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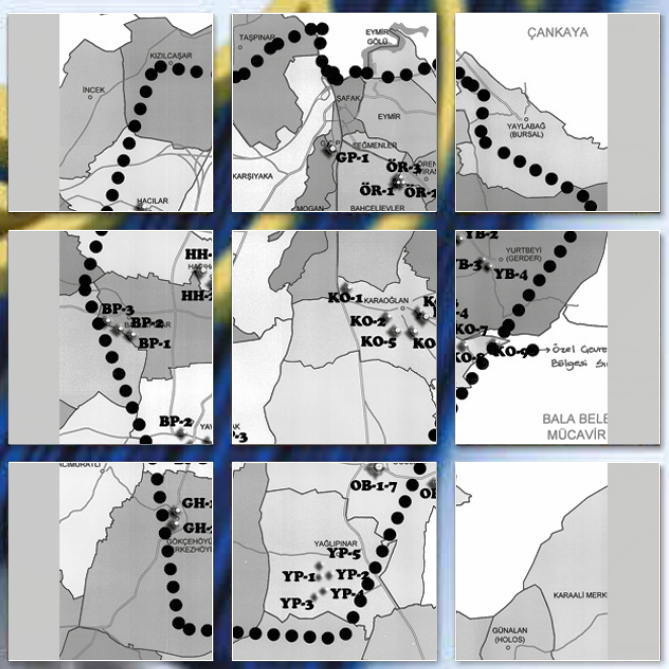

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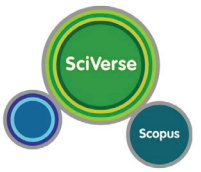

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Detection of Shape Manufacturing Defects of Flat Fan-Pattern Nozzle Orifices Using Elliptic Fourier Descriptors

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ABSTRACT

Shape defects originating from the manufacture in the orifice openings of the flat fan-pattern nozzles may result in deteriorating the spray pattern. This study has been conducted with the aim of detecting the manufacturing defects of the fan-pattern nozzle orifices in terms of shape uniformity using the elliptic Fourier descriptors (EFDs), and revealing the shape differences among the nozzle orifices made in polyacetal for various nominal sizes ranging from 01 to 06. At first, descriptive data describing dimensions (major and minor length, projected area, etc.) and shapes (shape factor, elongation and roundness) of the nozzle orifices were obtained using an image processing method. The next process, to evaluate the nozzles' orifice shape using elliptic Fourier analysis (EFA), the progresses of generating the orifice's contour data, derivation of EFDs, principal component analysis (PCA) of EFDs and visualization of shape variations estimated by the principal component scores (PCs) were followed respectively. Although the shape differences of the orifice outlines could be visually distinguished, the descriptive shape data were not able to discriminate the contour differences. The EFDs determined for each orifice size could individually detect the nozzle orifices with shape defect originating from the manufacture and they could be explicitly distinguished from the scatter plots. The results of the Hotelling's pairwise comparison test showed that the nozzle orifices in shape were significantly different from each other. Linear discriminant analysis demonstrated that the group centroids of the orifices of 03, 04 and 06 were found close-range to each other. The orifice of 01 which is rectangular in shape had an extraordinary attribute compared to the other orifices. The orifice outline of 015 with a smooth shape was in appearance of an oblate ellipse in shape. The contour of the nozzle orifice of 02 size was explicitly found different from the others. It was concluded that the EF method can be used intended for the manufacturers inspect and improve the quality of nozzle orifices.

Keywords: Image processing; Nominal size; Orifice contour; Orifice size; Shape analysis

Yelpaze Hüzmeli Meme Orifislerinde Şekilsel Üretim Hatalarının Eliptik Fourier Tanımlayıcılarıyla Tespiti

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ÖZET

Yelpaze hüzmeli memelerin orifis açıklığında üretimden kaynaklanan şekilsel hatalar, püskürtme deseninin bozulmasına yol açabilmektedir. Bu çalışma eliptik Fourier tanımlayıcılarını kullanarak yelpaze hüzmeli meme orifislerinin şekil düzgünlüğü açısından üretim hatalarını tespit etmeyi ve anma ölçüleri 01 ve 06 arasında değişen polyacetal malzemeden üretilmiş meme orifislerinin şekil farklılıklarını belirlemek amacıyla yürütülmüştür. Öncelikle, görüntü işleme metodu kullanılarak meme orifislerinin boyut (majör ve minör uzunluklar, izdüşüm alanı vd.) ve şekil (şekil faktörü, uzanım ve dairesellik) özelliklerini tanımlayan deskriptif datalar elde edilmiştir. Eliptik Fourier analiziyle memelerin orifis şeklini değerlendirmek için sonraki süreci sırasıyla orifis kontur datalarını oluşturma, eliptik Fourier tanımlayıcılarını elde etme, tanımlayıcıları temel bileşen analizine tabi tutma ve temel bileşen skorlarıyla tahmin edilen şekil değişkenlerini görselleştirme aşamaları takip etmiştir. Orifis konturlarının şekil farklılıkları gözlem yoluyla ayırt edilebilmesine karşın deskriptif şekil dataları kontur farklılıklarını gözetememiştir. Eliptik Fourier tanımlayıcı üretimden kaynaklanan şekil hatalarına sahip meme orifislerini ayrı ayrı tespit edebilmiş ve saçılım grafiklerinden belirgin bir şekilde ayırt edilebilmiştir. Hotelling eşli karşılaştırma testi sonuçları meme orifislerinin şekil açısından birbirlerinden önemli derecede farklı olduğunu göstermiştir. Doğrusal ayırma analizi sonuçları, 03, 04 ve 06 ölçülü orifislerin grup merkezlerinin birbirlerine oldukça yakın bulunduğunu göstermiştir. Diğerleriyle karşılaştırıldığında dikdörtgen biçiminde olan 01 ölçülü orifis, şekilsel açıdan sıra dışı bir özellik göstermiştir. Pürüzsüz bir kontura sahip olan 015 ölçülü orifisin şekilsel açıdan diğerlerine göre daha basık bir elips görünümünde olduğu saptanmıştır. 02 ölçülü orifis konturu diğerlerinden belirgin bir şekilde farklı bulunmuştur. Üreticilerin meme orifis kalitesini denetlemek ve arttırmak için Eliptik Fourier metodunu kullanabileceği kanısına varılmıştır.

Anahtar Kelimeler: Görüntü işleme; Nominal ölçü; Orifis konturu; Orifis ölçüsü; Şekil analizi

1. Introduction

Flat fan-pattern nozzles are one of the most widely used for both broadcast and banding spraying of herbicides and insecticides. These nozzles produce a tapered edge, flat-fan spray pattern. This attribute is the most basic distinguishing characteristic for the flat fan-pattern nozzles because their orifice is elliptical in shape and forms a triangular fan. The spray volume of the nozzles is the highest at the center of the pattern and dissipates toward the outer edge of the orifice.

Spray nozzle is the most important and precision component for a sprayer because the nozzles increase pesticide efficacy resulting in better insect, disease and weed control (Dursun et al 2000; Krause et al 2003). These nozzles can wear over time during pesticide application. The nozzle wear may lead to an increase in the nozzle flow rate, a decrease in the spray pressure, making the spray pattern irregular and produce larger droplets (Barber 2006). These occurrences result in ineffective and incautious pesticide use, waste of active gradient, and decrease spray deposition which potentially leads to increase the cost (Krause et al 2003).

In agro-chemical application, the spray nozzles made in polyacetal, stainless steel and ceramic are commonly used. As well as the spray nozzle wear leads to undoubtedly many problems, nozzle manufacturing defects should be also assumed as a significant quality factor affecting the spray performance. It is likely to come across the spray pattern disturbed by new spray nozzles during the nozzle spray test or calibration of any sprayer. There are many reasons for the deterioration of the spray pattern such as clogging, improper re-assembly, restricting flow and corrosion which can be visually detected. However, at first, the high quality standards relating to the manufacturing of the nozzles should be ensured.

The shape defects in the outline of the nozzle's orifice can be assumed as one of the most important manufacturing defect. Because the shape defects on orifice outline is completely undetectable with the naked eye, the nozzle tests have mostly focused on the change in the flow rate (Reichard et al 1991 cited in Ozkan et al 1992). These tests have been conducted with regard to the procedures standardized by American Society of Agricultural and Biological

Engineers organization (ASAE 1991 affirmed in 2012). According to these standardized procedures, the flow rate from a used nozzle is compared with the flow rate from a reference nozzle of the same size and type, rather than relying on visual inspection.

Ozkan et al (1992) reported that the spraying pressure, duration of test, type, abrasiveness, concentration of material used in the spray mixture, nozzle type, nozzle size, orifice shape and orifice material were the factors affecting the nozzle wear. It was indicated that much of the difference reported in the nozzle wear rates is due to different operating conditions used when testing nozzles (Krishnan et al 2004). However, the shape defects on a nozzle orifice can result in deteriorating the spray patterns, even though a nozzle's flow rate conformed to standards at a constant spray pressure.

Special equipment would be required to actually see the changes in the orifice size and shape. The studies conducted by Krause et al (2003) and Krishnan et al (2004) can be presented as an illustration. In these studies, scanning electron microscopy was used in order to observe the new and used fan-pattern nozzle orifices and, indicated that the scanning electron microscopy can provide nozzle manufacturers with the required information about nozzle to improve performance (Krause et al 2003).

The present study, without a nozzle wear test, aimed to detect the shape defect of fan-pattern nozzle orifices originating from the manufacturing, and to reveal the shape differences and/or similarities of the nozzle orifices with various nominal sizes using elliptic Fourier descriptors.

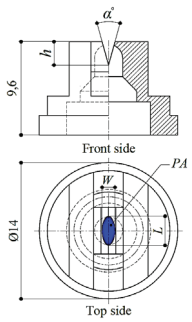
2. Material and Methods

2.1. Obtaining the orifice images of the nozzles and descriptive analysis

In the study, six flat fan-pattern nozzles, nominal sizes of which ranged from 01 to 06, of 110° spray angle were used and listed in Table 1. The number of each nozzle sample of identical orifice size ranged between 26 and 40. In order to get more information about the nozzles' design features, the nozzle images, resolutions of which are 2289 × 1752 pixels, were obtained using a stereo zoom microscope (Olympus SZ60, JP) equipped with a digital camera (Panasonic Lumix DMC-FZ50),

Table 1- Properties of flat fan-pattern nozzles used in the study and their orifice shapes with regard to the subjective assessment

Çizelge 1- Çalışmada kullanılan yelpaze hüzmeli memelerin özellikleri ve subjektif değerlendirmeye göre orifis şekilleri

	*Technical dimensions and designations*	*Orifice size*	*Nominal spray angle*	*Number of sample*	*Nozzle color code*	*Orifice shape*	*Material*	*V-slot angle (α)*	*V-slot height (h, mm)*
		01	110°	40	Orange	Rectangular	POM*	19°	1.2
		015	110°	26	Green	Elliptical	POM	19°	1.4
		02	110°	39	Yellow	Elliptical	POM	23°	1.3
		03	110°	40	Blue	Elliptical	POM	30°	1.4
		04	110°	40	Red	Elliptical	POM	32°	1.7
		06	110°	39	Grey	Elliptical	POM	28°	1.9

*, polyacetal

and the V-slot angle (α°) and height (*h*, mm) shown in Table 1 were measured using UTHSCSA ImageTool© version 1.28 CMEIAS software (The University of Texas Health Science Center in San Antonio, TX) after converting the length size in pixel to millimeter unit.

To capture the nozzles' orifice images, a video microscopy system consisting of a camera, a computer monitor and optics was used. A stereo microscope with 6.3:1 zoom (Leica S6 D, Leica Microsystems, DE) was integrated with a digital microscope color camera (Leica DFC295, Leica Microsystems, DE) offering a standard resolution of 2048 × 1536 pixels. The images were saved on a computer as colored .tiff extension files. SigmaScan®Pro version 5.0 software was used to determine the size and shape features of the orifice openings of the nozzles. The resolution for each image was 2048 × 1536 pixels. During the processing on the image, the region of each nozzle opening with a contrast color was manually marked and automatically colored with the contour of this region. The software automatically determined the opening's size parameters composing of the projected area (*PA*, cm^2), equivalent diameter (*ED*, mm), perimeter (*P*, mm), major length (*L*, mm) and minor length (*W*, mm). To reveal the shape features of the orifice openings of the nozzles, shape factor (*SF*) and elongation (*E*) (Sayinci et al 2012; Kara et al 2013), and roundness (*R*) (Mohsenin 1980) parameters, formulas of which were given in Table 2, were used. While the shape factor was also automatically determined by the software, the elongation and roundness parameters were calculated using these equations.

The nozzle orifices' size and shape data consisting of mean, standard deviation and range were tabulated. To test the variances of the size and shape parameters, the ANOVA with a 95% confidence level (P= 0.05) was performed and, the differences between the means were compared with Duncan's Multiple Range Comparison test using the SPSS version 20.0 statistical software.

2.2. Elliptic Fourier analysis

To evaluate the nozzles' orifice shape based on their elliptic Fourier descriptors (EFDs) SHAPE version 1.3 (Iwata & Ukai 2002) software performing the image processing, contour recording, derivation of EFDs, principal component analysis (PCA) of EFDs and visualization of the shape variations estimated by the principal components (PCs) was used.

