
APPLE STORAGE IN ULTRA-LOW OXYGEN COLD STORE

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Abstract

Apple storage under lower concentration of oxygen (1.0-1.3% in some cases lower than 1%) in controlled atmosphere cold stores is described as apple storage in ultra-low oxygen cold store. Ultra-low oxygen store room is an airtight gas cold room and its atmosphere is composed of lower rate of oxygen and higher amount of CO₂. It has been investigated and recorded that ultra-low oxygen cold store extends storage life of apple varieties (Royal Gala, Red Delicious, Idared, Jonagold and Golden delicious) from 3 to 6 months under common cold stores to 7-11 months with preserving its nutritional, sensorial and biological parameters and characteristics after harvest. For storage of apples in Afghanistan, mostly simple and cold storerooms are applied but inadequately and with local methods and facilities, due to application of ultra-low oxygen cold storage both can benefit farmers, customers and economic growth of the country.

Keywords: ULO cold store, Apple varieties under ULO Store room, Apple storage in Afghanistan

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Introduction

Ultra-low oxygen (ULO) cold store is an airtight gas cold room within its atmosphere composition; lower rate of oxygen 1.0-1.3% and higher amount of CO₂ 2.0-2.5 % and lifted amount of nitrogen. Moreover, temperature and humidity must be also adjusted and regularly controlled.

Apple is a seasonal variety and during harvest period when product is picked up, it is needed to store excess amount, which is out of market demand and process. This storing will control cost fluctuations, prohibit and or decrease deterioration and decomposition of fruit after harvest, enable us to transfer our product to far places, benefit farmers and mainly will secure fruit for consumption and demand of customers during winter and spring months with its desired quality and taste.

For storage of apple we can use different kind of storing methods but storage with ULO cold store had shown significant increase in holding shelf life of apple varieties (Royal Gala, Red Delicious, Idared, Jonagold and Golden delicious) from 90-180 days under common or unregulated store houses to 210-330 days together with maintaining its quality such as its nutritional and sensorial characteristics and controlling or decreasing post-harvest diseases. ULO storage is not only considered a useful approach for apple but it had also shown good results for extending

storage life of some other fruit crops such as pear, kiwi *etc.* together with preserving its post-harvest quality. The following some useful information are presented from credible sources and researches about controlled atmosphere and ULO storage, pre-storage activities, results of storing apple varieties (Golden delicious, Idared, Royal gala, Jonagold and Red Delicious) under ULO cold store and system of apple storage in Afghanistan. The study was undertaken due to lack of information on the issue and as of need for apple storing improvements in our society.

Materials and Methods

Review and investigation of secondary sources. Information were used in current study are from study materials available at Agriculture faculty of Kabul University and Slovak University of Agriculture in Nitra. Furthermore, some information from books, journals and research papers were searched, studied and gathered existing on campus in the library of Slovak University of Agriculture. Moreover, online sources accessible at library's and journals online were used. Statistics used are collected from Central Statistics Organization of Afghanistan, research papers and books. In addition, I shared information and consulted about the topic with relevant experts. Finally yet importantly, I used

my earned knowledge in writing and preparing the research article.

Results and Discussion

Apple and its nutritional value

Apple (*Malus domestica* Borkh.) is a perennial and deciduous temperate zone fruit crop. In 2001, this was recorded that exists about 2000 apple varieties. Apple fruit is composed of mostly water, has a good nutritional value and it is a good source of minerals and vitamins. Overall, it strengthens our organism and its consumption is allowed for diabetes patients (Richter, 1996). It reinforces immunity system, hearth, and bloodstream; stabilize the level of sugar in blood and has many other health promoting activities (Vlčková, 2003). It is a good source of bioactive compound vitamin C, it consist of about 30% pectin and fibers, which decrease the level of cholesterol, respectively blood lipids and bind toxic substances such as lead (Pb) and mercury (Hg), and it contains lesser amount of carbohydrates and fatty acids. Moreover, it contains salt of tartaric acid, which prevents harmful formation of ferments and bacteria in gut.

As several studies indicated nutritional and health promoting value of apples so it is necessary to have apple fruit for consumption during whole period of the year. For achieving, this to have apple during entire year is to store apples. We can apply different methods for apple storing but one of the effective methods is ULO cold store by which we can have apple fruit during whole year along with its desired quality and nutritional value.

