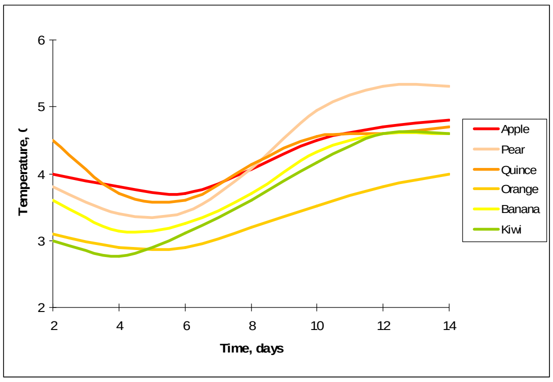

Figure 4. The variation of packed fruits' core temperature at refrigeration

In comparison with the bulk fruit the packed fruits as banana, apple and orange were registered the best results; this is a positive indicator in use of the LDPE bags.
In the following graphic is presented the water losses variation during refrigeration of packed fruits.

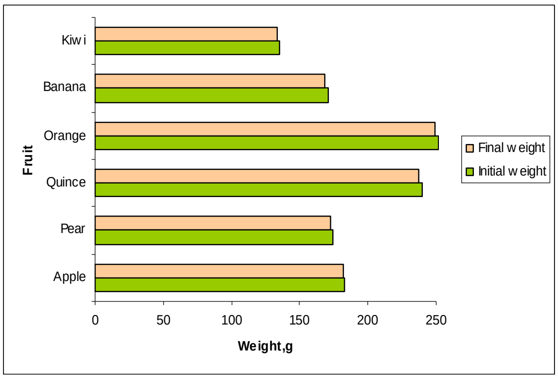

Figure 5. The water losses variation during refrigeration of packed fruits

The LDPE package is a very good protection for the water elimination, as it can be seemed all kinds of fruits presented a lower quantity of moisture content than the bulk fruits. The significant losses were diminishing since 10% for kiwi, 9% for orange and 17% for banana.
For the freezing storage preservation of the bulk and packed fruits there were lead the same analyses as for refrigeration. The storage temperature was -10°C for 14 days. Besides the refrigeration process, at freezing there were made two kinds of weight determination, before the thawing

and after it. The thawing temperature is the room temperature (21°C).

In Figure 6 is represented the core temperature variation of the freeze fruits.

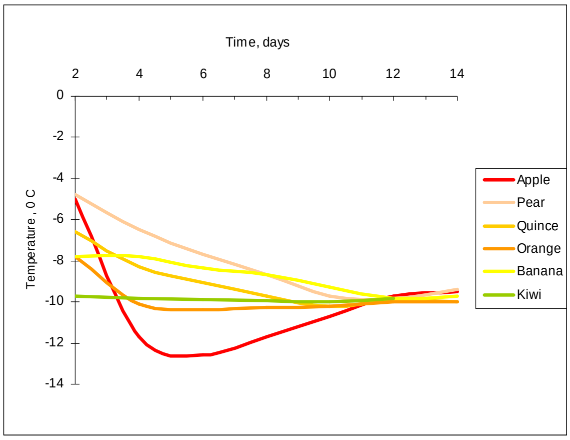

Figure 6 The core temperature variation of freeze bulk fruits

From the graphic it can be seemed that the biggest variation of the core temperature at freezing temperature is assigned to apple. Kiwi and orange had a constant variation during the freezing period.

The following graphic is presenting the water losses during the storage process at freezing temperatures for the bulk fruits.