Prior to the analysis, all digital images were converted to full color (24-bit) bitmap (*.bmp extension file) format. At the beginning of the image processing, the images were split into three colors (RGB) with 8-bit quantization and the orifice images' background were converted into a binary image (black and white) with an appropriate threshold value which can be also automatically assigned by the software. The closed contour of the orifice on the image came out by edge detection. After the noise reduction applied to eliminate undesirable marks on the image, the contour codes of the orifice with regard to their number were obtained as chain code. The EFDs were obtained from the chain codes and normalized so that the EFDs were invariant with respect to the size, rotation and starting point using elliptic Fourier transformation as suggested Kuhl & Giardina (1982). To generate the coefficient of the normalized EFDs, the first 40 harmonics approximating the shape of each nozzle orifice were used. The PCA based on the variance-covariance matrix was applied to the normalized coefficients of the EFDs having a very large data, and used to reduce the shape descriptors to a smaller number of independent shape variables.

To present the summary of the shape variations of the orifice contours visually and to indicate the percentages of variances explained by PCs, the first two principal component scores obtained from the shape descriptors for each orifice size were tabularized, and the visual differences were presented in figures.

The Multivariate tests (MANOVA) using PAST statistical software version 3.01 (Hammer et al 2001) were performed with the aim of assessing the PC scores obtained from the normalized chain codes

Table 2- Descriptive size and shape properties of the nozzle orifices with regard to their nominal size

Çizelge 2- Nominal ölçüye göre meme orifislerinin tanımlayıcı boyut ve şekil özellikleri

Orifice size	*Statistics*	*Size properties*					*Shape properties*		
		Orifice area (mm^2)	*Equivalent diameter (mm)*	*Perimeter (mm)*	*Major length (mm)*	*Minor length (mm)*	*Shape factor*	*Elongation*	*Roundness*
01	Mean±SD*	0.21±0.01	0.52±0.01	2.60±0.09	1.00±0.01	0.25±0.02	0.40±0.03 b	4.01±0.22 b	3.67±0.14 c
	Range	0.20-0.25	0.50-0.56	2.47-2.86	0.98-1.03	0.22-0.29	0.30-0.46	3.49-4.44	3.30-4.02
	CV**	4.7	2.3	3.4	1.1	6.0	8.0	5.4	3.8
015	Mean±SD	0.42±0.01	0.73±0.01	3.79±0.07	1.55±0.01	0.33±0.01	0.37±0.02 d	4.78±0.15 a	4.52±0.13 a
	Range	0.39-0.44	0.70-0.75	3.67-4.01	1.53-1.58	0.30-0.35	0.33-0.39	4.50-5.26	4.34-4.94
	CV	2.6	1.4	1.9	0.5	3.1	4.6	3.0	2.8
02	Mean±SD	0.50±0.01	0.80±0.01	3.80±0.12	1.56±0.01	0.39±0.01	0.44±0.02 a	4.02±0.11 b	3.78±0.10 b
	Range	0.48-0.53	0.78-0.82	3.61-4.19	1.54-1.59	0.37-0.41	0.37-0.48	3.82-4.23	3.60-3.99
	CV	2.6	1.2	3.1	0.5	2.8	5.5	2.8	2.5
03	Mean±SD	0.73±0.02	0.96±0.02	4.90±0.24	1.79±0.01	0.50±0.02	0.38±0.04 c	3.59±0.11 d	3.46±0.10 d
	Range	0.68-0.76	0.93-0.99	4.46-5.56	1.75-1.81	0.47-0.53	0.31-0.46	3.32-3.78	3.27-3.66
	CV	3.2	1.6	4.8	0.8	3.2	9.7	3.0	2.7
04	Mean±SD	1.05±0.03	1.15±0.02	6.08±0.50	2.09±0.01	0.62±0.01	0.36±0.05 d	3.38±0.07 e	3.29±0.07 e
	Range	0.99-1.11	1.12-1.19	5.35-7.47	2.07-2.12	0.59-0.65	0.24-0.49	3.26-3.56	3.13-3.47
	CV	2.6	1.3	8.2	0.5	2.3	14.4	2.1	2.2
06	Mean±SD	1.56±0.03	1.41±0.01	7.37±0.35	2.74±0.01	0.70±0.02	0.36±0.04 d	3.91±0.11 c	3.77±0.08 b
	Range	1.48-1.62	1.37-1.44	6.67-8.06	2.71-2.77	0.65-0.72	0.30-0.44	3.74-4.22	3.62-3.98
	CV	1.4	0.7	3.8	0.4	1.9	10.2	2.7	2.0

The equations relating to the shape properties of the nozzle's orifice contours (*PA*: projected area of the orifice opening (mm^2); *P*: perimeter of the orifice opening (mm); *L*: major length (mm); *W*: minor length (mm); A_L: the circular area calculated dependently the opening's major length (mm^2))

Shape factor (*SF*)	Elongation (*E*)	Roundness (*R*)
$SF = \frac{4 \cdot \pi \cdot PA}{P^2}$	$E = \frac{L}{W}$	$R = \frac{PA}{A_L}$

*, mean±standard deviation (SD); **, coefficient of variation %

referring to the orifice contours. The similarities or dissimilarities among the orifice contours were tested using Hotelling's pairwise comparisons with Bonferroni correction and uncorrected which make possible pairwise comparisons of the orifice contours.

To determine the class/classes of an orifice within orifices with different nominal sizes, linear discriminant analysis (LDA) which is known as Fisher's linear discriminant analysis or Canonical variate analysis was performed on the PC score data using SPSS statistical software version 20.0.

3. Results and Discussion

3.1. Visual and descriptive evaluation of the orifice shape

In Table 1, the sizes of V-slot angle and its height ranged between 19°-32° and 1.2-1.9 mm, respectively. As the shape of orifices ranged between 02 and 06, sizes were visually elliptical, and the shape of orifice of 01 was rectangular. The V-slot angle and height data in Table 1 are important design parameters in determining the nozzle capacity for flat fan-pattern nozzles. Design parameters such as angle and height concerning the nozzle orifice was in tendency to increase as the orifice size ranging from 01 to 06 increased.

The equivalent diameter and perimeter data of the nozzle orifices given in Table 2 were calculated as a function of orifice area varying between 0.21 and 1.56 mm^2. The highest CV within the size parameters was found at the minor length of the orifice of 01, and at perimeter of the orifice of 04. It was noted that the projected area, major and minor length of the orifice linearly increased, as the orifice size varying from 01 to 06 increased as seen in Table 2. Conversely, the CV data decreased as the orifice size increased from 01 to 06. This result showed that the manufacturing defects in the orifices of smaller size are much more than that of the largest ones.

The shape factor, elongation and roundness means in Table 2 ranged between 0.36-0.44, 3.59-4.78 and 3.29-4.52, respectively. As for the CV data for the shape factor, elongation and roundness parameters, the values varied between 4.6-14.4%, 2.1-5.4%, and 2.0-3.8%, respectively. The CV data in the shape factor were found remarkably higher than the data of the elongation and roundness. All shape descriptive data shows the circularity of the nozzle orifice. If their values were close to 1, this would mean that the shape of the orifice is akin to the circular. These data could be separately evaluated in terms of their shape differentials. However, the result of the Duncan test in Table 2 showed that there were significant differences among the descriptive shape parameters, because they had different variances. It was concluded that there were inconsistencies among three shape descriptions enlightening about the nozzles' orifice shape. The identical stance was also valid for the CV data of the shape parameters. Basic shape data, such as shape factor, elongation and roundness are acceptable as the most common features for the nozzle orifice shape. However, these data are not able to reveal the shape differentials relating to the manufacturing defect of the nozzle orifices.

3.2. Evaluation of the individual shape variations for each orifice contour

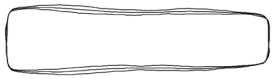
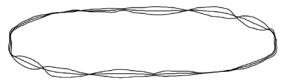
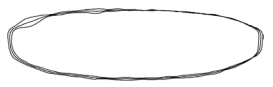
Shape variations between the contours of the orifices based on their first two significant principal components (PCs) were shown in Table 3. Shape contours shown in this table were obtained from the orifice samples analyzed individually for each orifice size. Their first two PCs except the orifice of 015, which had the lowest shape difference, constituted more than fifty percent of the total variance within the shape contour.

In Figure 1, the scatter plots of the first two component scores obtained from the PCA were displayed for the nozzles with different orifice sizes. In these plots, the orifices which are far from the PC1 and PC2 axis were the most deviated samples from the mean in shape.

The figures in Table 3 display prominently the differences of the nozzles' orifice contour. The orifice of 01 size had the rectangular shape, while the others had an elliptical shape with regard to the

Table 3- Shape variations in contours of each orifice size with regard to the first two component scores (PCs) obtained from the principal component analysis. The orifice contours from left to right display the PC scores corresponding to: (mean-2 SD, mean, and mean+2 SD)

Çizelge 3- Temel bileşenler analizinden elde edilen ilk iki bileşen skorlarına göre her bir orifis ölçüsünün konturlarındaki şekil değişimleri. Temel bileşenler skoruna karşılık gelen orifis konturları soldan sağa doğru: (ortalama-2 SS, ortalama, ortalama+2 SS)

Orifice size	*% of explained variance*	*-2 SD**	*Mean*	*+2 SD*	
01	PC1 (43.0%)				
	PC2 (23.7%)				
015	PC1 (31.6%)				
	PC2 (16.9%)				
02	PC1 (50.1%)				
	PC2 (20.5%)				
03	PC1 (32.4%)				
	PC2 (21.9%)				
04	PC1 (35.6%)				
	PC2 (19.7%)				
06	PC1 (37.3%)				
	PC2 (27.1%)				

*, standard deviation

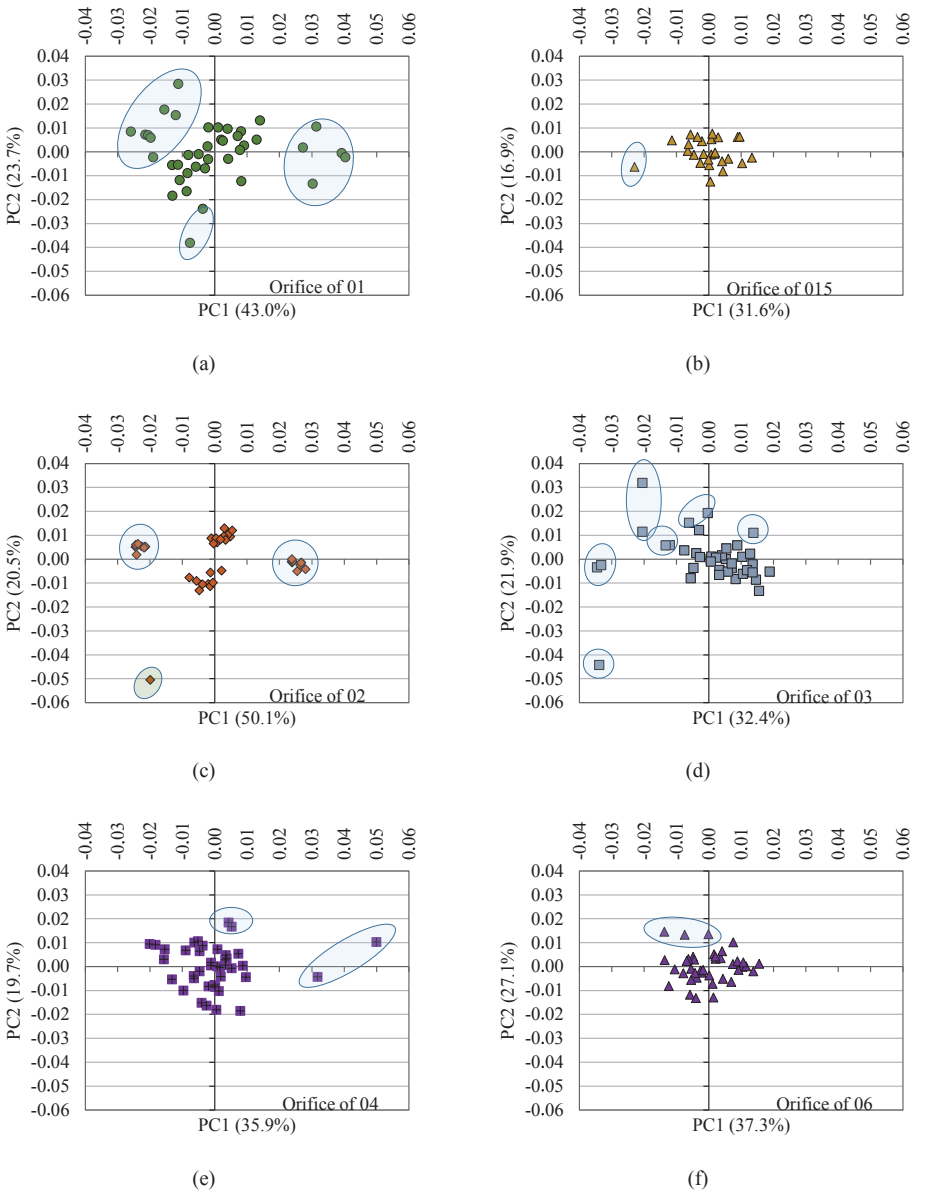


Figure 1- Principal component analysis scatter plot of orifice contours from flat fan-pattern nozzles with six various nominal size; a, orifice of 01 size; b, orifice of 015 size; c, orifice of 02 size; d, orifice of 03 size; e, orifice of 04 size; f, orifice of 06 size (The nozzles shown in ellipsoidal circle display the defective orifices. The orifice contours of the nozzles which is closer to the origin can be accepted as smooth)

Şekil 1- Altı farklı nominal ölçüye sahip yelpaze hüzmeli memenin orifis konturlarına ait temel bileşenler analizi saçılım grafiği; a, 01 orifisi; b, 015 orifisi; c, 02 orifisi; d, 03 orifisi; e, 04 orifisi; f, 06 orifisi (Daire içinde gösterilen memeler kusurlu orifisleri göstermektedir. Orijinine yakın olan memelerin orifis konturları düzgün olarak kabul edilebilir)

mean PCs scores. The highest variations in the 01 orifice size according to the PC1 score in Table 3 were the size differences at the right and left side of the orifice, which resulted in the enlargement-narrowing or extension-lessening of the side edges of the orifice. Although the orifice of 01 size was rectangular in shape, it had a remarkably irregular contour, and the orifice opening was expanded to just one direction. The highest variations of the orifice of 01 size displayed at PC1 score were determined in the major length/minor length ratio causing the elongation variation.