Introduction to storage, ULO cold store and apple pre storage activities

Storage is a post-harvest activity, which is applied for lengthening of the product shelf life. We apply storing activity; to have the product with better nutritional and sensory parameters for long period than normal, to maintain the product from deterioration and decomposition after harvest, to reduce and sustain fluctuation of prices (to control market), to transfer product to far places and to benefit farmers, ourselves and the economy of our community.

We use different kind of store rooms for apple and/or fruits, such as simple storing rooms (containing pits and basements) which were mostly used in high level decades ago and still we are practicing them in developing and undeveloped countries. Storage life in these store rooms is lesser because atmosphere is not controlled properly. Due to unregulated atmosphere, respiration rate and fruit ripening is faster, diseases and disorders occurrence and improvement is higher and quality of fruit is poor

in contrast with CA store rooms. We can practice simple storage room for apple varieties that we are planning to market them soon (simple store rooms are good for short holding of apples). Further types of storages are consist of air cooled common storage, cooled storage without controlled atmosphere and cold stores with controlled atmosphere (which is consist of CA storages, CA store houses with low oxygen concentration and CA store rooms with ultra-low oxygen concentrations) (Mendelová, 2015).

The most effective method for extending storage life of apple with maintaining its quality is controlled atmosphere ultra-low oxygen cold store. Storage with modified atmosphere (MA) and CA in particular ULO limits the concentration of oxygen by which it maintains the functional status of stored crops (Goliás, 2011), it involves refrigerating an insulated gastight room and controlling atmosphere within so that it is higher in CO₂ and lower in O₂ than normal (Hardenburg *et al.*, 1986). MA and CA storages offer several advantages by delaying ripening and aging process of horticultural products, control of some diseases and biological processes such as rancidity, insects, bacteria and decay, containing further diseases and processes (Elhadi, 2009). This holding of fruit in gas-tight refrigerated room extend the usable storage life of many cultivars 7 to 9 months or even more depending on efficiency of operation of the storage facility, the cultivar and the particular processed product being manufactured (Downing, 2012). In CA store houses the optimum concentration of O₂, CO₂ and temperature must be identified and adjusted because exposure of different types of foods (especially horticultural products) to lower levels of O₂ and/or higher levels of CO₂ above their optimum tolerable range can cause the initiation and/or aggravation of certain physiological disorders, irregular ripening, increased susceptibility to decay, development of off-flavor, and could eventually cause loss of product in short period of time than normal. The history of the discovery of the CA storage goes to early 1800s in France to chemist Jacques Étienne Berard. His studies revealed that harvested fruits utilized O₂ and produced CO₂ (Elhadi, 2009) and in a publication in 1821 he mentioned that fruits in an atmosphere devoid of O₂ didn't ripen and reported that storage life of fruits is increased (Burg, 2004; Elhadi, 2009; Thompson, 2010). History of refrigerated gas storage (CA) that lead to commercial CA storages goes to Franklin Kidd and Cyril West 1927 as after conducting their research they mentioned that fruit ripening could be reduced by increasing carbon dioxide and lowering oxygen in storage atmosphere. They recognized that disorders are associated with specific storage conditions and fruit volatile accumulated inside the storage can be harmful to fruits. Then during 1940 a group of postharvest

scientists gathered in New York decided to change the name from "gas storage" to controlled atmosphere (CA) storage and since it is called as CA store house or CA storage (Kupferman, 1989).

