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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Determination of Variability in Ambient Conditions During Cold Storage of Aronia Fruits

Aronya Meyvesinin Soğuk Depolanması Sırasında Ortam Koşullarındaki Değişkenliğin Belirlenmesi

Serap AKDEMİR

Abstract

In this research, temperature and relative humidity in a cold store with an evaporative cooling system were investigated during one-month cold storage of Aronia melanocarpa Nero fruits. Ambient temperature and relative humidity were measured by sensors at 36 points for different levels (top, medium and base level). The research was carried out in accordance with the randomized plot design for the purpose of storing Aronia melanocarpa in a cold store at +3ºC for 1 month. The results were evaluated by using variance analyses and descriptive statistics. In addition, spatial variability maps were created for evaluating of temperature and relative humidity variation at different levels. Variation of the temperature was determined between 3.40ºC and 5.32ºC for top level, 3.80ºC and 5.49ºC for middle level and 3.92ºC and 5.51ºC for base level at 3ºC storage temperature. Coefficient of variations was determined as 11.47% for top level, 11.48% for middle level and 7.10% for bottom level for temperature. The relative humidity values were changed between 74.00% and 88.09%. Mean coefficient of variation of the relative humidity varied between 3.22% and 4.43%. According to the results; distributions of the temperature and relative humidity for different levels were not uniform. Reason of high variability between measurement of the temperature and the relative humidity for different levels in the cold store was the distribution of the cold air. The cold air was ventilated by an evaporator and distributed according to the design of the cold store (dimensions, shape, and materials) and placement of fruit cases. Different storage conditions were determined at different levels in the cold store during storage of Aronia fruits in this research. In addition, there is generally one temperature/relative humidity sensor located back of the door inside the cold store used to control the cooling system. Measurement of the temperature and relative humidity from one point in a cold store is not enough to give an idea about the ambient conditions of the cold store. When storing agricultural products, the use of more temperature/relative humidity sensors in the cold store will enable the actual situation of the temperature and relative humidity values to be taken into account to control the operation of the cooling system. Additional cold air distribution systems such as ventilator, air curtains and placement of fruit cases may help to improve air distribution and decrease the spatial variability of the storage conditions in the cold store.

Keywords: Aronia, Cold storage, Evaporative cooling, Ambient factors, Spatial distribution

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Öz

Bu araştırmada, Aronia melanocarpa Nero meyvelerinin, evaporatif soğutma sistemli bir soğuk hava deposunda 1 ay boyunca depolanması sırasında, ortam sıcaklığının ve bağıl nemin farklı seviyelerdeki değişimi araştırılmıştır. Depolama sırasında ortam sıcaklığı ve bağıl nemi farklı seviyelerde (üst, orta ve alt seviyelerde) 36 noktada sensörler ile ölçülmüştür. Araştırma, aronya melanocarpa meyvelerinin +3ºC da soğuk hava deposunda depolanması amacıyla tesadüf parselleri deneme desenine uygun olarak 1 ay sürdürülmüştür. Araştırma sonuçları varyans analizi ve tanımlayıcı istatistikler kullanılarak değerlendirilmiştir. Ayrıca, soğuk hava deposunun farklı seviyeleri için ortam sıcaklığı ve bağıl nemin mekânsal değişkenlik haritaları değişkenliğin grafiksel olarak da değerlendirilmesi için oluşturulmuştur. Sıcaklık değişimi, üst seviye için 3.40ºC ile 5.32ºC, orta seviye için 3.80ºC ile 5.49ºC ve taban seviyesi için 3.92ºC ile 5.51ºC arasında saptanmıştır. Soğuk hava deposunda üst, orta ve alt seviyeler için varyasyon katsayıları sırasıyla %11.47, %11.48 ve %7.10 olarak belirlenmiştir. Bağıl nem %74.00 ile % 88.09 arasında değişmiştir. Bağıl nem varyasyon katsayısı %3.22 ile %4.43 arasında değişmiştir. Araştırma sonuçlarına göre; aronya meyvelerinin depolandığı soğuk hava deposunda, farklı seviyelerdeki düzlemler için ortam sıcaklığı ve bağıl nemin konuma bağlı dağılımı tekdüze değildir. Soğuk hava deposundaki farklı seviyelerde sıcaklık ve bağıl nem ölçümleri arasındaki yüksek değişkenliğin nedeni, soğuk havanın dağılımıdır. Soğuk hava, bir evaporatör tarafından depo içine gönderilmektedir ve soğuk deponun tasarımı (boyutlar, biçim ve malzeme) ve meyve kasalarının depo içinde yerleşimine göre dağılmaktadır. Bu araştırma çalışmasında; Aronia meyvelerinin muhafaza edilmesi sırasında soğuk depoda farklı seviyelerde farklı depolama koşulları belirlenmiştir. Ayrıca, soğutma sistemini kontrol etmek için kullanılan soğuk hava deposunun içinde, genellikle kapının arkasına yerleştirilmiş bir sıcaklık/bağıl nem sensörü bulunur. Soğuk hava deposunda bir noktadan sıcaklık ve bağıl nemin ölçülmesi, soğuk hava deposunun ortam koşulları hakkında fikir vermek için yeterli değildir. Tarım ürünleri depolanırken, soğuk depoda daha fazla sıcaklık/bağıl nem sensörünün kullanılması, soğutma sisteminin çalışmasını kontrol etmek için dikkate alınan sıcaklık ve bağıl nem değerlerini gerçek durumunun belirlenmesini sağlayacaktır. Vantilatör, hava perdeleri gibi ek soğuk hava dağıtım sistemlerinin kullanılması ve meyve kasalarının yerleşimi, hava dağılımını iyileştirmeye ve soğuk depodaki depolama koşullarının mekansal değişkenliğini azaltmaya yardımcı olabilir.