The major length/minor length ratio of the orifice of 015 in PC1 score had the most important variation in terms of shape differences, while the variation in PC2 score constituted at the side edges of the ellipse. However, the shape differences within the orifice of 015 were the lowest level as seen in Table 3.

It was visually noted that the orifice of 02 size had prominently the largest shape variations. The highest shape defect among the orifice images was almost seen all over the edges of the orifices of 02 size in PC1 score displayed in Table 3. It was concluded that the manufacturing defect for the orifice of 02 size was more apparent compared to the other orifices. The variations in PC2 for the orifice of 02 were not seen in PC1. These variations were the shape defects causing the distortion of the orifice's ellipse form.

There was a defect at the top-left side of the orifice of 03 in PC1 score compared to the mean PC score displayed in Table 3. This defect reflected to the PC2 score as enlargement-narrowing of the orifice size through the orifice's external line. The manufacturing defect of the orifice of 04 caused the inferior edge of the orifice for PC1 score. The differences in the 04 orifice in PC2 score originated from the variation of the minor length of the orifice.

Although the highest shape variation among the orifices had been visually seen in the 02 orifice, these distortions could be explicitly seen based on the result of the comparison test of the shape factor mean in Table 2.

In Figure 1, nozzle samples deviating from the mean PC scores were seen, and the shape differences within the nozzles with the identical orifice size could be distinguished. These were displayed within the circular area in the plots. The principal component scores obtained from the elliptic Fourier descriptors which are determined for each orifice size provided to distinguish the nozzles which have the manufacturing defect.

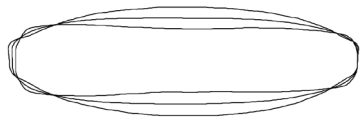
3.3. Comparison of the nozzle orifices with different nominal sizes in terms of shape variation

Table 4 presented the relative proportions of the first ten PCs based on a PCA of 224 orifice contours (total sample number for 6 orifice sizes). Each orifice contour was a 40 harmonic reconstruction from elliptic Fourier data. The first ten independent shape variables constituted 95.3% of the total variance. The PC1, PC2, PC3, PC4 and PC5 were the most important scores explaining the proportions of 59.7%, 19.1%, 5.6%, 3.2% and 2.0% of the total variance, respectively. All orifice contours were analyzed together and their variations were seen in Table 4. Variations in the shape resulted from the enlargement or narrowing in minor length of the mean ellipsoidal and rectangular contour for PC1, the narrowing or extension of major length of the ellipse and geometrical shape difference for PC2, the variation of minor length of the ellipsoidal geometry for PC3, the size variations on top-side edges of the rectangular and ellipse geometry for PC4, and the shape destruction on contour for PC5. The proportions in the total variance of the other components ranging from PC6 to PC10 were considerably low, and they displayed smaller differences in the orifice contour in shape.

The results of the MANOVA test were presented in Table 5. The results showed that independent variables which are the first ten principal components (PC1 to PC10) were statistically different at the significance level of 95% ($P<0.000$) as indicated by Wilks' Lambda and Pillai Trace statistics. According to the Hotelling's pairwise comparison results, the orifice shapes of the flat fan-pattern nozzles with different nominal sizes were significantly different

Table 4- Eigenvalues and proportions of the first ten principal components (PCs) as shape variables in orifices of 01, 015, 02, 03, 04 and 06, based on a PCA of 224 orifice contours obtained from all nozzle images

Çizelge 4- Temel bileşenler analizine göre tüm meme görüntülerinden elde edilen 224 adet temel bileşenin şekil konturuna bağlı olarak belirlenen 01, 015, 02, 03, 04 ve 06'lık orifislere ait şekil değişkenlerinin ilk on temel bileşen yüzdeleri ve öz değer istatistikleri

Components	*Eigenvalues*	*Proportion (%)*	*Cumulative proportion (%)*	*Shape variations within the orifice contours*
PC1	1.084E-03	59.7	59.7	
PC2	3.466E-04	19.1	78.8	
PC3	1.022E-04	5.6	84.4	
PC4	5.802E-05	3.2	87.6	
PC5	4.158E-05	2.3	89.9	
PC6	3.623E-05	2.0	91.9	
PC7	2.298E-05	1.3	93.1	
PC8	1.479E-05	0.8	94.0	
PC9	1.284E-05	0.7	94.7	
PC10	1.250E-05	0.7	95.3	

from each other. Wilk's Lambda statistic in Table 5 is the percent of the variance in the nozzles' orifice sizes (dependent variables). As the Wilk's Lambda statistic ranging from 0 to 1 decreased towards 0, the differences between the orifice sizes being analyzed increased. Pillai Trace statistic considered the most reliable among the Multivariate measures takes account of the sum of the variance in the dependent variable that is explained by the greatest discrimination of the independent variables (Foster at al 2006). Both statistics illustrated prominently the differences among the orifice sizes according to the shape discrimination based on the elliptic Fourier descriptors. The results of the Hotelling's pairwise comparison test demonstrated that the orifice shapes of the nozzles with different nominal sizes had the attributes which are dissimilar to each other.

The results of the linear discriminant analysis containing the effects of the canonical discriminant functions were shown in Table 6. The proportion of 96.0% in the classification was correctly grouped in reference to the nozzles' orifice sizes. The discriminant function analysis in Table 6 was performed using the stepwise method instead of the overall method. For the discriminant analysis, five canonical functions were obtained. The canonical correlation value is defined as a proportion of the total variance, and indicates the relation between discriminant scores and groups. The canonical correlation value of the first function explained a proportion of 97.6% (square of 0.988) of the total variance in the dependent variables. The second and third ones were the functions explaining a proportion of 92.2% and 82.4% of total variance, respectively. It has been indicated that the eigenvalue statistic which is higher than 0.40 provide the best discrimination in dependent variables (Kalayci 2006). Thus, it could be concluded that the first three discriminant functions in reference to the eigenvalue statistics in Table 6 had a drastic distinctive attribute. The Wilk's Lambda statistic is defined as an unexplained proportion of the total variance among the groups and the discriminant scores, and the unexplained proportions deduced from the table had a considerably low rate. Table 6 revealed a distinctive attribute among the orifice shapes and demonstrated that the orifice shapes with different nominal sizes of the identical nozzle type were dissimilar to each other. Totally, the proportion of 96.0% in the classification in terms of the orifice shape was located in its own group.

Table 5- Similarities and differences among the nozzle orifices based on their contour variations in shape

Çizelge 5- Kontur değişkenlerine bağlı olarak şekilsel açıdan meme orifisleri arasındaki benzerlikler ve farklılıklar

A. MANOVA results (computed in PAST ver. 3.01)

Effects	Statistics	Value	df1	df2	F	P (Sigma)
Orifice sizes	Wilks' Lambda	2.42E-04	50	956.6	99.62	0.000*
	Pillai Trace	3.019	50	1065	32.46	3.279E-178*

B. The results of the Hotelling's pairwise comparisons. Bonferroni corrected P - values in lower triangle, P - values uncorrected significance in upper triangle (computed in PAST ver. 3.01)

Orifice sizes	*01*	*015*	*02*	*03*	*04*	*06*
01		1.3E-47	2.4E-57	6.4E-60	3.2E-61	1.5E-59
015	1.9E-46*		1.5E-30	1.4E-34	1.5E-38	1.1E-25
02	3.6E-56	2.2E-29		1.9E-34	4.3E-41	1.8E-31
03	9.6E-59	2.1E-33	2.8E-33		7.4E-13	3.2E-16
04	4.7E-60	2.2E-37	6.5E-40	1.1E-11		2.5E-27
06	2.2E-58	1.7E-24	2.6E-30	4.8E-15	3.8E-26	

*, P<0.000

Table 6- Summary of canonical discriminant functions and classification results (%) of the linear discrimination analysis of the PCs obtained from elliptical Fourier descriptors (96.0% of cross-validated grouped cases correctly classified)

Çizelge 6- Kanonik ayırma fonksiyonlarının özeti ve eliptik Fourier tanımlayıcılarından elde edilen temel bileşen skorlarının doğrusal ayırma analizine göre sınıflandırma sonuçları (%) (gruplandırmada % 96 oranında doğru sınıflandırma)

Eigenvalue statistic				
Function	*Eigenvalue*	*% of variance*	*Cumulative (%)*	*Canonical correlation*
1	39.83	70.4	70.4	0.988
2	11.62	20.5	91.0	0.960
3	4.71	8.3	99.3	0.908
4	0.35	0.6	99.9	0.510
5	0.04	0.1	100.0	0.195
Wilks' Lambda statistic				
Test of functions	*Wilks' Lambda*	*Chi - square*	*df*	*Sigma (P)*
1 - 5	2.42E-04	1790.2	50	0.000*
2 - 5	9.88E-03	992.7	36	0.000*
3 - 5	1.25E-01	447.6	24	0.000*
4 - 5	7.12E-01	73.1	14	0.000*
5	9.62E-01	8.3	6	0.216^{ns}

Linear discriminant analysis for the orifice sizes assignment (%)							
Orifice sizes	*01*	*015*	*02*	*03*	*04*	*06*	*Total*
01	100.0	0.0	0.0	0.0	0.0	0.0	100
015	0.0	100.0	0.0	0.0	0.0	0.0	100
02	0.0	0.0	100.0	0.0	0.0	0.0	100
03	0.0	0.0	0.0	85.0	5.0	10.0	100
04	0.0	0.0	0.0	5.0	95.0	0.0	100
06	0.0	0.0	0.0	2.6	0.0	97.4	100

*, P<0.000; ^{ns}, non-significant

Figure 2 shows the group centroids and orifice distributions in shape based on the PC scores obtained from the linear discriminant function analysis. According to the group centroids of the orifices in Figure 2a showing the relation between the canonical variate 1 and 2, the outmost orifices of the axis were 01 and 015. In the Figure 2b referring to the relation between canonical variate 1 and 3, the 01 and 02 orifices were at the outmost of the axis. The group centroids of the orifices of 03, 04 and 06 were in close-range to each other as seen in both figures. The centroid locations of the orifice groups in Figure 2a and Figure 2b displayed clearly the shape similarities or differences of the orifices with different nominal sizes. The orifice of 01, shape of which is rectangular, had an extraordinary attribute in shape compared to others. Although the orifice of 015 had a smoother shape than the other orifice contours, this orifice has an oblate ellipse in shape. Because of this, this attribute of

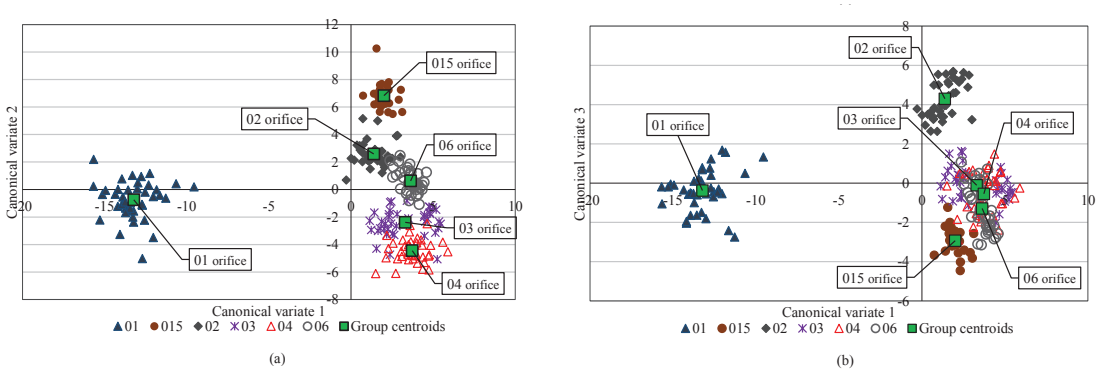


Figure 2- Group centroids and distribution of nozzles' orifices with regard to canonical discriminant functions

Şekil 2- Kanonik ayırma fonksiyonlarına göre meme orifislerinin dağılımı ve grupların merkezi konumu

the 015 orifice revealed at the first two canonical discriminant functions. The extraordinary features of the 02 orifice, the manufacturing defect of which is much more than the other orifice, were explicitly seen in Figure 2b. In both Figure 2a and 2b, it could be seen that the group centroids of 03, 04 and 06 orifices were closer than the other. Thusly, the findings and outputs were found compatible with the classification results in the linear discriminant analysis.

