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Effects of Storage Conditions and Packaging on Moisture Content, Water Activity and Tissue Hardness of Dried Apricots

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Abstract

Dried apricot fruit is subject to slow or rapid quality losses due to environmental conditions during the period from completion of drying until consumption. During long storage periods, these losses reach to greater dimensions. These losses can be slowed down if the storage period conditions are kept under control. The apricot variety Hacıhaliloğlu that is dried traditionally and fumigated with sulphur dioxide was used in this experiment. Dried apricot fruits packed in different packing materials (wooden crates, jute sacks, PE bags) were put in cold storage (4±1°C, 55-65% RH) as well as in normal storage. Fruit samples were taken at specified intervals from different levels of stacks (bottom, middle, top) and investigated for quality and deterioration. The moisture content decreased and water activity of the product increased in cold storage conditions. The tissue hardness was greater in case of the product stored in normal storage conditions. In the fruits present on the top of the heap, dry matter decreased and water activity increased. Whereas fruits in PE bags showed high dry matter and low water activity, the lower tissue hardness have been achieved in fruits in jute sacks and wooden crates.

Key words: Dried apricot, storage, mass packing, quality

Depo Koşulları ve Ambalajların Kuru Kayısıların Su Miktarı, Su Aktivitesi ve Doku Sertliğine Etkileri

Özet

Kuru kayısı meyveleri, kurutmadan tüketiciye sunuluncaya kadarki dönemde ortam koşullarının etkisiyle yavaş veya hızlı kalite kayıplarına maruz kalır. Uzun depolama dönemlerinde, bu daha büyük boyutlara ulaşır. Depolama sürecinde ortam koşulları kontrol altında tutulursa, bu kayıplarda yavaşlama olabilir. Bu çalışmada geleneksel olarak kurutulan ve kükürt dioksit ile fümige edilen Hacıhaliloğlu kayısı çeşidi kullanılmıştır. Kuru kayısı meyveleri soğutmalı (4±1°C, 55-65% oransal nem) ve normal depo koşullarında farklı ambalaj kaplarında (tahta kasa, jüt çuval, PE torba) saklanmıştır. Ambalajların farklı düzeylerden (alt, orta, üst) belirlenen aralıklarla alınan meyve örneklerinde kalite ve bozulma durumları incelenmiştir. Soğuk depo koşullarında kuru kayısıların su miktarı ve su aktivitesi artmıştır. Doku sertliği, normal depolama koşullarında saklanan kuru kayısı meyvelerinde daha yüksek bulunmuştur. Yığının üzerindeki meyvelerin kuru maddesi azalmış ve su aktivitesi artmıştır. PE torbalardaki meyveler, yüksek kuru madde ve düşük su aktivitesi gösterirken, jüt çuval ve tahta kasalardaki meyvelerin doku sertliği daha düşük bulunmuştur.

Anahtar Kelimeler: Kuru kayısı, depolama, kitlesel ambalaj, kalite

1. Introduction

Generally, special care is not taken in the storage of dried fruits, because of their low water content, they become more resistant. But, in prolonged storage the deterioration reaches to important levels (Cemeroğlu and Acar, 1986; McBean et al., 1971; Sen et al., 2009; Sen et al., 2015). Because of the hygroscopic conditions, the dried fruits absorb water thus the water ratio of the product increases while the resistance decreases rapidly (Ayrancı et al., 1990). However dried fruits treated with sulphur dioxide, the resistance differs according to the amount of absorbed sulphur dioxide. Although sulphur dioxide may have harmful effect on human health, it is being used today (Taylor et al., 1986; Taylor, 1993). It is important to find out its minimum dose which provides resistance and this point was dealt in previous reseaches (Asma et al., 2005; EFSA, 2013). On the other hand, low temperature can be an important solution. The long-term marketing of dried apricot fruit renders mass storage necessary in highly producing regions. Generally, dried fruits are stored as 70-80 cm heap and at the same time kept there for long periods by shuffling (mixing) (Sen et al., 2009). The product is stored under conditions where humidity and temperature are not controlled. Deterioration depended upon the level of dryness and the fruit sulphur dioxide content. The objective of this study was to investigate and find out new solutions for the mass storage of dried apricot fruits and to compare it with the traditional storage methods.