Anahtar Kelimeler: Aronya, Soğuk depolama, Evaporatif soğutma, Ortam koşulları, Yersel değişkenlik

1. Introduction

Cold storage is one of the important process after harvesting of agricultural products. Cold storage conditions affect directly quality and quantity of stored products. There are different cooling systems such as evaporative cooling systems and chiller cooling system. In addition, size, shape, pressure inlets, suction outlets, door and construction of the construction are also important for cold storage. The cooling system determines distribution of the temperature and relative humidity in the cold stores. Type, size and placement of the storage cases determine distribution of the ambient factors such as air velocity, temperature and relative humidity in a cold store. Another factor is cold stored product for creating effect on the distribution of the storage factors in a cold store. The design of the cold store, type of the cooling system, cold storage boxes/cases and stored products have effect on storage conditions. Because of all these factors is important for cold storage. In this research, ambient temperature and relative humidity of a cold store were investigated during the cold storage of Aronia melanocarpa Nero variety fruits.

Black chokeberry (Aronia melanocarpa (Michx.) Elliott) belongs to the Rosaceae family, subfamily Maloideae, and is a deciduous shrub originating from the eastern part of North America (Persson et al., 2004; Ochmian et al., 2012). Aronia is a berry species. It consists of with its high antioxidant capacity and anthocyanin content (Karadal et al., 2019). Aronia melanocarpa is a source of bioactive compounds. Fresh chokeberry fruits are generally used for juices, nectars, syrups, jams, preserves, wines, tinctures, fruit desserts, jellies, fruit teas and dietary supplements (Sidor and Gramza-Michałowska, 2019). The Aronia fruit has more antioxidants than blueberries, acai berries and goji berries. It is used from juices to powdered supplements to baby food (Kashian et al., 2016). The composition and properties of aronia berries also depend on their cultivar. "Nero," "Galicjanka," "Viking," "Fertodi," "Hugin," and¨ "Aron" are popular varieties in Europe (Borowska and Brzoska, 2016). Chokeberry products consists of 27 polyphenolic compounds, 7 anthocyanins, 11 flavanols, 5 phenolic acids, 3 flavan-3-ols and 1 flavanone according to the results of a research. In addition, derivatives of three anthocyanin were determined (Oszmianski and Lachowicz, 2016). Aronia berries and leaves are rich in total polyphenol and flavonoid content that enables the plant to register higher antioxidant activity in comparison to many other culinary herbs and medicinal plants in use (Shahin et al., 2019). Berries can be processed into many values added products giving a boost to the local economy. Possible usage of black chokeberry for protection against unfavourable health effects of substances was evaluated. According to the evaluations; fruit and the leaves of Aronia melanocarpa and their products may be effective for prevention and treatment of the effects of toxic action of some xenobiotics in humans (Borowska and Brzoska, 2016). The influence of storage temperature and period on the phytochemical content and antioxidant activity of aronia was investigated in a research. The total polyphenol and flavonoid contents of aronia extract were found to be 308.48 µg gallic acid equivalent/g dry weight and 5.33 µg quercetin equivalent/g dry weight, respectively. Long-term storage of Aronia at 4°C reduced the levels of health promoting compounds (Hwang and Yeom, 2019). Aronia fruits can both be processed and consumed freshly, and sold at quite good prices, the interest for Aronia production keeps growing. It shows high resistance to frost, mechanized harvesting, damage during transportation and cold storage. Due to these advantages, popularity of chokeberry has increased recently (Wawer, 2006).