4. Conclusions

This study focused to reveal the shape differences among the nozzle orifices made in polyacetal for various nominal sizes ranging from 01 to 06. In the present study, the nozzle orifices with shape defect could successfully be distinguished using shape descriptors obtained from elliptic Fourier analysis (EFA). The elliptic Fourier method provided an excellent discrimination among the polyacetal flat fan-pattern nozzles with various orifice sizes in respect to the orifice's shape similarities and/or differences, and their shape defects originating from the manufacturing. The orifice shape of the nozzles made from the polyacetal material may be different than those of the other material such as ceramic and stainless steel. Although this study did not have any nozzle wear test study, the results obtained from the study showed that the elliptic Fourier descriptions will be also able to distinguish the worn nozzles. The next step will be to determine the maximum allowable limits of shape defect disturbing the spray pattern for a nozzle orifice with the experimental studies.

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Farklı Kaplama Bileşenleriyle Kaplamanın Derin Yağda Kızartılan Piliç Nuggetların Bazı Kalite Karakteristikleri Üzerine Etkileri

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ÖZET

Bu çalışmada farklı tahıl ve baklagil unlarının (buğday, mısır, çavdar ve soya) derin yağda kızartılmış piliç nuggetların kalite karakteristikleri (nem miktarı, yağ miktarı, kaplama tutunma yüzdesi, pişirme verimi, kaplama kalınlığı, penetrometre değeri ve renk) üzerine etkileri incelenmiştir. Piliç nuggetlar eşit oranda but ve göğüs eti karışımından üretilmiş, ardından 180 °C'ye ısıtılmış ayçiçek yağında 5 dakika süreyle derin yağda kızartılmıştır. Kaplama formülasyonları; piliç nuggetların kaplama tutunma yüzdesi, pişirme verimi, kaplama kalınlığı ve penetrometre değerlerini önemli ($P<0.05$) düzeyde etkilemiştir. En yüksek pişirme verimi sırasıyla mısır ve buğday unlu kaplamalarda elde edilmiştir. Çavdar unu kullanımı piliç nuggetların penetrometre değerini önemli ($P<0.05$) düzeyde artırmıştır. Piliç nuggetların nem miktarları kaplama formülasyonundan etkilenmezken, yağ miktarları değişiklik göstermiştir. Tüm kaplama formülasyonları kırmızılık (+a*) değerleri açısından farklılık göstermezken ($P>0.05$) en yüksek sarılık (+b*) değeri mısır unlu kaplamalarda elde edilmiştir.

Anahtar Kelimeler: Piliç nugget; Sıvı kaplama; Kalite; Derin yağda kızartma; Pişirme verimi

Effects of Different Batter Formulation on Some Quality Characteristics of Deep-Fat Fried Chicken Nuggets

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ABSTRACT

In this study the effect of various cereal and legume flours (wheat, corn, rye and soy) on some quality characteristics (moisture content, oil content, coating pick up, cooking yield, coating thickness, penetrometer values and color) of deep-fat fried chicken nuggets were studied. Chicken nuggets were prepared with equal amounts of ground thigh and breast meat and fried at 180 °C for 5 min in sunflower oil. Batter formulations significantly ($P<0.05$) affected coating pick up, cooking yield, coating thickness and penetrometer values of chicken nuggets. The highest cooking yield was found in corn flour and wheat flour, respectively. The uses of rye flour significantly ($P<0.05$) increased the penetrometer values

of chicken nuggets. There were no significant (P>0.05) differences between the moisture content of chicken nuggets. The batter formulation significantly changed the oil content of chicken nuggets. All the batter formulations had similar redness (+a*) values whereas batter containing corn flour showed the highest yellowness (+b*) value.

Keywords: Chicken nugget; Batter; Quality; Deep fat frying; Cooking yield

1. Giriş

Tüm dünyada olduğu gibi ülkemizde de kanatlı etlerine ve bunlardan üretilen ürünlere olan talep giderek artmaktadır. Kanatlı etlerine talebi artıran faktörler arasında cazip fiyat, sağlıklı olma, kolay ulaşılabilirlik ve hazırlanabilirlik başta gelmektedir. Özellikle ileri işlenmiş kanatlı eti ürünleri katma değeri yüksek ürünler olup; kâr oranlarının yüksek olması nedeniyle üreticiler, ürün çeşitliliğinin fazla olması nedeniyle de tüketiciler tarafından tercih edilmektedir. İleri işlenmiş ürünler içerisinde de kaplamalı ürünlere ilgi gün geçtikçe artmaktadır. Özellikle altın sarısı kaplama rengi, gevrekliği, ve lezzetli yapısı ile her daim sıcak olarak kısa sürede servis edilebilen kaplamalı ürünler, her yaştan tüketici için caziptir (Fiszman & Sanz 2010).

Kaplanmış ürünler farklı kompozisyonlarda birkaç katmandan oluşan sandviç benzeri bir yapıya sahiptir. Dışta kuru, sıkı ve gevrek bir kabuk, içte ise yumuşak yapılı et tabakası bulunur. Bu yapının oluşmasında ürünün nem içeriği, et parçalarının büyüklüğü, kaplama materyalinin bileşimi, pişirme işlemi, pişirme süresi ve sıcaklığı büyük önem taşımaktadır (Albert et al 2014).

Kaplamalı kanatlı ürünlerin en çok tercih edileni piliç nuggetlardır. Üretim aşamasında piliç nuggetlar önce buğday, mısır unu, nişasta ve yumurta gibi katkılar bulunan sıvı bir kaplamaya daldırılır, ardından tercihen galeta unlu bir kuru kaplamayla işlenir ve son olarak derin yağda belirli süre kızartılır (Suderman 1983; Fiszman & Salvador 2003; Altunakar et al 2004; Albert et al 2009).

Kaplanmış ürünlerde kaplama materyalinin viskozitesi, adhezyon özelliklikleri (kaplamanın ürüne tutundurulması) ve kızartma sırasında yağ absorbsiyonunun azaltılması gibi kriterler kaplama bileşimiyle doğrudan ilişkilidir. Bunun yanı sıra kaplama bileşimi, son ürünün tekstür, renk ve lezzet gibi kalite kriterleri; pişirme sıcaklığı, yöntemi ve süresini de etkilemektedir (Ergezer et al 2008). Farklı unların kaplama sistemleri üzerindeki etkileri pek çok araştırıcı tarafından incelenmiştir. Buğday unu içermiş olduğu gluten ve glutenin film oluşturucu özellikleri nedeniyle piliç nuggetlarda nem kaybını azaltıp, gevrekliği artırmaktadır. Buğday ununun yanı sıra pirinç, mısır ve soya unu da kaplama formülasyonlarında denenmiş ve başarılı sonuçlar alınmıştır (Suderman 1983; Fiszman & Salvador 2003; Altunakar et al 2004; Ergezer et al 2008; Albert et al 2009; Fiszman & Sanz 2010; Albert et al 2014).

Soya unu ile gerçekleştirilen kaplama çalışmalarında pirinç ununa kıyasla piliç nuggetlarda nem kaybının ve yağ absorbsiyonunun daha az olduğu, rengin iyileştiği ve gevrekliğin de arttığı belirlenmiştir (Altunakar et al 2004).

Mısır unu, içermiş olduğu karoten pigmenti nedeniyle kaplanmış ürünlerde aranan altın sarısı renk için önemli ve doğal bir kaplama materyali olarak kullanılmaktadır. Ayrıca mısır unu bileşiminde bulunan zein proteini hidrofilik özelliği nedeniyle ürünün içerisinde suyun alıkonmasına yardımcı olmakta ve kızartma yağının da ürüne geçmesine engellemektedir. Bu nedenle son ürünün içi sulu ve dışı daha gevrek algılanmaktadır (Fiszman & Sanz 2010).

Bu çalışmada, farklı kaplama bileşenlerinin derin yağda kızartılmış piliç nuggetların bazı kalite parametreleri üzerindeki etkileri incelenmiştir.

2. Materyal ve Yöntem

2.1. Materyal

Çalışmada ticari bir tavuk kesimhanesinden temin edilmiş, kemiksiz ve derisiz but ve göğüs etleri kullanılmıştır. Kaplama ve piliç nugget formülasyonlarının hazırlanmasında kullanılan karragenan (Tunçkaya Kimya); peynir altı suyu tozu

ve mono sodyum glutamat (AD Kimya); buğday, mısır, soya ve çavdar unları; galeta unu, karabiber, kimyon, soğan, tuz ve ayçiçek yağı piyasadan temin edilmiştir.

2.2. Yöntem

2.2.1. Piliç nuggetların hazırlanışı

Tavuk but ve göğüs etleri 5 mm ayna gözlü kıyma makinesinde (Arı Makine, PKM 12, Türkiye) çekilmiştir. Araştırmada Çizelge 1'de belirtilen piliç nugget formülasyonu kullanılarak elle yoğurmak suretiyle hamur hazırlanmıştır. Elips şeklindeki paslanmaz çelikten imal edilmiş kalıplar (1.5 x 5.5 x 4 cm) kullanılarak hamur nugget formuna getirilmiştir.

Çalışmada kaplama bileşeni olarak % 35 un (buğday, mısır, soya ve çavdar), % 1 karragenan, % 1 tuz ve % 63 su kullanılarak 4 farklı kaplama grubu oluşturulmuştur.

Piliç nuggetlar hazırlanmış kaplama formülasyonlarına daldırılmadan önce daha etkin bir tutunma sağlamak amacıyla peynir altı suyu tozuyla ön unlamaya tabi tutulmuştur. Kaplama uygulamalarında sıvı kaplama tercih edilmiş olup kaplama çözeltisi 45±1 °C'deki su içerisinde 30 sn karıştırılarak hazırlanmıştır. Ön unlamanın ardından piliç nuggetlar bu kaplama çözeltisine 10 sn daldırılmak suretiyle kaplanarak kızartıcıya konulmuştur. Kaplanan piliç nuggetlar 180 °C'ye ayarlanmış kızartıcıda (Tefal, Filtra One 1900 watt, Fransa) 5'er dakika ayçiçek yağı içerisinde kızartılmıştır (Altunakar 2003).

Çizelge 1- Çalışmada uygulanan nugget formülasyonu

Table 1- Formulation of chicken nuggets

Bileşen	*Oran (%)*
Tavuk kıyması (1:1; göğüs:but)	82.5
Galeta unu	5
Kimyon	0.5
Karabiber	0.5
Soğan	10
MSG (mono sodyum glutamat)	0.5
Tuz	1

2.2.2. Analizler

Pişmiş örneklerin nem miktarı etüvde (Memmert UNE400, Almanya) 105±2 °C'de kurutma (AOAC 2000), yağ miktarı Soxhlet ekstraksiyonu yöntemine göre belirlenmiştir (AOAC 2000). Örneklerin renk değerleri kızartma sonrası (Hunter lab Miniscan XE Plus, ABD) renk ölçüm cihazı ile belirlenmiştir. CIELAB sistemi, D65 referans aydınlatma ve 10°'lik görüş açısında 4 ayrı okuma ile kuartz örnek kabı içerisinde yapılmıştır. Sonuçlar açıklık-koyuluk (L*), kırmızılık (+a*) ve sarılık (+b*) değerleri kullanılarak saptanmıştır (CIE 2001).

Çiğ piliç nugget örneklerinde kaplama tutunma yüzdesi ve pişirme verimi Eşitlik 1 ve 2'de şu şekilde hesaplanmıştır (Altunakar 2003).

$$\% \text{ Kaplama tutunma} = (C\text{-}I/I) \times 100 \quad (1)$$

Burada; C, kaplanmış piliç nugget ağırlığı (g); I, kaplanmamış piliç nugget ağırlığı (g).

$$\% \text{ Pişirme Verimi} = (CW/C) \times 100 \quad (2)$$

Burada; CW, pişmiş piliç nugget ağırlığı (g); C, çiğ piliç nugget ağırlığı (g).

Kaplanan piliç nuggetlar kızartıldıktan sonra, kaplama bir bıçak yardımıyla sıyrılmış ve kaplamanın kalınlığı (mm) dijital kumpas (Mitutoyo CD-6 CSX, Japonya) ile belirlenmiştir.

Hazırlanan örneklerin sertlik değerinin belirlenmesi amacıyla penetrometre cihazı (Koehler, K95500 ABD) ile, 100 g ağırlığa sahip ve et ürünlerinde ölçüm için kullanılan konik başlık 3 farklı noktadan olmak üzere delme derinliği 10^{-1} mm cinsinden belirlenmiştir (Ergezer et al 2014).

2.3. İstatistiksel analiz

Elde edilen veriler ışığında sonuçlar ANOVA (Varyans Analizi) kullanılarak analiz edilmiştir. Sonuçlar Duncan Çoklu Karşılaştırma Testiyle değerlendirilmiş ve uygulama grupları arasında farklılık olup olmadığı SPSS istatistik paket programı kullanılarak test edilmiştir (IBM SPSS 2012).