In controlled atmosphere cold store under ULO conditions; during harvesting period apples to be carefully picked by hand into bulk pallet boxes and quickly transferred to store houses because a delay of 3 days in orchard or in a warm packing shed may shorten storage life as much 30 days, even if they are stored at -1°C (Hardenburg *et al.*, 1986). Pre storage sorting and grading is an important operation and must be applied; fruits are sorted according to its health status and size. During sorting; damaged, inappropriate and poor quality fruits must be removed. Then for apples precooling is to be applied. Better way of precooling (precooling is for preventing of temperature shock, removal of excess heat and to limit respiration rate after harvest and before storage) is by flowing of water and/or cold air (Mendelová, 2015). Among options for precooling, immersion pre-cooling of apple is the most effective method, because it could be applied together with cleaning process and use of shelf life extension chemicals. At the same time this was recorded that immersion precooling is 60% more effective method in accordance with air cooling as of its direct contact with water (CHAMP, 2016). In addition, to note, one of further key points for extending and or keeping shelf life of apples with its proper quality indices is to apply last dose of irrigation no later than before three weeks of picking of apples. Because if we irrigate thereafter although applefruit size will enhance but it will reduce storage life of apple (Mezey, 2014). Tomention about general factors that are mainly affecting shelf life of apples widely differ according to its cultivar, climate conditions, cultural practices, maturity when picking up, method, materials and handling during picking and grading, time of transferring to store houses, precooling, efficiency of storage facilities, and according to adjustment of desired conditions in storage.

Useful Hints

- An airtight room is very necessary for proper controlled atmosphere storage of fruits and vegetables, particularly with the recent recommendations for ultra-low oxygen conditions (Storage Control System, Inc., 2015).
- ULO storage is a controlled atmosphere cold store room with lower amount of O₂ and higher rate of CO₂.
- Apple is a climacteric fruit; it means it got ripen after harvest. Ripening associated with increase in respiration rate and ethylene production.
- Respiration rate can be controlled with atmosphere regulation by reducing the amount of O₂ and increasing the amount of CO₂ (Mendelová, 2015).

- Lower amount of O₂ and higher amount of CO₂ slow and regulate ripening process and control development of some storage disorders such as apple scald.
- Apples respire and soften about twice as fast at 4°C as at 0°C ; and at 15°C , about three times as fast as at 4°C (Patchen, 1971).
- Storage life is reduced as storage temperature is increased (Hardenburg *et al.*, 1986).
- In CA and ULO stores, O₂ partial pressures must be increased when storage temperature is higher (Weber *et al.*, 2011).
- For maximum storage life, apples to be harvested when they are mature not fully ripe.
- Apples for purpose of storage should be harvested by hand.
- CA storages extend storage life of apples from 90-120 days under unregulated storages to 270-350 days (Mendelová, 2015).
- ULO cold store is a best approach to extend shelf life of following mentioned apple varieties with its desired quality. However, before application there is an urgent need to evaluate and analyze our product, storage quantity, cost, and benefits. Because preparing components of CA and ULO storages are expensive and need skilled workers (Hakimi, 2018).

General conditions of apple storage

Optimum storage temperature for apples is between 0.5°C to 4.0°C (Mendelová, 2015) as also Hardenburg *et al.* (1986) mentioned between the range of -1° to 4°C with an optimum of -1 to 0°C with 90 to 95 percent of relative humidity for most apple cultivars. The highest freezing point for apple is about -1.5°C , hence they can be stored at -1°C or above but the storage temperature must to be well-controlled and freezing of the apple to be avoided (Hardenburg *et al.*, 1986). Susceptible varieties such as Jonathan, Belle de Boskoop, McIntosh red etc. are exception that they require optimum of $3-4^{\circ}\text{C}$ temperature (Mendelová, 2015). The same way Hardenburg *et al.* (1986) mentioned that McIntosh often develops brown core during extended storage at 0°C ; hence, they should be stored at 2° to 3°C .

Optimum relative humidity for most apple cultivars is between 85-95%.

For atmosphere composition under ULO also CA and LO cold stores; system of 100% can be applied. System of 100% is defined as (O₂ + CO₂) + N₂ = 100 % (Horčín and Brindza, 2007). This 100% is consisting of 1.0-5.0 % O₂, 0.25-5.0 % CO₂ and 84-98% of N₂.

Atmosphere composition for apple in ULO cold store is stated as:

O ₂	1.0 - 1.3 %
CO ₂	2.0 - 2.5 %

and lifted amount consist of N₂.

Results of storing apple varieties in ULO cold store

Decades ago, research had shown better quality retention with low oxygen level of 1 percent for McIntosh, Golden Delicious, and Delicious cultivars (Anderson, 1967; Lidster *et al.*, 1981; Richardson and Meheriuk, 1982; Hardenburg *et al.*, 1986).