Aronia industry is considered to grow with the increase of its production in Turkey (Engin et al., 2016; Engin and Boz, 2019). Aronia berry (Aronia melanocarpa) is native to North America. Aronia is being cultivated commercially in Europe. First studies began in Atatürk Horticultural Central Research Institute in 2012 in Turkey. Commercial cultivation began in 2017 with the establishment of larger orchards particularly in Marmara and Black Sea Regions in Turkey. The optimum harvest dates were determined for 'Nero' and 'Viking' Aronia cultivars. The second week of September was determined as optimum harvest time for 'Nero' and 'Viking' Aronia cultivars (Engin and Mert, 2020).

Distribution of temperature, relative humidity and air velocity were determined for different storage temperatures such as 0ºC, 1ºC, 2ºC and 3ºC in a store. Spatial variability maps were created. Storage temperature and the relative humidity were not uniform in the cold store (Akdemir and Arin, 2006). Temperature variation in cold store can be minimized with adequate air circulation. Most stores are designed to provide an airflow of $0.3 m^3 min^{-1}$ per ton of stored product. This is needed to cool product to storage temperature and also may be needed if the product has a high respiration rate (Arkema et al., 1999). Air velocity should be $0.2 ms^{-1}$. Its mean is equivalent velocity to change empty volume of cold store for 25-30 times per hour (Cemeroğlu et al., 2001). An improved internal structure was proposed to improve the distribution of cooling capacity in refrigerated container in a research. The velocity and temperature of the previous refrigerated container and the improved refrigerated container were obtained and compared. The cold airflow distribution in the improved refrigerated container was more uniform. The cooling performance of the two refrigerated containers were also obtained. The variation of temperature distribution was within ±1°C and the cooling time was also reduced by at least 22.9% in the improved refrigerated container (Jiang et al., 2020). A Computational fluid dynamics (CFD) model was developed, validated and used to analyse cooling characteristics of two different package designs used for postharvest handling of pomegranate fruit. The model incorporated geometries of fruits, packaging box, tray and plastic liner. The accuracy of the model to predict airflow and temperature distributions were validated against experimental data. The model predicted airflow through the stacks and cooling rates within experimental error. Stack design markedly affected the airflow profile, rate and uniformity of cooling. Profile of high and low temperature regions depended considerably on packaging box design (Ambaw et al., 2017). An experimental investigation of airflow field, temperature characteristics (fruits and air), convective heat transfer coefficient, half cooling time and weight loss measurement of fruits loaded in crates inside the cold room was carried out. Results showed significant cooling heterogeneity inside the cold room during the cooling period. The maximum cooling heterogeneity identified along the length of the cold room (Bishnoi and Aharwal, 2020). Temperature and relative humidity distribution in an experimental cold store fully loaded with apples were investigated with experimental and numerical methods. An unsteady three-dimensional computational fluid dynamics model was developed to assess the distribution of temperature and relative humidity in a cold store fully loaded with apples. Relative error of the model was calculated 13% for temperature and 1.43% for relative humidity (Akdemir and Bartzanas, 2015). Computational Fluid Dynamic (CFD) method was also used to estimate ambient conditions of tractor cabin. (Akdemir et al., 2016). Spatial variability of ambient temperature, relative humidity and air velocity in an empty cold store were determined by using management zone analysis methods. The measured data were analysed by MZA software which performed fuzzy clustering to delineate the full cold storage, half full cold storage and empty cold storage. In addition, Surfer mapping software was utilized to create the maps of the measured parameters. The results indicated that there was significant spatial variation of the basic storage parameters such as ambient temperature, relative humidity and air velocity in the cold storage, which denotes the significance of management zones delineation in these facilities so as to maximize the storage (Akdemir and Tagarakis, 2014).

In this research; Aronia melanocarpa Nero variety fruits were stored in a cold store has an evaporative cooling system. Temperature and relative humidity in the cold store were measured for different levels during storage. Temperature and relative humidity were measured by Testo 177H1 sensor. Measurements were realized for top, medium and base level of the cold store. The spatial variability maps of the temperature and relative humidity were created for when Aronia fruits stored. In addition, statistical analyses were applied to compare spatial distribution of different levels.

2. Materials and Methods

2.1. Cold store

The cold store has an evaporative cold store. The evaporative cooling system consists of compressor, condenser and evaporator. Cold air was ventilated in the cold store by evaporator. Its volume was 392 m^3 (11.85 x 7.75 x4.27 m) *(Figure 1).* Specifications of the cooling system was given in *Table 1.* Cooling system performance was given in *Table 2.*

Table 1. Specifications of the cooling system

Specifications	Value
Refrigerant	R404A
Evaporation temperature (°C)	-10.0
Condensation temperature (°C)	45.0
Reference temperature (°C)	Dew point temperature
Suction gas temperature (°C)	20.0
Evaporator outlet temperature (°C)	20.0
Liquid subcooling (K)	0.0