3. Bulgular ve Tartışma

3.1. Kalite karakteristiklerindeki değişimler

Kaplamalı ürünlerde son ürün kalitesi üzerine etkili faktörlerden birisi kaplanacak ürüne kaplama materyalinin tutundurulma yüzdesidir. Kaplama formülasyonlarına ilave edilen protein içeriği yüksek unlar ve değişik karakterdeki hidrokolloidler kaplama tutunma yüzdesi üzerine etkilidir (Chen et al 2008). Farklı kaplama formülasyonlarına daldırılan çiğ piliç nuggetların kaplama tutunma yüzdesi % 11.53-14.28 arasında değişiklik göstermiş olup (Çizelge 2) örnekler arasındaki farklılık istatistiki olarak önemli bulunmuştur (P<0.05). En yüksek kaplama yüzdesine çavdar unu kullanılarak hazırlanan piliç nuggetlarda ulaşılmıştır. Buğday, soya ve pirinç ununun piliç nuggetlarda kaplama bileşeni olarak kullanıldığı bir çalışmada kaplama tutunma yüzdesi soya>buğday>pirinç unu şeklinde gerçekleşmiştir (Dogan et al 2005). Bu çalışmada kaplama tutunma yüzdesini artırmak amacıyla karragenan kullanılmıştır. Benzer bir çalışmada buğday ve mısır unu içeren kaplama formülasyonlarına farklı oranlarda ilave edilen gamların balık nuggetlarda kaplama tutunma yüzdesini önemli düzeyde artırdığı gözlenmiştir (Chen et al 2009). Ancak balık nuggetların kullanıldığı farklı bir çalışmada ise gam olarak kullanılan okside nişasta, ksantan gam ve hidroksipropil metil selülozun kaplama tutunma oranını artırmadığı, aksine kontrol grubuna göre daha düşük değerler elde edildiği görülmüştür. Bu durumda asıl tutunmayı sağlayan yapının kaplama formülasyonuna ilave edilen undan kaynaklandığı öne sürülmüştür (Albert et al 2009).

Pişirme verimi, pişirme sırasında kaplamanın yüzeye tutunabilme özelliğinin bir göstergesidir ve verim arttıkça ürünün ekonomik değeri de artmaktadır (Altunakar et al 2004). Örneklerin pişirilmesini takiben elde edilen verim sonuçlarına göre en yüksek değer mısır unlu (% 82.64) ve en düşük değer de soya unlu (% 78.10) kaplamalarda bulunmuş ve örnekler arasında farklılık olduğu gözlenmiştir (P<0.05). Nişasta jelatinize olduğunda kaplanan yüzey üzerinde bir film oluşturmakta ve dolayısıyla da pişirme veriminde artışa neden olmaktadır. Hububat unlarından farklı olarak bir baklagil olan soyanın bileşiminde daha az nişasta bulunmaktadır ve dolayısıyla da soya unu kullanılarak kaplanan piliç nuggetlarda pişirme verimi düşük kalmıştır. Hububat unları ile kaplanmış piliç nuggetlarda ise verim açısından herhangi bir farklılık bulunmamıştır. Farklı nişasta tiplerinin piliç nuggetlarda kaplama verimi üzerine etkilerinin incelendiği bir çalışmada tapioka (veya tapyoka) nişastası buğday ve mısır nişastasına göre daha iyi sonuçlar vermiştir (Altunakar et al 2004).

Pişirme sonrası kaplama kalınlıkları incelendiğinde en kalın kaplamanın soyalı örneklerde olduğu (1.28 mm) ve örnekler arasında farklılık olduğu görülmüştür (P<0.05). Ancak buğday, mısır ve çavdar unu kullanılan örnekler arasında kalınlık açısından farklılık olmadığı tespit edilmiştir (P>0.05). Benzeri bir sonuca pişirme verimi değerlerinde de ulaşılmıştır. Bu çalışmada piliç nugget örneklerinde pişirmeden sonra soyalı olanların kaplama kalınlıklarının diğer örneklerden daha fazla bulunması, protein içeriği yüksek olan kaplamanın kızartma esnasındaki davranışı veya

Çizelge 2- Nuggetlarda kalite karakteristikleri*

Table 2- Quality characteristics of chicken nuggets

Örnek	*Kaplama tutunma yüzdesi (%)*	*Pişirme verimi (%)*	*Kaplama kalınlığı (mm)*	*Penetrometre değeri (10^{-1} mm)*
Buğday	11.53±0.58^{b}	82.34±2.21^{a}	1.17±0.09^{b}	65.77±1.38^{ab}
Mısır	13.19±0.65^{a}	82.64±1.52^{a}	1.18±0.06^{b}	59.88±3.65^{b}
Soya	12.11±1.12^{ab}	78.10±1.02^{b}	1.28±0.14^{a}	53.25±2.92^{b}
Çavdar	14.28±1.43^{a}	81.91±1.46^{a}	1.15±0.12^{b}	73.62±3.43^{a}

*, 2 tekrarlı analizlerin sonuçları ortalama ± standart sapma şeklinde verilmiştir; ^{a,b}, aynı sütunda farklı harflerle işaretlenen ortalamalar arasındaki farklar önemlidir (P<0.05)

kaplama materyalinin partikül büyüklüğü ile alakalı olduğu düşünülmektedir (Çizelge 2). Pişirme sırasında bazı kaplamalarda ortamdan buharlaşmayla uzaklaşacak su, yapı tarafından tutulmakta ve bu durumda gözeneklilik artış gösterebilmektedir. Buna bağlı olarak da pişme işlemi sonrası kaplama kalınlığı artabilmektedir. Benzer bir çalışmada soya unu kullanılan kaplamalarda daha fazla gözenekli yapıya rastlanılmıştır (Dogan et al 2005).

Kaplanmış ürünlerde en önemli tekstürel özellik gevrekliktir. Gevreklik tüketici tercihlerinde ürünün taze olduğunun bir göstergesi olarak kabul edilmektedir (Ergezer et al 2008). Ürünün tekstürel özelliklerini belirlemek üzere kullanılan aletsel objektif analizlerden biri olan penetrometre değeri arttıkça ürünün daha yumuşak ve arzu edilir tekstürde olduğu söylenebilir (Candogan & Kolsarici 2003). Penetrometre değerleri incelendiğinde tekstürel açıdan en yumuşak ürün çavdar unlu formülasyonla kaplanan piliç nuggetlarda elde edilmiştir. Soya ve mısır unlu kaplamalarda ise penetrometre değeri benzer olup ($P>0.05$), çavdar ve buğday unlu kaplamalardan daha düşük değerler elde edilmiştir. Bu değerlere göre soya ve mısır unuyla kaplanmış örneklerin sertlik değerlerinin çavdar ve buğday unuyla kaplanmış örneklere göre daha yüksek olduğu söylenebilir. Örneklerin penetrometre değerleri 53.25-73.62x10^{-1} mm arasında değişiklik göstermiş (Çizelge 2) ve örnekler arasında farklılık olduğu görülmüştür ($P<0.05$).

Üründe arzu edilen tekstürün sağlanabilmesi kaplama bileşenlerinin karakterine bağlıdır. Kaplama amacıyla kullanılan farklı karakterdeki unların, nişastaların ve gamların son ürün tekstürü üzerinde etkili olduğu pek çok araştırma tarafından ortaya konmuştur (Mukprasirt et al 2000; Chen et al 2009). Sorgum ve buğday unlu piliç nuggetların karşılaştırıldığı bir çalışmada sorgum unu kullanılan örneklerin daha sert olduğu gözlemlenmiştir (Devatkal et al 2011). Bu çalışmaya benzer bir başka çalışmada ise buğday ve pirinç unu kullanılarak üretilen piliç nuggetlarda buğday unu kullanılan örneklerde daha yumuşak bir yapı elde edilmiştir (Jackson et al 2009). Yulaf ununun kaplama bileşeni olarak kullanıldığı başka bir çalışmada ise formülasyonda yulaf unu arttıkça sertliğin de arttığı belirlenmiştir (Santhi & Kalaikannan 2014).

3.2. Yağ ve nem miktarı

Çizelge 3'te pişmiş örneklere ait yağ ve nem miktarları verilmiştir. Piliç nuggetların yağ miktarı % 8.50-9.93 arasında değişiklik göstermekte ve örnekler arasında farklılık bulunmaktadır ($P<0.05$). Pişirme sırasında en az yağ çeken örnek mısır unuyla kaplanan örnekler olmuştur. Örneklerin nem miktarları arasında herhangi bir farklılık tespit edilmemiştir ($P>0.05$).

Kaplanmış ürünlerin tüketimindeki en önemli problemlerden biri pişirme sırasında emilen yağ miktarıdır. Sağlık riskleri açısından bu tür ürünlerin kızartılması sırasında yağ absorbsiyonunun minimum düzeyde tutulması için pek çok çalışma yapılmaktadır. Kaplanmış ürünlerde pişirme koşulları (sıcaklık, süre), ön işlemler (ön unlama), gıdanın fiziko-kimyasal özelikleri, pişirmede kullanılan yağın kimyasal bileşimi ve kullanılan katkı maddelerinin özellikleri yağ absorbsiyonunu etkileyen önemli faktörler arasında yer almaktadır (Cuesta et al 2001; Rimac-Brnčić et al 2004; Dana & Saguy 2006). Kaplamalı ürünlerde kullanılan değişik karakterli (nem, bileşen ve protein fonksiyonelliği) unlar ve bunların amiloz ve amilopektin içeriği son ürünün tekstürel karakteristikleri, yağ absorbsiyonu ve duyusal özellikleriyle çok iyi bir korelasyon göstermektedir (Fiszman & Salvador 2003; Fiszman et al 2005; Fiszman & Sanz 2010). Kaplamada kullanılan unda su, amilopektin veya protein oranının artması son üründe yağ absorbsiyonunu artırmakta ve gevreklik özelliğini azaltıcı yönde etki yapmaktadır. Bu çalışmada da benzer şekilde protein miktarı daha yüksek olan soya unlu gruplarda yağ içeriği diğer gruplara oranla daha yüksek bulunmuştur (Çizelge 3). Ancak başka bir çalışmada karideslerin kaplanmasında kullanılan soya ununun yağ absorbsiyonunu azalttığı, mısır ununun ise artırdığı belirlenmiştir. Mısır unlu karideslerde yağ içeriğinin fazla bulunması bu undan hazırlanan sıvı kaplamalarda viskozitenin daha düşük kalması sonucu yağ absorbsiyonu için etkili bir bariyer oluşmamasına bağlanmaktadır (Nasiri et al 2012).

Bilindiği üzere viskozitenin artırılması amacıyla değişik gamlar kaplama bileşenleri içerisine dâhil edilebilmektedir. Bu çalışmada da viskoziteyi artırabilmek amacıyla kullanılan karragenanın yağ absorbsiyonunu azalttığı düşünülmektedir.

Çizelge 3- Derin yağda kızartılmış nugget örneklerinde yağ ve nem miktarı*

Table 3- Oil and moisture content of deep fat fried chicken nugget samples

Örnek	*Yağ miktarı (%)*	*Nem miktarı (%)*
Buğday	8.96±0.18^{ab}	60.19±1.43^{a}
Mısır	8.50±0.44^{b}	59.50±0.65^{a}
Soya	9.93±0.22^{a}	59.39±0.99^{a}
Çavdar	9.18±0.36^{ab}	61.40±1.05^{a}

*, 2 tekrarlı analizlerin sonuçları ortalama ± standart sapma şeklinde verilmiştir; ^{a,b}, aynı sütunda farklı harflerle işaretlenen ortalamalar arasındaki farklar önemlidir (P<0.05)

Piliç nugget gibi kaplamalı ürünlerde aranan duyusal özelliklerden biri de sululuktur. Pişirme sırasında kaplama bileşenleri doğal bir bariyer görevi görerek etin bileşimindeki suyun dışarı çıkışını azaltır ve böylece ürünün sulu kalması sağlanır. Kaplama formülasyonlarına ilave edilen değişik karakterdeki tahıl ve bakliyat unlarının derin yağda kızartılmış ürünlerde nem miktarını etkilediği farklı araştırıcılar tarafından belirtilmiştir (Fiszman & Salvador 2003; Salvador et al 2005; Fiszman & Sanz 2010). Ancak bu çalışmada piliç nuggetların nem miktarının kullanılan undan etkilenmediği gözlenmiştir. Derin yağda kızartma sırasında ortam sıcaklığının değişmesi nem miktarının değişmesine neden olmaktadır. Özellikle yağ sıcaklığı arttıkça son üründe nem miktarının azaldığı bildirilmektedir (Nasiri et al 2012). Bu çalışmada kızartma ortamının sıcaklığının değişmemiş olmasının nem miktarının da değişmemesine neden olabileceği düşünülmektedir. Ayrıca çalışmada kullanılan hidrokolloid yapıdaki karragenanın da nemi tutmada etkili olduğu düşünülmektedir.

3.3. Renk

Pişmiş örneklerin renk değerleri Çizelge 4'te verilmiştir. Piliç nuggetların açıklık-koyuluk (L*) değerleri 28.79-39.16 arasında değişmiş ve örneklerin birbirinden farklı olduğu görülmüştür (P<0.05). En açık örneğin buğday kaplı, en koyu örneğin ise soya kaplı piliç nuggetlar olduğu görülmektedir. Piliç nuggetların kırmızılık değerleri (+*a**) arasında istatistiksel olarak farklılık tespit edilememiştir (P>0.05). Piliç nuggetların albenisini ortaya koyan altın sarısı renk (+*b**) bu çalışmada en iyi mısır unu ile kaplanmış örneklerde (18.88) tespit edilmiştir. Mısır ununa yakın özellikler sergileyen örnekler buğday unlu kaplamalarda saptanırken, soya unuyla kaplananların açıklık-koyuluk ve sarılık açısından en düşük değerlere sahip olduğu gözlenmiştir.