2. Material and methods

2.1. Material

Commercially sun-dried apricots (*Prunus armeniaca* 'Hacıhaliloğlu') were provided by Malatya Fruit Research Institute of the Ministry of Agriculture and Rural Affairs in Turkey. Fresh apricot fruits are first washed, graded according to their maturity, placed on trays, and then treated with SO_2 in special chambers by burning sulfur. Sun-drying is practiced by placing trays under direct sunshine. After drying, initial SO_2 concentrations were determined to be 1606 mg·kg^{-1} in the dried Hacihaliloglu fruit.

2.2. Methods

The product was spread over a PE sheet and mixed thoroughly in order to get on homogenous sample and was covered with PE sheet for 2 days (Göğüş, 1992). The dried apricot fruits were put into 3 different packaging types: wooden crates (40x40x80 cm), jute sacks (50 kg) and PE bags (40x60 cm) thickness of 80 mikron. The samples wooden crates were stored both in cold and normal storage conditions and were taken from different levels (bottom, middle, top) after 3, 6 and 9 months of storage. In order to keep the situation of whole stored product after taking samples, perforated PVC pipes (12.25 cm diameter) were fixed in the wooden crates. The samples for analyses were taken from jute sacks and PE bags in addition to the samples taken from covered wooden crates stored in cold and normal storage at the end of 9th months of storage period.

The probes of the instruments (Ebro EBITH-612, GmbH & Co. KG, Ingolstadt, Germany) measuring temperature and humidity were fixed in the wooden crates at the height of 15 cm and 45 cm whereas the same were fixed in the middle of the jute sacks. Dried apricots were placed at the height of 70 cm in the wooden crates. The product was stored at 4±1°C, with 55-65% RH in cold storage and 6-26°C with 49-65%RH in the normal storage (Table 1).

Table 1. Temperature and humidity changes in cold and normal storage

Storage Period	Cold storage (wooden crate)				Normal storage (wooden crate)				Air	
	15 cm		45 cm		15 cm		45 cm			
	°C	%	°C	%	°C	%	°C	%	°C	%
Mean	4	53	3	52	15	52	15	51	15	59
Min-max	3-4	51-55	3-4	51-53	10-23	50-55	10-24	49-54	9-26	42-65

2.2.1. Moisture content

Moisture content (%) was measured by drying in an oven (65°C, UM400, Memmert, Schwabach, Germany) up to a constant weight (AOAC, 1990) and calculating the percentage weight loss.

2.2.2. Water activity (a_w)

Samples taken from the ground dried apricots were placed in the containers of the apparatus and filled to 2/3 of its final volume. A water activity meter (Novasina TH 500, Pfaeffikon, Switzerland) was used to measure water activity values at 25℃.

2.2.3. Tissue hardness

The tissue hardness of the fruit was measured using an Instron Universal Testing Machine (model 1140, Bucks, UK). Full-scale load was set at 50 kg and chart drive and crosshead speeds were 200 mm min^{-1} (Bourne, 1982). The plunger used to cut the fruit samples (15 samples for each replication) was Warner Bratzler shear (13 mm diameter). Data are expressed in Newton (N).

2.3. Statistical analysis

Conditions inside the storage room were regarded homogeneous, and a completely randomized plot design with three replicates was chosen as the experimental design. All data were subjected to analyses of variance (ANOVAs). Significant differences among groups were determined using Duncan's multiple range tests at $P<0.05$. All computation and statistical analyses were done using IBM® SPSS® Statistics 19 statistical software (IBM, New York, USA).

3. Results

3.1. Moisture Content

The moisture content of the dried fruits decreased gradually during the storage period. The moisture content of decrease was more during the last three months. During this period in cold storage conditions, the moisture content of the fruits increased slightly. The position of the product in the crate had no effect on water content in the cold storage while there were some fluctuations in normal storage conditions (Table 2). In the 9th month, the moisture content of the product was lower in PE bags as compared to crates and jute sacks. It was similar in jute sacks and crates. No significant difference between different packing material was found in cold storage while a difference was found in normal storage.