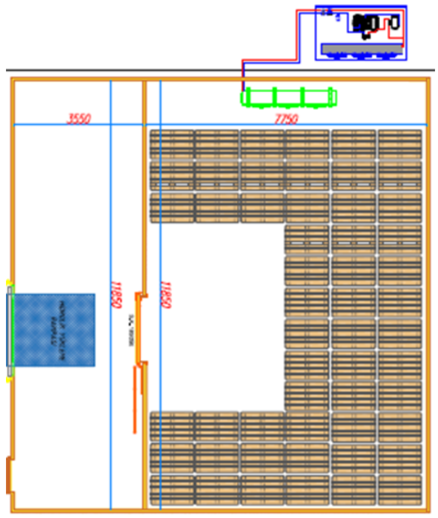

Figure 1. General view and dimensions of the cold store

Table 2. Cooling system performance

	Evaporator	Compressor
Cooling capacity (W)	18310	18310
Power absorbed (kW)	8.37	8.37
Total heat removed (kW)	26.67	26.67
Coefficient of Performance (COP)	2.19	2.19
Mass flow quantity (kgh^{-1})	550.1	550.1
Compression temperature (°C)	88.9	88.9

2.2. Aronia

Chokeberry (black chokeberry) is a species with lower cultivation requirements within Rosaceae family. It is cultivated also in East European countries and Germany (Kulling and Rawel, 2008). In this research; Aronia melanocarpa Nero variety chokeberry was cold stored *(Figure 2).*

Figure 2. Aronia melanocarpa (Anonymous, 2021)

2.3. Sensors

The temperature and relative humidity were measured during cold storage of the Aronia melanocarpa. Testo 177 H1 data loggers were used to measure temperature and relative humidity. Measurement limits and accuracy of sensors were -20ºC and +100ºC and accuracy ± 1% for temperature, 0 - 100% RH and accuracy were 2% for relative humidity.

2.4. Experimental design

Aronia Melanocarpa Nero variety was stored for 5 weeks (14th September 2021 and 17th October 2021). Temperature was set as 4ºC for cold storage. Humidification was not applied during cold storage. Aronia melanocarpa fruits were cold stored in plastic cases and carton boxes. Aronia fruits were in nets and located in the carton cases during cold storage *(Figure 3).*

Total amount of the cold stored Aronia melanocarpa was 21000 kg. It was cold stored in plastic and carton cases.

Figure 3. Plastic and carton cases

2.5. Ambient temperature and relative humidity measurements

Temperature and relative humidity were measured from cold store and in the plastic cases for 3 different levels (bottom, middle and top level). Measurements were realized from 12 points (4 in length and 3 points in width of the cold store) for each level and for 3 levels as top, middle and base level. Temperature and relative humidity were measured from 36 points *(Figure 4)* (Akdemir and Bal., 2014). The distances between measurements were 2m in width, 2.5 m in length and 0.5 m in height of the cold storage boxes.

Figure 4. Measurements points and sensors in the cold store

The measured data of the ambient temperature and relative humidity were evaluated by using descriptive statistics such as mean, minimum, maximum, standard deviation (SD) and coefficient of variation (CV%). In addition, the results were compared by statistically. The experiment was designed as 3 factor factorial design in 4 replications and variance analysis and F test were used to compare differences between factors and their interactions. According to the F test, Duncan grouping test was used for grouping of the significant factors and interactions. SPSS statistical software was used for variance analysis and MSTAT software for grouping of the significant factors and interactions. If effect of main and interactions of ambient temperature and relative humidity were found statistically significant, Duncan grouping test were used. Standard error of means for main factor and their interactions were also given for Duncan grouping tests (Soysal, 2000; Soysal and Gurcan, 2012).

2.6. Producing of Spatial Variability Maps

Spatial variability maps of the temperature and relative humidity for storage of the Aronia melanocarpa Nero fruits in the cold store with evaporative cooling system.

Surfer Graphic Programme was used to create maps. Measured data arranged in a file to use by Surfer Programme. Surfer Programme created grid data files. The grid data files were used to create contour maps. The maps were investigated to determine changing of the temperature, air velocity and relative humidity in the cold store (Akdemir and Blackmore, 2004).

3. Results and Discussion

3.1. Ambient temperature

Measured temperatures values for different levels and descriptive statistics were given in *Table 3.*

Variation of the temperature of the cold store at 3ºC storage temperature changed between 3.40ºC and 5.32ºC for top level, 3.80ºC and 5.49ºC for middle level and 3.92ºC and 5.51ºC for base level. Mean Coefficient of variations of top, middle and bottom level at the cold store were determined ad 11.47%, 11.48 % and 7.10%, respectively.