Çizelge 4- Derin yağda kızartılmış nugget örneklerine ait renk değerleri*

Table 4- Color values of deep fat fried chicken nuggets

Örnek	*L**	*a**	*b**
Buğday	39.16±1.60^{a}	11.93±0.67^{a}	16.57±1.78^{a}
Mısır	37.67±1.35^{a}	12.37±0.88^{a}	18.88± 0.27^{a}
Soya	28.79±2.27^{b}	11.96±0.46^{a}	13.11±1.05^{b}
Çavdar	30.00±1.31^{b}	12.01±0.41^{a}	14.05±0.15^{ab}

*, 2 tekrarlı analizlerin sonuçları ortalama ± standart sapma şeklinde verilmiştir; ^{a,b}, aynı sütunda farklı harflerle işaretlenen ortalamalar arasındaki farklar önemlidir (P<0.05)

Kaplanmış ürünlerde tüketici beğenisinde önemli kalite karakteristiklerinden biri de renktir. Bu tür ürünlerde arzu edilen renk altın sarısıdır. Üründe istenen renk daha çok pişirmeyle ortaya çıktığı için pişirme yöntemi, kızartma yağının sıcaklığı, çeşidi, kullanım süresi ya da sıklığı ve kaplama materyalinin bileşimi büyük önem taşımaktadır (Ballard 2003). Renk stabilitesinin sağlanabilmesi için kızartma sırasında oluşan sıcaklık profili sürekli izlenmelidir. Kaplanmış ürünün soğuk veya aşırı sıcak yağın içine atılmaması gereklidir. Bununla birlikte ürünün kızartıcıda kalma süresi renk stabilitesi açısından çok önemlidir. Yine kızartma için kullanılan bitkisel yağın çeşidi ve durumu da renk açısından önemlidir. Kullanılacak kızartma yağının dumanlanma noktası yüksek olmalı, hidrolize veya polimerize olmuş yağlar kullanılmamalıdır. Yağa gıdadan geçen organik kirlilikler sık sık temizlenmelidir.

Kaplama bileşiminde kullanılan katkı maddelerinin de renk üzerinde önemli etkisi bulunmaktadır (Fiszman et al 2005). Altın sarısı rengin sağlanabilmesi için mısır ununun kullanımı oldukça yaygındır. Bu çalışmada kızartma sıcaklığı, süresi, kullanılan yağ sabit tutulmuş sadece kaplama bileşenleri değiştirilmiştir. Çalışmada en koyu renk soya unu ile kaplanmış piliç nuggetlarda elde edilmiştir (Çizelge 4). Bu durumun soyanın protein miktarının tahıl unlarına göre daha fazla olması nedeniyle kızartma sırasında Maillard reaksiyonlarına daha fazla girme eğiliminden kaynaklanmış olabileceği düşünülmektedir. Piliç nugget örneklerinde en açık değer buğday unlu kaplamalarda elde edilmiş olup örneklerin kırmızılık değerleri kullanılan kaplama bileşenlerinden etkilenmemiştir. Nugget benzeri kaplanmış ürünlerde en önemli renk parametresi sarılık olup mısır unu ile kaplanmış örnekler bu açıdan en çok tercih edilen örnekler olmuştur. Mısır unlu örnekleri takiben sarılık değerleri sırasıyla buğday>çavdar>soya şeklinde gerçekleşmiştir. Benzer sonuçlar farklı araştırıcılar tarafından da ortaya konmuştur (Baixauli et al 2003; Fiszman et al 2005; Chen et al 2009).

4. Sonuçlar

Kanatlı etlerinde tüketimi artırmanın etkili yollarından biri nugget tipi kaplanmış ürünlerdir. Kaplama formülasyonları hazırlanırken standart buğday unlu kaplamalar yerine farklı tahıl ve baklagil unlarının da kullanımıyla daha lezzetli, gevrek, sulu ve besleyici değeri yüksek ürünlerin üretilmesi mümkün olabilecektir. Bu çalışmada elde edilen tüm parametreler göz önünde bulundurulduğunda kaplama formülasyonlarına mısır ve çavdar unu ilavesinin ürün üzerinde olumlu etkilerde bulunduğu ancak soya unu ile kaplanan piliç nuggetlarda ise aynı düzeyde olumlu etkiye ulaşılamadığı belirlenmiştir.

Kısaltmalar ve Semboller	
*L**	Açıklık-koyuluk
*+a**	Kırmızılık
*+b**	Sarılık
MSG	Mono sodyum glutamat

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Physical and Chemical Properties of Pekmez (Molasses) Produced with Different Grape Cultivars

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ABSTRACT

In this study, some physical and chemical properties of pekmez samples produced using the traditional method with fourteen different grape cultivars were investigated. The water-soluble dry matter, pH, titratable acidity and hydroxymethylfurfural (HMF) content of the samples were determined to be 66.19-80.57%, 3.59-5.23, 0.27-1.81 g 100 g^{-1} and 5.93-762.22 mg kg^{-1}, respectively. The mean fructose and glucose contents of the pekmez samples were determined to be 28.42 g 100 g^{-1} and 31.67 g 100 g^{-1}, respectively. The densities and electrical conductivities varied between 1.33-1.43 g cm^{-3} and 1.96-4.51 mS cm^{-1}, respectively. The content of the macro element K identified in the pekmez samples (4449.86 mg kg^{-1}) was greater than that of Ca (1275.52 mg kg^{-1}), P (369.96 mg kg^{-1}), Mg (344.79 mg kg^{-1}) and Na (119.56 mg kg^{-1}). The pekmez samples have antioxidant activities, ranging between 38.20 to 64.45 µmol TE g^{-1}. Six phenolic compounds, caffeic acid, ellagic acid, ferulic acid, gallic acid, *p*-coumaric acid and rutin hydrate, were identified in the pekmez samples, and significant differences were observed between samples ($P<0.01$).

Keywords: Grape; Antioxidant activity; Phenolic composition; Mineral; Pekmez

Farklı Üzüm Çeşitleri ile Üretilen Pekmezlerin Fiziksel ve Kimyasal Özellikleri

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ÖZET

Bu çalışmada on dört farklı üzüm çeşidinden geleneksel olarak üretilen pekmez örneklerinin bazı fiziksel ve kimyasal özellikleri incelenmiştir. Örneklerin suda çözünür kuru madde miktarı, pH, titrasyon asitliği ve hidroksimetilfurfural (HMF) içerikleri sırasıyla % 66.19-80.57, 3.59-5.23, 0.27-1.81 g 100 g^{-1} ve 5.93-762.22 mg kg^{-1} olarak belirlenmiştir. Pekmez örneklerinin ortalama fruktoz ve glikoz içerikleri sırasıyla 28.42 g 100 g^{-1} ve 31.67 g 100 g^{-1} olarak saptanmıştır.

Yoğunluk ve elektriksel iletkenlik değerlerinin sırasıyla 1.33-1.43 g cm^{-3} ve 1.96-4.51 mS cm^{-1} aralığında olduğu belirlenmiştir. Pekmez örneklerinde belirlenen makro element K miktarı (4449.86 mg kg^{-1}), Ca (1275.52 mg kg^{-1}), P (369.96 mg kg^{-1}), Mg (344.79 mg kg^{-1}) ve Na (119.56 mg kg^{-1}) miktarından daha olmuştur. Pekmez örneklerinin antioksidan aktivitesi 38.20 ile 64.45 µmol TE g^{-1} aralığında değişmiştir. Pekmez örneklerinde kafeik asit, ellajik asit, ferulik asit, gallik asit, *p*-kumarik asit ve rutin hidrat olmak üzere altı adet fenolik bileşik tanımlanmış ve örnekler arasında önemli farklılıklar olduğu belirlenmiştir ($P<0.01$).

Anahtar Kelimeler: Üzüm; Antioksidan aktivite; Fenolik kompozisyonu; Mineral; Pekmez

1. Introduction

Pekmez (molasses), which has been produced for a long time in Turkey, is one of the popular and traditional Turkish foods (Tosun & Üstün 2003). Pekmez is a concentrated and extended shelf-life form of several fruit juices, and it is formed by boiling without the addition of sugar or other food additives (Yoğurtçu & Kamışlı 2006). Pekmez is produced primarily from grapes by concentrating juices with a soluble dry matter content of up to 70-80% (Alpaslan & Hayta 2002; Batu et al 2007). In Turkey, approximately 4185.126 tons of grapes are produced per year (TUIK 2012), and approximately 30% of the grapes produced in Turkey are used for pekmez, wort and sausage with pekmez production in a year. Furthermore, some fresh or dried fruits that contain high amounts of sugar, such as fig, mulberry, carob, juniper, sugar beet, sugar cane, melon, watermelon, apple and apricot, can also be used to produce pekmez (Karababa & Isikli 2005; Akbulut et al 2008). Fresh fruits are directly squeezed, whereas dried fruits are subjected to extraction in an aqueous medium and then pressed and derived extract called as must is homogenized (Aliyazıcıoğlu et al 2009).

Pekmez samples are produced in all regions of Turkey and are named after the geographic locations in which they are produced, such as Zile Pekmez in Zile, Ağda in Gaziantep, Çalma in Kırşehir, Bulama in Balıkesir and Masara in Kahramanmaraş (Tosun & Üstün 2003). However, the varieties of grapes and processing techniques used in pekmez production can be different in these regions. Pekmez is produced using traditional and vacuum evaporation methods in Turkey. However, most of rural regions that do not have modern processing units use the traditional production method (Arici et al 2004; Batu 2006). Pekmez processing techniques vary according to the species of fruits used during production (Kaya & Belibağlı 2002; Arici et al 2004).

Pekmez is a good energy and carbohydrate source due to its high sugar content (up to 50-80%) in the form of glucose and fructose; therefore, it easily passes into the blood without digestion. The average energy value of pekmez is 293 kcal 100 g^{-1} (Simsek & Artık 2002; Tosun & Ustun 2003). It contains organic acids and, essential minerals such as Fe (2.62-16.30 mg 100 g^{-1}), P (0-95.06 mg 100 g^{-1}), Ca (50.9-206.1 mg 100 g^{-1}) and K (792-929 g 100 g^{-1}) (Üstün & Tosun 1997; Yoğurtçu & Kamışlı 2006; Batu 2011). The high Fe content makes pekmez a recommended supplement for anemia (Öztürk & Öner 1999). Pekmez, which is an important product for human nutrition due to its composition (Batu & Gök 2006), is consumed at breakfast as jams and marmalades by mixing with tahini as a dessert, used in place of sugar in several traditional products such as halva and it is also processed for snacks such as sweet tarhana, köfter and köme (Yoğurtçu & Kamışlı 2006; Koca 2014).

There is little information about the physical and chemical properties of grape pekmez. The purpose of this study was to determine the physical and chemical properties of grape pekmez produced using the traditional (classical) method with fourteen different grape cultivars as well as to determine the phenolic composition and antioxidant activity.

2. Material and Methods

2.1. Materials

In this study, fourteen different grape varieties (Alphonse Lavallée, Müşküle, Razakı, Eksenez, Erenköy Beyazı (Bursa), Pafi, Hatun Parmağı, Horoz Karası (Hatay), Şıra Üzümü 1, Narince (Tokat), Parmak Üzümü (Nevşehir), Izabella (Giresun), Siyah Dimrit (Manisa) and Şıra üzümü 2 (Amasya)) were used for the production of Pekmez samples. Pekmez samples were prepared from these grape varieties according to traditional (classical) method.

Standards and chemicals: rutin hydrate (R5143), quercetin hydrate (337951), and gallic acid (G7384) were purchased from Sigma-Aldrich (St. Louis, USA); caffeic acid (822029), *p*-coumaric acid (800237), erulic acid (822070), methanol, hydrochloric acid, oxalic acid, formic acid and acetonitrile were purchased from Merck (Darmstadt, Germany); and ellagic acid (45140) was purchased from Fluka (Buchs, Switzerland). All chemicals used were of analytical grade.

2.2. Methods

Pekmez preparation: Traditional method was used preparation of pekmez samples. At first, grapes were crashed by human power to obtain must. Pekmez earth (75.84% $CaCO_3$) was added to must and kept for one night to acid reduction and clarification. The obtained liquid must was boiled in open boilers till pekmez sample become optimum consistency. The samples arriving to the laboratory were placed in jars with a volume of 100 mL and stored at 20 °C in darkness.

Chemical analyses: The water-soluble dry matter content of the pekmez samples was determined using a refractometer (Kem RA-500N, Tokyo, Japan) at 20 °C. The titratable acidity was determined (tartaric acid g 100 g^{-1}) using the potentiometric method (0.1 N NaOH solution up to a pH of 8.1), and the pH was determined using a pH meter (Mettler Toledo Seven Easy, Switzerland).

Determination HMF content: The HMF was quantitatively determined following the procedure described by the International Honey Commission (IHC 2002) based on the colorimetric reaction between barbituric acid, *p* toluidine and HMF, which forms a red-colored complex. The intensity of the red color was measured at 550 nm using a UV-Vis-NIR-5000 spectrophotometer.