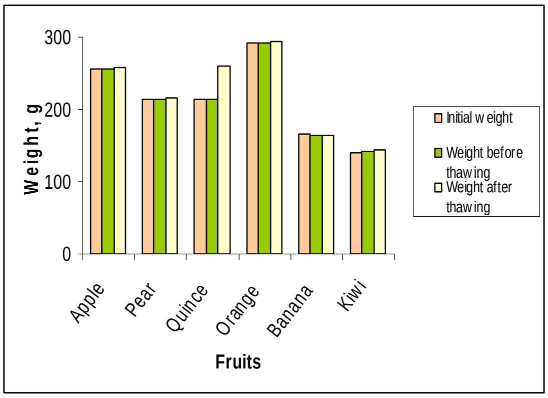

Figure 7. The water losses variation during freezing of bulk fruits

It can be observed that the evolution of the quantity of moisture lost from the product is very similar for apple and pear in all three phases (freeze, before thawing and after thawing).

The quince had hard texture and for this consideration it retained a big quantity of water (~20%) after thawing, by hydrating the fibers and the pectin.

Even the banana had a big content of starch (29.6%) or sugars (glucose – 4.7%, fructose – 8.6% and sucrose – 13.7%) after the thawing it didn't received a proportional quantity of water, this fact may be put on the protective thick peel which didn't allow the mass transfer. Banana is the only fruit which is registering a water loss after thawing.

Figure 8 presents the core temperature variation of freeze packed fruits.

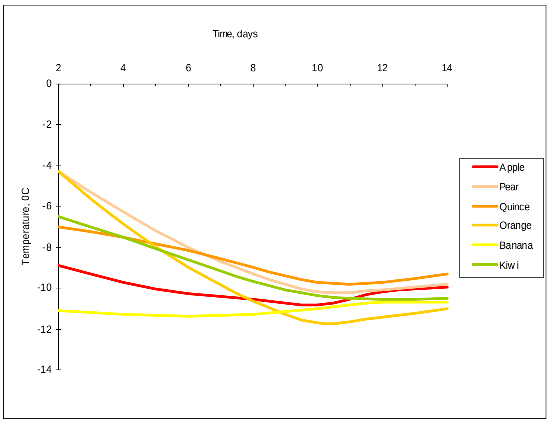

Figure 8. The core temperature variation of freeze packed fruits

The allure of the temperature curves is constant, almost similar for the pome fruits. The minimum temperature inflexion is detected after 10 days of storage for the majority of the studied fruits.

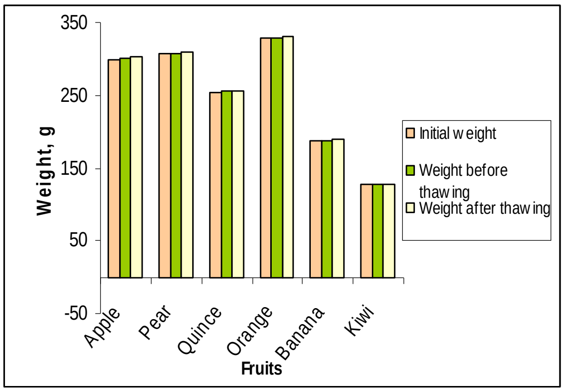

Figure 9. The water losses variation during freezing of packed fruits

The water losses variation is lower than in the bulk fruits; almost the weight increasing is minimal (~3 g) for all the fruits. These aspects can be justified by the LDPE bags protection.

4. Conclusions

As a final conclusion apples and oranges are both suitable to refrigeration and freezing storage both in bulk as in packed state.

Due to the natural wax protection layer the apple complies with this kind of preservation methods.

The exotic fruits represented by banana and kiwi did not comply with this kind of cold preservation, being improper for later consumption. After refrigeration the exotic fruits had been dehydrated, while after thawing the tissue structure was soaked.

For the cooling rate the product is considered 'half cool' when its temperature drops to half the difference between its initial temperature and the cooling medium temperature. After another half-cooling period the product is 'three-quarters' cool. The product is usually finished at 'seven-eighths' or 'fifteen-sixteenths' cool. The cooling time predictions can be made by equations presented by Thompson et al. (1998) or a graphical method by Sargent et al. (1988).

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