Table 3. Ambient Temperature (ºC)

	Top Level				Medium Level				Base Level			
	Width				Width				Width			
Length	**1**	**2**	**3**	**Mean**	**1**	**2**	**3**	**Mean**	**1**	**2**	**3**	**Mean**
1	5.14	4.84	5.11	**5.03**	5.25	3.99	3.98	**4.40**	5.15	5.15	5.15	**5.15**
2	3.97	4.22	3.81	**4.00**	5.25	5.15	4.18	**4.86**	5.18	5.15	5.15	**5.16**
3	3.91	4.22	4.98	**4.37**	3.99	3.99	3.99	**3.99**	4.17	5.15	5.15	**4.82**
4	4.26	4.22	4.30	**4.26**	3.99	3.99	3.99	**3.99**	5.15	3.99	5.15	**4.76**
Mean	4.32	4.37	4.55	**4.41**	4.58	4.30	4.10	**4.33**	4.89	4.89	5.14	**4.97**
Min.	3.60	3.86	3.40	**-**	3.80	3.92	3.92	**-**	4.10	3.92	5.03	**-**
Max.	5.32	5.28	5.27	**-**	5.49	5.23	5.23	**-**	5.51	5.23	5.23	**-**
SD	0.50	0.43	0.59	**0.51**	0.66	0.53	0.31	**0.50**	0.46	0.51	0.08	**0.35**
CV(%)	11.60	9.91	12.89	**11.47**	14.48	12.44	7.52	**11.48**	9.49	10.32	1.50	**7.10**

Spatial distribution maps of the ambient temperature were given in *Figure 5* for top, middle and base level of the cold storage boxes.

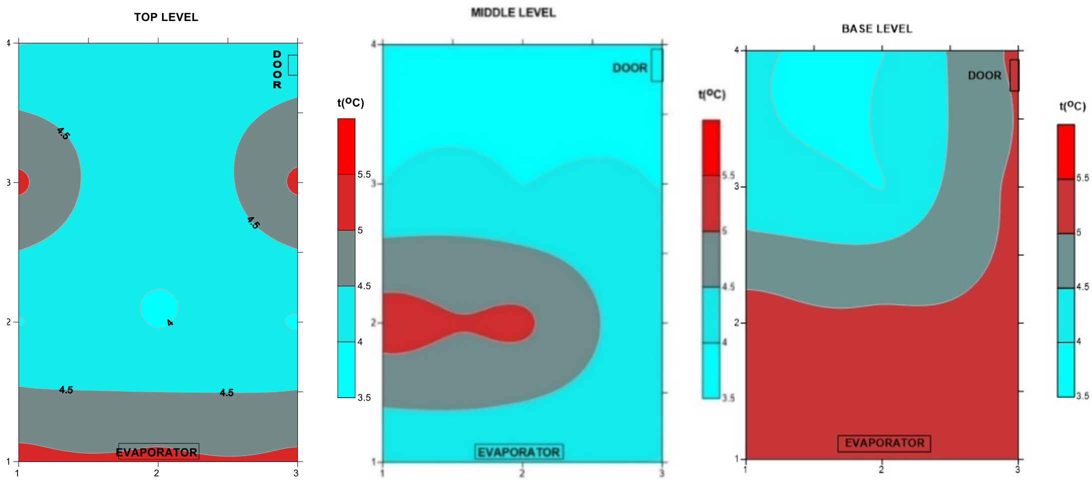

Figure 5. Spatial distribution maps of the ambient temperatures

Variation of the ambient temperature of the cold store at 3ºC storage temperature changed between 3.5ºC and 5.0ºC for top level, 3.5ºC and 5.5ºC for middle level and base level. There were 3 or 4 different cold zone for the stored fruits. There were important heterogeneities of the spatial distribution of ambient temperature for different levels. There were different storage conditions for cold stored Aronia fruits located at different levels of cold store. The spatial variability was also an indicator of unevenness of cold air distribution affected by cooling system, cold store construction (size, geometry, materials), storage boxes and cold stored product. Variance analysis of the measured temperature data was given in *Table 4*.

Table 4. Variance analysis of measured ambient temperature (ºC)

Source	Sum of Squares	Degree of Freedom	Mean Square	F	Sig.
Levels	12.150	2	6.075	119.992	0.000
Width	0.321	2	0.160	3.168	0.046
Length	6.522	3	2.174	42.937	0.000
Level * Width	3.627	4	0.907	17.910	0.000
Level * Length	8.219	6	1.370	27.055	0.000
Width * Length	7.270	6	1.212	23.932	0.000
Level * Width * Length	4.900	12	0.408	8.066	0.000
Error	5.468	108	0.051		
Total	3047.317	144			

According to the variance analysis; differences between temperature values for levels (F=119.992, α=0.001), width

(F=3.168, α=0.046), and length of the levels (F=42.937, α=0.001) and all interactions were also found statistically important. Main factors and interaction were grouped for α= 0.05 significant levels by Duncan test. Standard error and Duncan test results of main factors (Levels, width and length) and interactions between main factors (level x width, level x length, width x length, level x with x length) were given in *Table 5* and *Table 6*, respectively.