Table 2. Moisture content (%) changes of dried apricots at different levels in crates stored for 9 months in different storage conditions

Storage	Level	3rd month	6th month	9th month	Mean	Mean
Cold	Top	16.75 bc	16.80 bc	16.04 c	16.53	
	Middle	17.13 b	15.75 cd	15.51 cd	16.13	16.34 a
	Bottom	17.10 b	16.65 bc	15.34 cd	16.36	
	Mean	17.00 a	16.40 b	15.63 c		
Normal	Top	17.63 ab	18.07 a	13.37 e	16.35	
	Middle	16.16 c	16.10 c	14.97 d	15.75	15.93 b
	Bottom	16.62 bc	15.46 cd	14.97 d	15.68	
	Mean	16.81 ab	16.54 b	14.44 d		
	Mean	16.90 a	16.47 b	15.03 c		

The position of the product was not effected the moisture content in cold storage whereas low moisture content was detected in the samples which was taken from the top of packing types in normal stores (Table 3).

Table 3. Effects of different packing materials and levels in packages on moisture content (%) of dried apricots in different storage conditions at the end of the 9 month

Storage	Level	Crate	PE bag	Jute sack	Mean	Mean
Cold	Top	16.04 b	14.43 c	17.41 a	15.96 a	
	Middle	15.51 b	16.12 b	15.37 b	15.67 a	15.15 a
	Bottom	15.34 b	14.26 cd	15.05 bc	14.88 ab	
	Mean	15.63 a	14.94 ab	15.94 a		
Normal	Top	13.37 d	13.52 d	14.15 d	13.68 c	
	Middle	14.97 bc	11.73 e	14.94 bc	14.55 b	14.15 b
	Bottom	14.97 bc	13.36 d	14.32 c	14.22 ab	
	Mean	14.44 b	13.54 c	14.47 b		
	Mean	15.03 a	14.24 b	15.21 a		

3.2. Water Activity (a_w)

During 9 months a_w in cold storage had increased continuously, whereas in normal storage a_w was found to be increased until the 6th month and then decreased in the 9th month. The average values of a_w were higher in cold storage than in normal storage. The position of the product in package had not been changed the a_w value in cold storage. But in the normal storage a_w had been found to be increased in the top layers (Table 4). Different packing types had changed a_w after 9th months of cold storage. a_w of the fruits in PE bags was lower in crates and jute sacks. But in normal storage different packing had no effect on a_w. In cold storage top layer fruits showed high a_w values, whereas in normal storage lower a_w values were recorded. Position of the fruit in crates has no effect on a_w, but bottom layer fruits packed in jute sacks and PE bags presented low values in cold storage. In normal storage, lowest a_w value was found in the bottom layer of crates and top layer of jute sacks and PE bags (Table 5).

Table 4. Water activity of changes of dried apricots at different levels in crates stored for 9 months in the different storage conditions

Storage	Level	3rd month	6th month	9th month	Mean	Mean
Cold	Top	0.528 d	0.574 b	0.605 a	0.569 a	
	Middle	0.539 cd	0.558 bc	0.600 c	0.566 a	0.568 a
	Bottom	0.593 cd	0.573 b	0.594 a	0.569 a	
	Mean	0.535 d	0.569 b	0.599 a		
Normal	Top	0.555 c	0.589 ab	0.558 bc	0.567 a	
	Middle	0.539 cd	0.555 c	0.549 c	0.548 b	0.551 b
	Bottom	0.517 d	0.555 c	0.540 c	0.537 b	
	Mean	0.537 d	0.566 b	0.549 c		
	Mean	0.536 c	0.567 b	0.574 a		

Table 5. Effects of the different packing material and levels in packages on the water activity of the dried apricot in the different storage conditions at the end of 9 month