Determination sugar content: The fructose (g 100 g^{-1}) and glucose (g 100 g^{-1}) contents of the pekmez samples were determined according to the International Honey Commission (IHC 2002) with HPLC. HPLC was conducted using a system composed of a Shimadzu LC-10 A pump and a RID-10A detector using a reversed-phase waters carbohydrate column (300 mm × 3.9 mm). The mobile phase consisted of 80% acetonitrile and 20% water, with a flow rate of 0.9 mL min^{-1}. The retention times (t_R) of fructose and glucose were determined to be 4.8 and 5.2 min, respectively.

Determination mineral content: Approximately 0.5 g of each completely homogenized sample was placed into a Teflon crucible with 6 mL of pure HNO_3+1 mL H_2O_2. The samples were incinerated in a Milestone microwave oven, and the incinerated samples were diluted to 25 mL with distilled water. The mineral elements (Ca, Fe, K, Mg, Na, and P) were analyzed using ICP-OES (Yıldız et al 2009).

Determination antioxidant activity: The antioxidant activities of the pekmez samples were determined using the 2,2,-diphenyl-2-picryl-hydrazyl (DPPH) method (Türkben et al 2010) with some modifications. Approximately 1 g samples were extracted with 80% aqueous methanol (4.5 mL) on a mechanical shaker for 2 h. The mixture was centrifuged at 10,000 rpm for 15 min, and the supernatant was decanted into polypropylene tubes. The pellets were extracted under identical conditions. The supernatants were combined and filtered, and the clear extracts were analyzed for antioxidant activity. A 1.5 mL aliquot of 0.1 mM DPPH radical in methanol was added to a test tube with 0.5 mL of the sample extracts. Pure methanol, rather than the methanolic extract of the samples, was used as a

control. The reaction mixture was vortex mixed and allowed to stand at room temperature in the dark for 1 h before the decrease in absorbance (A) at 517 nm by Shimadzu UV/VIS 1800 model (Kyoto, Japan) spectrophotometer was measured. The results were expressed as µmol Trolox equivalents (µmol TE g^{-1}).

Determination phenolic compounds: The methanol extraction method was applied with some modifications as described by the International Honey Commission (IHC 2002). HPLC was conducted using a system composed of a Shimadzu LC-10 A pump and a SPD-M10AVP detector using a reversed phase Nucleodur C18 column (250 mm × 4.0 mm i.d, 5.0 µm). The mobile phase consisted of 0.05% formic acid and methanol (Table 1), and the flow rate was 0.9 mL min^{-1} at 250-280 nm. The retention times (t_R) of each compound are presented in Table 2.

Table 1- HPLC conditions for the determination of phenolic compounds

Çizelge 1- Fenolik bileşiklerin belirlenmesi için kullanılan HPLC koşulları

Time (min)	*HPLC conditions*
0.01	95% formic acid 5.0% methanol
50.00	50% formic acid 50% methanol
55.00	100% formic acid 0.0% methanol
57.00	100% formic acid 0.0% methanol
60.00	5.0% formic acid 95% methanol
65.00	5.0% formic acid 95% methanol

Table 2- Retention times (t_R) of standard phenolic compounds

Çizelge 2- Standart fenolik bileşiklerin alıkonma zamanları (t_R)

Phenolic compounds	*t_R (min)*
Gallic acid	9.95
Cafeic acid	27.4
p-Cumaric acid	34.9
Ferrulic acid	37.5
Rutin hydrat	45.3
Ellagic acid	46.0
Quercetin	56.5

Physical analyses: The electrical conductivity of a 20% pekmez solution (dry matter basis) in CO_2-free deionized distilled water was measured at 20 °C using a WTW InoLab Cond Level 1 Digital Ec-meter (Weilheim, Germany) and the result was expressed as mS cm^{-1} (AOAC 1990).

The density determinations of the pekmez samples were performed using the oscillating U-tube method. For this purpose, approximately 1 g of pekmez was placed into a temperature-controlled sample cell, and oscillation frequency data obtained from the density-meter (KEM-DA-505, Tokyo, Japan) were saved. By measuring the oscillation frequency of a calibration fluid with a known density and using predetermined cell coefficients, the densities of the samples (g cm^{-3}) were calculated.

2.3. Statistical analyses

The experiment was conducted in a completely randomized design with three replications. The results were statistically evaluated by one-way analysis of variance (ANOVA) using the JMP software package version 7.0 (SAS Institute Inc. NC, 27513). The significance of the treatments was determined at the 0.01 probability level using the F-test.

3. Results and Discussion

Some physical and chemical properties of grape pekmez samples produced from fourteen different grape varieties are given in Table 3. The water-soluble dry matter content was found to be 66.19-80.57%. The water-soluble dry matter in fruits is primarily formed by sugars, including fructose, glucose and sucrose, and by acids, such as citric acid and malic acid (Cemeroğlu 2010). Alpar (2011) estimated the water-soluble dry matter content in white grape pekmez processed using the traditional method to be 61.50%. Koca et al (2007) and Üstün & Tosun (1997) also reported that the water-soluble dry matter content in grape pekmez ranged from 69.00-73.90% and 68.60-78.30%, respectively.

The pH in grape pekmez was found to range from 3.59 to 5.23. The titratable acidity (in terms of tartaric acid) was determined to be the highest

and lowest in the Pafi (0.27 g 100 g^{-1}) and Izabella (1.81 g 100 g^{-1}) samples, respectively (P<0.01). Titratable acidity is inversely proportional to pH. Acidity may vary depending on the herbal sources and producing regions (Batu et al 2013). According to Grape Pekmez Notification (2007), pekmez is classified as sweet pekmez if their pH range is from 5 to 6, and they are classified as sour pekmez when their pH range is from 3.5 to 5. Therefore, while Eksenez, Erenköy Beyazı, Pafi, Hatun Parmağı, Horoz Karası, and Şıra Üzümü 2 pekmez are sweet pekmez samples, the other samples are classified as sour pekmez. The pH and titratable acidity of grape pekmez have been identified in several studies as 4.36 to 5.12 and 0.08-0.97% (Üstün & Tosun 1997), 5.20 to 5.33 and 0.71-0.79% (Simşek & Artık 2002), 8.11 and 0.59% (Alpar 2011), respectively.

HMF is not naturally found in fruits; rather, it is formed from monosaccharides by the action of heat and acid and is a limited compound for preventing the application of excess heat in many products. It is an important quality factor that reflects the severity of heat treatment (temperature and time) that were applied to the foods thickened with the application of a heat treatment (Tosun & Üstün 2003; Cemeroğlu 2010). The HMF contents of the grape pekmez samples varied from 5.93 mg kg^{-1} (Pafi) to 762.22 mg kg^{-1} (Izabella). According to Pekmez Standards, the allowed formation of HMF in liquid pekmez is 75 mg kg^{1}, whereas in solid pekmez, 100 mg kg^{-1} is allowed. This value in pekmez samples derived from grape varieties such as Alphonse Lavallée (380.08 mg kg^{-1}), Müşküle (116.93 mg kg^{-1}), Razakı (206.31 mg kg^{-1}), Erenköy Beyazı (333.37 mg kg^{-1}), Izabella and Şıra Üzümü 1 (163.10 mg kg^{-1}) were quite high. A study conducted on the traditional methods in homes with found an HMF content that was approximately 20 times higher in high

Table 3- Physical and chemical properties of traditionally processed grape pekmez samples

Çizelge 3- Geleneksel olarak üretilen pekmez örneklerinin fiziksel ve kimyasal özellikleri

Grape cultivars	*Water-soluble dry matter (%)*	*Titratable acidity (g 100 g^{-1})*	*pH*	*HMF (mg kg^{-1})*	*Electrical conductivity (mS cm^{-1})*	*Density (g cm^{-3})*
Alphonse Lavallée (Bursa)	68.38 d	0.79 d	4.73 g	380.08 b	4.07 b	1.363 c
Müşküle (Bursa)	69.43 cd	0.53 g	4.84 f	116.93 f	3.59 d	1.380 b
Razakı (Bursa)	69.54 cd	0.82 c	4.70 g	206.31 d	3.85 c	1.347 de
Eksenez (Bursa)	66.19 f	0.35 j	5.04 c	57.21 ıj	3.02 g	1.327 f
Erenköy Beyazı (Bursa)	68.10 de	0.45 h	5.05 c	333.37 c	1.96 ı	1.337 ef
Parmak Üzümü (Nevşehir)	68.52 d	0.42 ı	4.95 de	60.85 gh	2.97 g	1.340 def
Izabella (Giresun)	68.86 cd	1.81 a	3.59 ı	762.22 a	2.48 h	1.340 def
Pafi (Hatay)	66.33 f	0.27 k	5.23 a	5.93 l	3.26 f	1.350 cde
Hatun Parmağı (Hatay)	66.73 ef	0.37 j	5.13 b	44.13 k	3.41 e	1.340 def
Horoz Karası (Hatay)	66.30 f	0.41 ı	5.00 cde	58.13 hı	3.09 g	1.350 cde
Siyah Dimrit (Manisa)	80.57 a	1.02 b	4.17 h	46.87 k	3.01 g	1.430 a
Şıra Üzümü 1 (Tokat)	74.27 b	0.69 e	4.75 g	163.10 e	3.70 d	1.393 b
Narince (Tokat)	68.59 d	0.56 f	4.94 e	63.61 g	4.05 b	1.353 cd
Şıra Üzümü 2 (Amasya)	70.07 c	0.43 hı	5.00 cd	54.57 j	4.51 a	1.363 c
LSD	1.47	0.02	0.06	1.00	0.13	0.01
CV (%)	1.27	2.26	0.73	1.23	2.39	0.63

*, mean values within a column with different superscript letters were significantly different (P<0.01); CV, coefficient of variation

temperature-produced pekmez (681.40 mg kg^{-1}) compared with the pekmez produced under vacuum (35.25 mg kg^{-1}) commercially (Batu 1991). The high content of HMF in the grape pekmez samples is a result of the boiling process in an open vessel at high temperature. In the literature, the amounts of HMF in grape pekmez samples range from 7.38 to 166.05 mg kg^{-1} (Üstün & Tosun 1997), from 18.4 to 200 mg kg^{-1} (Kus et al 2005) and from 29.56 to 801.80 mg kg^{-1} (Koca et al 2007).

The sugar contents of the pekmez samples are given in Figure 1. In the study of grape pekmez, the amount of fructose changed from 22.34 g 100 g^{-1} of (Hatun Parmağı) to 34.69 g 100 g^{-1} (Parmak Üzümü) and was determined to be 28.42 g 100 g^{-1} on average. On the other hand, the glucose ratios ranged from 27.57 g 100 g^{-1} (Hatun Parmağı) to 41.11 g 100 g^{-1} (Siyah Dimrit), with an average value of 31.67 g 100 g^{1}. Simşek & Artık (2002) reported that the fructose and glucose contents of 25 commercially produced grape pekmez samples changed from 30.14 to 34.42% and from 30.73 to 34.99%, respectively. The densities of the pekmez samples were found to range between 1.33 g cm^{-3} (Eksenez) and 1.43 g cm^{-3} (Siyah Dimrit). The electrical conductivity values also showed variations between 1.96 mS cm^{-1} (Erenköy Beyazı) and 4.51 mS cm^{-1} (Şıra Üzümü 2). Electrical conductivity provides more information about mineral salts, organic acids, and protein concentrations. When the product contains high contents of mineral salts, organic acids, and proteins, the electrical conductivity is higher (Akbulut & Özcan 2008). Akbulut et al (2008) reported that the density and electrical conductivity values of *Juniperus drupacea* (andız) pekmez were 1.34 g cm^{-3} and 6.14 mS cm^{-1}, respectively. In another study, the electrical conductivity of sweet sorghum pekmez was identified as 13.53 mS cm^{-1} (Akbulut & Özcan 2008).