Table 5. Standard error of means for main factors and interactions

	Level	Width	Length	Levels x Width	Level x Length	Width x Length	Level x Width x Length
Standard Error of Means	0.02053	0.03283	0.12379	0,11885	0.09511	0.13031	0.09249

Table 6. Duncan Test Results for Ambient Temperature (°C)

Levels	Width	Length 1	Length 2	Length 3	Length 4	Mean	Mean (Level)
1 (Top)	1	5.14 ab	3.97 cde	3.91 de	4.26 cd	**4.32 d**	**4.41 B**
	2	4.84 b	4.22 cd	4.22 cd	4.22 cd	**4.37 d**	
	3	5.11 ab	3.81 e	4.98 ab	4.30 c	**4.55 c**	
	Mean (Level x Length)	**5.03 ab**	**4.00 e**	**4.37 d**	**4.26 d**		
2 (Medium)	1	5.25 a	5.25 a	3.99 cde	3.99 cde	**4.62 c**	**4.3 C**
	2	3.99 cde	5.15 ab	3.99 cde	3.99 cde	**4.28 d**	
	3	3.98 cde	4.18 cde	3.99 cde	3.99 cde	**4.03 e**	
	Mean (Level x Length)	**4.40 d**	**4.86 bc**	**3.99 e**	**3.99 e**		
3 (Base)	1	5.15 ab	5.18 ab	4.17 cde	5.15 ab	**4.91 b**	**4.97 A**
	2	5.15 ab	5.15 ab	5.15 ab	3.99 cde	**4.86 b**	
	3	5.15 ab	5.15 ab	5.15 ab	5.15 ab	**5.15 a**	
	Mean (Level x Length)	**5.15 a**	**5.16 a**	**4.82 c**	**4.76 c**		
Means (Width x Length)	1	5.18 a	4.80 b	4.02 e	4.46 d	**4.61 A**	
	2	4.66 bc	4.84 b	4.45 d	4.06 e	**4.50 A**	
	3	4.75 b	4.38 d	4.70 b	4.48 cd	**4.58 A**	
Mean (Length)		**4.86 A**	**4.67 B**	**4.39 C**	**4.33**		

According to the *Table 5* and *Table 6*; effect of levels on the ambient temperature variability was determined as different group ($S_{\bar{x}}$=0.02053, α=0.05). Minimum ambient temperature was determined as 4.31°C in the middle level. Its means is evaporative cooling system and placement of cold storage cases affected distribution of the ambient factors. Storage temperature was not same for all levels. Even there were differences between ambient temperature measurements for widths, mean values were evaluated in the same group ($S_{\bar{x}}$=0.03283, α=0.05). Significant level was calculated as 4.6%. It is close to 5% significant level used generally for grouping of the statistically significant factors. Duncan test did not evaluate as different group for α=0.05 level because of 4.86% as significant level is close to 5%. Differences between ambient temperature measurements for length were statistically important. The ambient temperature measurements for length were classified in 3 groups by Duncan test ($S_{\bar{x}}$=0.12379, α=0.05). First measurement point of the length close to the evaporator was the first and the highest temperature measured for this point. Temperature was smaller than 3rd and 4 measurement points located far away from evaporator. Effect of main factors on variation of the ambient temperature were important consequently their interactions effects were fount statistically important on the ambient temperature. Levels x Width interactions were classified in 5 groups ($S_{\bar{x}}$=0,11885, α=0.05), Levels x Length ($S_{\bar{x}}$=0.09511, α=0.05) and Width x Length interactions ($S_{\bar{x}}$=0.13031, α=0.05) in 7 groups and Level x Width x Length interactions in 9 groups ($S_{\bar{x}}$=0.09249, α=0.05) after Duncan Grouping tests.

3.2. Relative humidity

Measured relative humidity values for different levels and descriptive statistics were given in *Table 7*. Variation of the relative humidity changed between 75.73% and 88.09% for top level, 74.00% and 86.70% for middle level and

74.13% and 85.64% for base level. Mean Coefficient of variations of top, middle and bottom level at the cold store were determined ad 4.43%, 4.02 % and 3.22%, respectively. Ambient relative humidity of the cold store was not controlled by the cooling system, automatically or manual because of cold stored Aronia Melanocarpa Nero fruits requirement.