Storage	Level	Crate	PE bag	Jute sack	Mean	Mean
Cold	**Top**	0.605 ab	0.557 c	0.611 a	0.591 a	
	Middle	0.600 ab	0.582 b	0.606 ab	0.569 b	0.587 a
	Bottom	0.594 b	0.544 cd	0.587 b	0.575 b	
	Mean	0.599 a	0.561 b	0.601 a		
Normal	**Top**	0.558 c	0.525 e	0.530 de	0.538 d	
	Middle	0.549 cd	0.533 de	0.555 c	0.546 cd	0.545 b
	Bottom	0.540 d	0.552 cd	0.556 c	0.549 c	
	Mean	0.549 c	0.537 c	0.548 c		
	Mean	0.574 a	0.549 b	0.575 a		

3.3. Tissue Hardness

Tissue hardness of the fruits in crates decreased gradually throughout the entire storage period. This decrease was more evident, especially, during the last three months of storage the period. Tissue hardness of the fruits in crates was not affected in cold and normal storage. The bottom layer fruits in the cold storage had lower hardness values whereas in normal storage were same hardness values (Table 6). In PE bags tissue hardness was higher than that of those in stored in crates and jute sacks. The average tissue hardness values were lower in cold storage than normal storage. Position of fruits displayed no difference in all packing materials (Table 7).

Table 7. Effects of different packing levels in packages on the tissue hardness (N) of the product in different storage conditions at the end of 9 month

Storage	Level	Crate	PE bag	Jute sack	Mean	Mean
Cold	**Top**	6.88 ab	7.06 ab	4.89 c	6.27 b	
	Middle	7.03 ab	7.42 a	6.29 b	6.91 ab	6.50 b
	Bottom	6.11 b	7.09 ab	6.61 ab	6.60 b	
	Mean	6.67 b	7.19 ab	5.93 b		
Normal	**Top**	7.29 a	7.12 ab	7.55 a	7.07 a	
	Middle	6.67 ab	7.31 a	6.89 ab	6.96 ab	7.12 a
	Bottom	6.76 ab	7.31 ab	7.15 ab	7.35 a	
	Mean	6.91 ab	7.25 a	7.20 ab		
	Mean	6.79 b	7.22 a	6.56 b		

Table 6. The change in the tissue hardness (N) of the product at different levels in crates stored for 9 months in the different storage conditions

Storage	Level	3rd month	6th month	9th month	Mean	Mean
Cold	**Top**	8.37	8.60	6.88	7.95 a	
	Middle	9.16	8.39	7.03	8.20 a	7.82
	Bottom	8.26	7.60	6.11	7.32 b	
	Mean	8.60	8.20	6.67		
Normal	**Top**	8.34	7.43	7.29	7.69 ab	
	Middle	8.40	7.98	6.67	7.62 ab	7.83
	Bottom	8.85	8.90	6.76	8.17 a	
	Mean	8.53	8.04	6.91		
	Mean	8.56 a	8.12 b	6.97 c		

4. Discussion

During the study, in cold storage the humidity was controlled. Therefore ; the fruits on the top layer were affected by these conditions and show a stable development. Since the temperature and humidity is not stable in normal storage fruits present on the surface are subjected to variable environmental conditions (day–night, summer–winter) and so do not show stable behaviour. In the mass storage, the air movement with in the heap can cause a change in the internal environment and thus creating an effect due to location of the product (Hall, 1980). The temperature and humidity measurements taken from dried fruit heap in cold and normal storage showed clear differences in temperature but the RH values were very close to each other. That is important because water activity of the fruit is determined by the humidity value. In the heap, with the increase in the height, the temperature increases and humidity decreases (Table 1) but the absolute humidity also increases. Between 15-45cm level, these factors have been found to be stable. The air movement in the heap for high heaps can change and humidify the internal environment at the top or bottom parts of the heap (Hall, 1980).

The water content and a_w have increased in cold storage, because humidity of the air at lower temperature is a bit higher as compared to normal storage Tissue hardness is also high in normal depot. Location of the fruit in the heap has increased the water content and increased the a_w of the top layer fruit in cold room. The results are in accordance with Ayrancı and coworkers (1990). In cold storage, air circulation affects the sample uniformly in the heaps. The PE bag separates the product from the external environment and internal conditions are produced by the product itself (Selke, 1994). Change in temperature affects it too. Therefore, the PE bags showed low water content and low a_w. The tissue hardness results were in the same manner because they were affected by the humid environmental conditions of the environment in the same way.

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