The best ultralow oxygen condition for storage of Royal Gala apples is 1.0 kPa O₂ combined with 2.0 kPa of CO₂ at 1°C. The 1°C storage temperature can keep quality of Royal Gala apples after eight months of CA storage. The storage of Royal Gala apples under ULO (below 0.8 kPa of O₂) conditions reduces post-storage quality and increases the occurrence of physiological disorders in fruit (Weber *et al.*, 2011).

Red Delicious apple in commercial rooms with 1% level of O₂ had shown very good success and is seem adequate and near to 0.5% of O₂ may result some injury (Olsen, 1986). Researchers mentioned that Golden Delicious apples under ULO (0.9 % O₂ and 1.2 % CO₂) in contrast of CA (1.5 % O₂ and 2.0 % CO₂) with 1°C temperature and 97% of relative humidity after seven months of storage showed feasibility due to higher firmness and lower content of organic acid at the end of storage and had greater ability of producing volatiles with post-storage ripening. Also their result confirmed that CA storage suppresses volatile production (Rizzolo *et al.*, 1997).

A research was made in Slovakia on three varieties Idared, Jonagold and Golden Delicious of apple in CA storage under ULO concentration. Research was conducted for two years under following conditions: temperature between 0 to 1°C, relative humidity 87-90% and atmosphere composition 1.0-1.5% of O₂ and 1.0-3.0% of CO₂. Main goal was to measure biological, nutritional and sensorial characteristics of mentioned apple varieties. Although all varieties had shown good results but during storage this were obtained that most appropriate variety among these is Idared which had shown best result for all three measuring characters. It also included higher amount of organic acids. Least but not bad variety among these were identified Golden delicious which had not shown good results and contained minimum composition of acids. Variety of Jonagold had shown good result in sensorial analysis. At beginning, end and during storage period there had not been detected any big differences on the parameters which study was conducted for. Overall, this was obtained that mentioned apple varieties in CA cold stores under ULO concentration, preserve its nutritional and biological characteristics and this enable us to have apple fruit during spring and late summer

months. This was achieved that storing of cited varieties under ULO conditions extend storage life of them up to 200-230 days together with maintaining its nutritional and biological values (Mrázik, 2008).

Apple storage in Afghanistan

Afghanistan has a total of 26847 ha area under apple cultivation with 170443-ton production and an export rate of 22755 tons in 2017/18 (Afghanistan Statistical Yearbook, 2017-18). Current growing varieties are almost from exotic varieties imported around 20 years ago. But three varieties Red Delicious, Golden Delicious and Granny Smith are grown commercially (Safi and Bunnel, 2013).

In Afghanistan, most of the times after harvest apple get spoil or lose their quality in market or farm but some growers use simple storerooms to prevent damages to their products. In addition, a less amount (around 1500 tons) of apple is stored in cold storages but without maintaining norms and standards and without regulating temperature and atmosphere composition properly. In Afghanistan, there is lack of common cold stores, CA cold stores (mostly ULO storages) and market facilities for apple and all other fruits. Due to produce amount out of market demand and process, get spoil or sold up by low prices to neighboring countries and the local product doesn't exist during winter and spring months. Because of that during winter and beginning of next season apple is imported from neighboring countries, which is mostly not profitable for growers, people and to economic growth of the country.

Conclusion and Recommendations

ULO cold store is a useful approach for extending shelf life of apple varieties (Golden Delicious, Idared, Royal gala, Jonagold and Red Delicious) up to 7-11 months with maintaining its quality characters in a desired condition. By ULO storage we can have and consume apple fruit during whole year and spring months with its desired quality indices.

For Afghanistan, in fact not only for Afghanistan but overall places with higher rate of apple production that they have produce out of their use and market demand during peak season and they don't have access to their own apple during winter and spring months; related post-harvest offices, public and private sectors should apply ULO cold storage for storing of mentioned apple varieties. But they should consider amount of their product, cost and benefits. Further they should conduct researches on their own commercial varieties under ULO storage conditions. Subsequent researches should be applied for improvement of current conditions and discovering of new approaches for extending

storage life of apples as sometimes may natural disasters can affect our product. Researches must be applied to transfer desired post-harvest characters (capability of long-term storage with low amount of decrease in its quality and resistance to post-harvest diseases) of some proved varieties to certified varieties with good quality but lower storage capability.

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