Table 7. Relative Humidity (%)

	Top Level				Medium Level				Base Level			
	X Axis				X Axis				X Axis			
Y Axis	**1**	**2**	**3**	**Mean**	**1**	**2**	**3**	**Mean**	**1**	**2**	**3**	**Mean**
1	76.66	80.39	78.59	**78.54**	77.00	83.39	83.39	**81.26**	75.65	77.17	77.17	**76.66**
2	85.55	85.37	85.09	**85.34**	77.00	77.17	83.39	**79.19**	76.43	77.17	77.17	**76.93**
3	85.65	85.37	77.52	**82.85**	83.01	83.39	83.39	**83.26**	82.45	77.17	77.17	**78.93**
4	83.84	85.37	81.72	**83.64**	83.01	83.39	83.39	**83.26**	77.17	83.39	77.17	**79.25**
Mean	82.93	84.13	80.73	**82.59**	80.01	81.84	83.39	**81.74**	77.93	78.73	77.17	**77.94**
Min.	76.10	76.76	75.73	-	74.00	75.73	75.73	-	74.13	75.73	75.73	-
Max.	88.09	87.62	87.20	-	86.70	85.64	85.64	-	84.29	85.64	79.00	-
SD	4.37	3.21	3.40	**3.66**	3.95	3.35	2.51	**3.27**	3.09	3.09	1.37	**2.52**
CV(%)	5.27	3.81	4.21	**4.43**	4.93	4.09	3.03	**4.02**	3.96	3.94	1.77	**3.22**

Spatial distribution maps of the relative humidity were given in Figure 6 for top, middle and base level of the cold storage boxes.

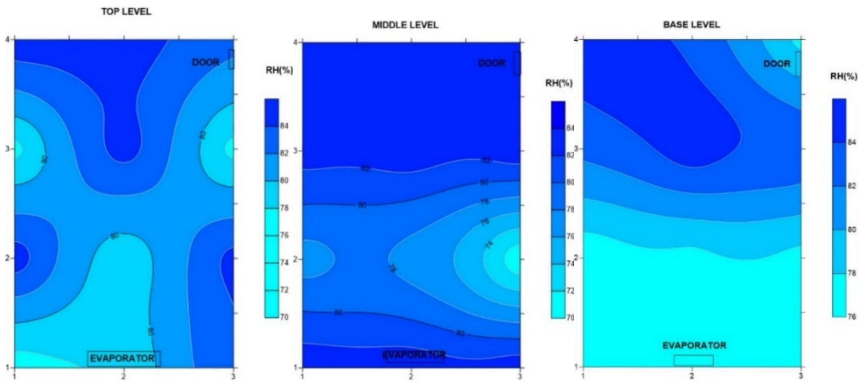

Figure 6. Spatial distribution maps of the relative humidity (RH %)

Variation of the relative humidity of the cold store was changed between 70% and 84% for top level, middle level and base level. There were 3 or 4 different cold zone for the stored fruits. There were important heterogeneities of the spatial distribution of relative humidity for different levels. Variance analysis of the measured relative humidity data was given in *Table 8*.

Table 8. Variance analysis of measured relative humidity (%)

Source	Sum of Squares	Degree of Freedom	Mean Square	F	Sig.
Levels	588.799	2	294.399	69.379	0.000
Width	46.994	2	23.497	5.537	0.005
Length	228.147	3	76.049	17.922	0.000
Level * Width	159.377	4	39.844	9.390	0.000
Level * Length	273.662	6	45.610	10.749	0.000
Width * Length	282.177	6	47.029	11.083	0.000
Level * Width * Length	137.908	12	11.492	2.708	0.003
Error	458.283	108	4.243		
Total	941351.154	144			

According to the variance analysis; differences between relative humidity values were important for levels (F=69.379, α=0.001), width (F=5.537, α=0.005) and length (F=17.922, α=0.001) of the levels and all interactions. Main factors and interaction were grouped for α= 0.05 significant levels by Duncan test. Standard error and Duncan test results of main factors (Levels, width and length) and interactions between main factors (level x width, level x length, width x length, level x with x length) were given in *Table 9* and *Table 10*, respectively.

Table 9. Standard error of means for main factors and interactions

	Level	Width	Length	Levels x Width	Level x Length	Width x Length	Level x Width x Length
Standard Error of Means	1.42955	0.40399	0.72758	0.85245	0.82980	0.59288	0.58418

Table 10. Duncan Test Results for Ambient Temperature (^oC)

Levels	**Width**	**Length**					**Mean (levels)**
		1	**2**	**3**	**4**	**MEAN**	
1	**1**	76.66 l	85.55 a	85.65 a	83.84 c	82.92 ab	**82.59 A**
	2	80.39 h	85.37 ab	85.37 ab	85.37 ab	84.12 a	
	3	78.59 i	85.09 b	77.52 j	81.72 g	80.73 cd	
	Mean (Level x Length)	**76.44 j**	**79.66 h**	**83.70 b**	**81.34 d**		
2	**1**	77.00 k	77.00k	77.00k	83.01e	80.00 de	**81.74 B**
	2	83.39 d	77.17jk	83.39d	83.39d	81.84 bc	
	3	83.39 d	83.39 d	83.39d	83.39 d	83.39 a	
	Mean (Level x Length)	**80.32 f**	**79.91 g**	**81.98 c**	**84.05 a**		
3	**1**	75.65 m	76.43 l	82.45f	77.17 k	77.93 fg	**77.94 C**
	2	77.17 k	77.17 k	77.17k	83.39d	78.73 ef	
	3	77.17k	77.17k	77.17k	77.17k	77.17 g	
	Mean (Level x Length)	**79.72 h**	**81.89 c**	**79.36 i**	**80.76 e**		
Mean (Length)		**78.82 C**	**80.48 B**	**81.68 A**	**82.05 A**		
	Width					**Mean**	
Means	**1**	78.54de	85.34 a	82.85bc	83.64 b	**80.28 b**	
	2	81.26 c	79.19 d	83.26b	83.26 b	**81.56 a**	
	3	76.66 f	76.93 ef	78.93d	79.25 f	**80.43 b**	

According to the *Table 9* and *Table 10*;

- Effect of levels on the relative humidity variability was determined as different group ($S_{\bar{x}}$=1.42955, α=0.05). Minimum relative humidity was determined as 77.94% in the base level. Its means is evaporative cooling system and placement of cold storage cases affected distribution of the relative humidity.
- The relative humidity for measurement points on width of the cold store were determine in 2 groups by Duncan test ($S_{\bar{x}}$=0.40399, α=0.05). The difference between two groups was 1.28%. Even differences between width measurement points were statistically important, in the practice, 1.28% is not important for humidity control because the relative humidity sensors accuracy was 2% and this value is smaller than accuracy values. When we look the relative humidity values for width, there are very close each other.
- Differences between relative humidity measurements for length of the cold store were statistically important. The relative humidity measurements for length were classified in 3 groups by Duncan test ($S_{\bar{x}}$=0.72758, α=0.05). First measurement point of the length close to the evaporator was the first and the relative minimum relative humidity value was determined as 78.82. The highest relative humidity was measured at 3rd and 4 measurement points located far away from evaporator. Evaporative cooling system affected variability of the relative humidity along the cold store.
- Levels x Width interactions were classified in 8 groups ($S_{\bar{x}}$=0.85245, α=0.05), Levels x Length ($S_{\bar{x}}$=0.82980, α=0.05) and Width x Length interactions ($S_{\bar{x}}$=0.59288, α=0.05) in 7 groups and Level x Width x Length

interactions in 9 groups ($S_{\bar{x}}$=0.58418, α=0.05) by Duncan Grouping tests. Effect of main factors on variation of the relative humidity were statistically important, consequently their interactions effects were also found statistically important.

4. Conclusions

Homogeneity of the ambient temperature and relative humidity is important to protect agricultural product in a cold store. There are different cooling systems that used in cold stores. In this research, a cold store with evaporative cooling system was used to determine spatial distribution of ambient temperature and relative humidity for Aronia melanocarpa Nero variety. Temperature and relative humidity sensors used in this cooling system located at one point of the cold store. The ambient temperatures and relative humidity were determined at top, middle and floor level in the cold store for storage temperatures as 3ºC. Mapping software and descriptive statistics (mean, maximum, minimum, standard deviation and coefficient of variation) were used to evaluate data. Ambient temperature varied between 3.40ºC and 5.32ºC for top level, 3.80ºC and 5.49ºC for middle level and 3.92 ºC and 5.51 ºC for base level at 3ºC storage temperature. Relative humidity changed between 74.00% and 88.09%.

The results showed that distribution of the ambient temperature and the relative humidity was not uniform for this system. Maximum differences were observed near the walls of the cold store. A more homogeneous distribution was achieved in the middle of the cold store both for air temperature and relative humidity. Reason of bad spatial distribution of ambient temperature was bad spatial distribution of air velocity generated by evaporator fan. There were different storage conditions for cold stored Aronia fruits located at different levels of cold store. The spatial variability is also an indicator of unevenness of cold air distribution affected by cooling system, cold store construction (size, geometry, materials), storage boxes and cold stored product. In addition, there is generally one temperature and relative humidity sensor to measure the ambient temperature and the relative humidity in the cold store to control cooling system. These sensors measure from one point of cold store. Using more sensor to get data from different levels of the cold store will help to decrease spatial variability in the cold store.

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