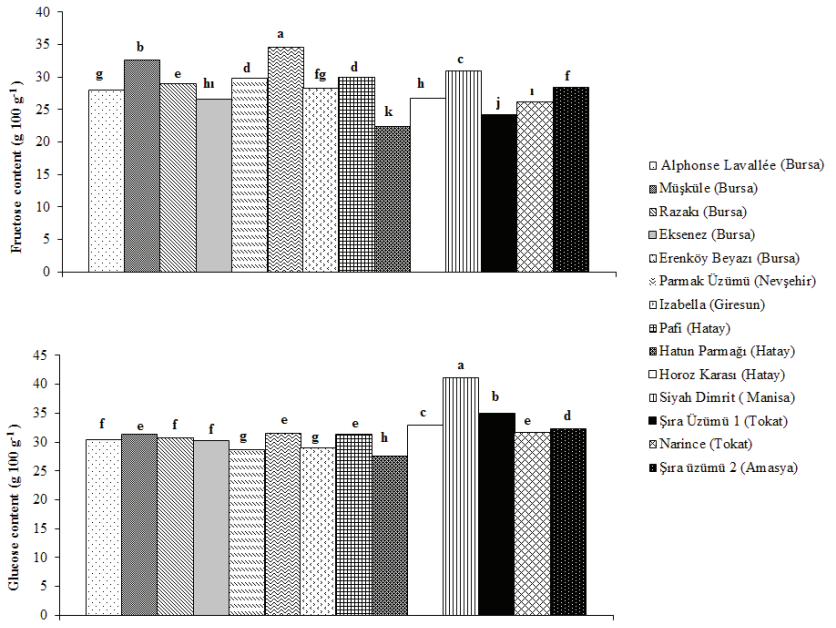

Figure 1- The sugar contents of traditionally processed grape pekmez samples. Bars with different superscript letters were significantly different (P<0.01)

Şekil 1- Geleneksel olarak üretilmiş üzüm pekmezi örneklerinin şeker içerikleri. Farklı harflerle belirtilen değerler istatistiki açıdan farklıdır (P<0.01)

Minerals are food ingredients that are vital. The mineral contents of the grape pekmez samples are given in Table 4. The contents of macro elements found in grape pekmez samples produced from different grape varieties were determined to range from 48.70 mg kg^{-1} (Horoz Karası) to 5109.56 mg kg^{-1} (Horoz Karası) ($P<0.01$). In terms of the average values of macro elements, the highest amount was found for K, with the value of 4449.86 mg kg^{-1}, followed by Ca (1275.52 mg kg^{-1}), P (369.96 mg kg^{-1}), Mg (344.79 mg kg^{-1}) and Na (119.56 mg kg^{-1}). Several studies have reported that the K content was highest in grape pekmez (Yumlu 2006; Akbulut & Özcan 2009; Alpar 2011; Çoklar & Akbulut 2012). The micro element Fe was identified in the pekmez samples (average 46.91 mg kg^{-1}), and it was found in lower amounts than other minerals. The pekmez sample produced from Şıra Üzümü 2 has the highest Ca content (4973.93 mg kg^{-1}), the Müşküle sample has the highest Fe (403.67 mg kg^{-1}) and P (597.87 mg kg^{-1}) contents, the Izabella sample has the highest Mg (612.83 mg kg^{-1}) content, and the Narince sample has the highest Na (344.28 mg kg^{-1}) content with statistical significance ($P<0.01$). The pekmez samples produced from Horoz Karası varieties have the highest K content (5109.56 mg kg^{-1}), and there is no significant difference between Erenköy Beyazı (5063.11 mg kg^{-1}) and Izabella (5045.81 mg kg^{-1}) ($P>0.01$). Alpar (2011) determined that the Ca, K, Mg, Na, P and Fe contents of pekmez samples produced from white, black and red grapes using the traditional method ranged from 1.56 to 1491.65 mg kg^{-1}, from 1811.79 to 9581.34 mg kg^{-1}, from 187.34 to 332.33 mg kg^{-1}, from 153.14 to 248.86 mg kg^{-1}, from 192.44 to 492.43 mg kg^{-1} and from 49.53 to 132.13 mg kg^{-1}, respectively. On the other hand, Yumlu (2006) reported that the most abundant mineral in the grape pekmez was K (302.50 mg 100 g^{-1}), followed by Ca (153.49 mg 100 g^{-1}), Mg (62.19 mg 100 g^{-1}) and Na (54.84 mg 100 g^{-1}). Aliyazicioglu et al (2009) determined the Ca, K, Na, P and Fe contents in grape pekmez to be 186, 831, 1353, 48 and 3.4 mg kg^{-1}, respectively.

Table 4- Mineral contents of traditionally processed grape pekmez samples (mg kg^{-1})

Çizelge 4- Geleneksel olarak üretilen pekmez örneklerinin mineral içerikleri (mg kg^{-1})

Grape cultivars	*Ca*	*Fe*	*K*	*Mg*	*Na*	*P*
Alphonse Lavallée (Bursa)	265.50 ı	10.95 f	4007.93 h	412.16 d	84.67 g	307.09 gh
Müşküle (Bursa)	894.62 f	403.67 a	4560.95 d	257.62 h	133.64 e	597.81 a
Razakı (Bursa)	528.12 g	7.42 g	4693.47 cd	476.88 c	80.82 g	367.19 e
Eksenez (Bursa)	507.17 g	13.56 e	4059.66 gh	241.67 ı	153.55 d	331.81 f
Erenköy Beyazı (Bursa)	3515.88 b	42.51 b	5063.11 ab	553.52 b	84.05 g	303.08 h
Parmak Üzümü (Nevşehir)	1322.33 e	9.89 fg	4933.78 b	191.97 j	173.36 c	401.94 d
Izabella (Giresun)	1743.63 c	34.04 c	5045.81 ab	612.83 a	107.39 f	370.70 e
Pafi (Hatay)	404.39 h	40.25 b	3370.58 ı	250.08 hı	52.59 hı	226.76 j
Hatun Parmağı (Hatay)	163.12 j	15.80 e	4396.53 e	250.29 hı	52.59 hı	272.31 ı
Horoz Karası (Hatay)	564.17 g	2.27 h	5109.56 a	308.17 g	48.70 ı	513.04 b
Siyah Dimrit (Manisa)	271.58 ı	26.08 d	3961.60 h	328.27 f	51.44 hı	361.69 e
Şıra Üzümü 1 (Tokat)	1405.18 d	10.84 f	4206.90 f	320.89 fg	249.39 b	489.56 c
Narince (Tokat)	1297.67 e	15.93 e	4191.56 fg	370.53 e	344.28 a	316.21 gh
Şıra Üzümü 2 (Amasya)	4973.93 a	23.52 d	4696.66 c	252.13 hı	57.32 h	320.30 fg
LSD	78.99	2.59	132.67	13.46	7.13	13.62
CV (%)	3.71	3.30	1.79	2.34	3.58	2.21

*, mean values within a column with different superscript letters were significantly different ($P<0.01$); CV, coefficient of variation

Grapes are one of the richest sources of phenolic substances in fruits, and the antioxidant activity of these fruits results from the abundance of phenolic substances (Revilla et al 1997). The antioxidant activities and contents of phenolic compounds of the grape pekmez samples are given in Table 5. The antioxidant activities of the pekmez samples changed from 38.20 to 64.45 μmol TE g^{-1}, and significant differences were observed between samples ($P<0.01$).

In this study, six phenolic compounds, caffeic acid, ellagic acid, ferulic acid, gallic acid, *p*-coumaric acid and rutin hydrate, were determined in pekmez samples. The HPLC chromatograms of standards and the Narince (Tokat) sample are shown in Figure 2. The caffeic acid, ferulic acid, *p*-coumaric acid, rutin hydrate and gallic acid contents of the samples changed from 1.95 (Hatun Parmağı) to 14.69 (Narice) mg kg^{-1}, from 0.35 (Parmak Üzümü) to 2.62 (Şıra Üzümü 1) mg kg^{-1}, from 0.41 (Şıra Üzümü 1) to 20.4 (Alphonse Lavallée) mg kg^{-1}, from 0.51 (Alphonse Lavallée) to 7.48 (Parmak Üzümü) mg kg^{-1}, and from 0.35 (Eksenez) to 10.14 (Müşküle) mg kg^{-1}, respectively. Quercetin hydrate was not determined in any of the pekmez samples, whereas ellagic acid was determined only in the samples produced from Izabella (0.20 mg kg^{-1}), Şıra Üzümü 1 (0.23 mg kg^{-1}) and Narince (0.32 mg kg^{-1}). Phenolic compounds in grapes are affected by many factors, such as properties of the varieties, cultivation conditions, the location of the production area and the degree of ripeness of the grapes (Revilla et al 1997). Alpar (2011) determined that the antioxidant activity changed from 86.44% to 93.40% and that the total phenolic content changed from 20.447 mg L^{-1} to 24.188 mg L^{-1} in pekmez produced using the traditional method. Kelebek et al (2012) reported that the contents of gallic acid, *p*-coumaric acid and caffeic acid in white grape pekmez were 8.93, 0.03 and 0.20 mg kg^{-1}, respectively, and similarly, they were 5.50, 0.03 and 0.25 mg kg^{-1} in black grape pekmez, respectively.

Table 5- The antioxidant activities and contents of phenolic compounds (mg kg^{-1}) of traditionally processed grape pekmez samples

Çizelge 5- Geleneksel olarak üretilen pekmez örneklerinin antioksidan aktivite değerleri ve fenolik bileşikleri (mg kg^{-1})

Grape cultivars	*Caffeic acid*	*Ferulic acid*	*p-coumaric acid*	*Rutin hydrate*	*Gallic acid*	*Ellagic acid*	*Antioxidant activity (μmol TE g^{-1})*
Alphonse Lavallée (Bursa)	12.50 b	1.58 b	20.04 a	0.51 g	2.59 d	nd	61.52 b
Müşküle (Bursa)	10.69 c	1.35 c	1.39 j	nd	10.14 a	nd	55.36 f
Razakı (Bursa)	6.60 e	0.58 g	1.87 h	nd	nd	nd	58.59 d
Eksenez (Bursa)	9.46 d	0.84 e	3.78 e	0.84 f	0.35 e	nd	54.94 f
Erenköy Beyazı (Bursa)	9.56 d	0.73 f	3.30 f	nd	3.75 c	nd	59.76 c
Parmak Üzümü (Nevşehir)	4.45 g	0.35 ı	1.73 hı	7.48 a	nd	nd	50.53 g
Izabella (Giresun)	5.76 f	0.54 g	1.87 h	2.83 d	nd	0.20 b	45.42 h
Pafi (Hatay)	9.69 d	2.62 a	6.32 d	nd	nd	nd	56.53 e
Hatun Parmağı (Hatay)	1.95 ı	0.83 e	2.65 g	1.10 e	nd	nd	61.37 b
Horoz Karası (Hatay)	nd	1.36 c	1.51 ıj	nd	nd	nd	63.65 a
Siyah Dimrit (Manisa)	12.42 b	1.33 c	9.67 b	3.37 c	9.68 b	nd	38.20 ı
Şıra Üzümü 1 (Tokat)	3.36 h	2.62 a	0.41 k	2.73 d	nd	0.23 b	64.45 a
Narince (Tokat)	14.69 a	1.17 d	7.57 c	4.66 b	0.49 e	0.32 a	61.52 b
Şıra Üzümü 2 (Amasya)	4.68 g	0.45 h	1.33 j	0.66 fg	nd	nd	63.48 a
LSD	0.15	0.14	0.14	0.15	0.15	0.17	0.31
CV (%)	2.27	3.90	4.06	5.49	3.32	6.93	1.12

*, mean values within a column with different superscript letters were significantly different ($P<0.01$); nd, not detected; CV, oefficient of variation

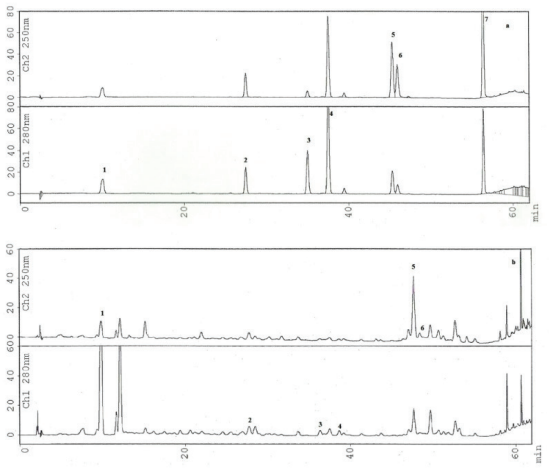

Figure 2- HPLC chromatograms of standard phenolic compounds (a) and the Narince (Tokat) pekmez sample (b). (1, Gallic acid; 2, Caffeic acid; 3, *p*-coumaric acid; 4, Ferulic acid; 5, Rutin hydrate; 6, Ellagic acid; 7, Quercetin hydrate)

Şekil 2- Standart fenolik bileşiklerin (a) ve Narince (Tokat) (b) pekmez örneğinin HPLC kromotogramları. (1, Gallik asit; 2, Kafeik asit; 3, p-kumarik asit; 4, Ferulik asit; 5, Rutin hidrat; 6, Ellajik asit; 7, Kuersetin hidrat)

4. Conclusions

Grape pekmez is routinely produced in Turkey, and open vessels are used with traditional methods in many areas for the production of grape pekmez. With the use of traditional methods for the production of pekmez and the absence of any standard implementation, the quality of the pekmez is decreased, and compounds that are harmful to human health, such as HMF, are also formed in large amounts. To produce better quality pekmez, standardization in production should be applied by using modern technology, and traditional production should be adapted to this technology.

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The Factors Affecting Heavy Metal Levels in the Muscle Tissues of Whiting (*Merlangius merlangus*) and Red Mullet (*Mullus barbatus*)

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ABSTRACT

This study aims to determine heavy metal accumulation levels in the muscles tissues of two economically most important demersal fish species in the Eastern Black Sea, Turkey, red mullet (*Mullus barbatus*) and whiting (*Merlangius merlangus*), and evaluate the effects of fish species, sampling locations, fishing season and size groups on heavy metal accumulation levels. Chromium (Cr), manganese (Mn), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd) and lead (Pb) concentrations in fish muscle samples were measured with Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Co, Zn, As and Cd accumulation levels in both species differed significantly ($P<0.05$). The metal concentrations of muscle tissues of both species, in general, were higher during summer and autumn. In the study, the differences in concentrations levels of As and Pb in whiting, Co, Cu, and Pb in red mullet muscle tissues were significantly related to fishing locations. The results of metal concentrations were compared with various legal limits such as Turkish Food Codex (TFC 2011), European Communities Commission Regulation (EC 2006) and Food and Agriculture Organization (FAO 1983) and the obtained metal levels of fish muscle tissues of both species were found to be below the limit values which are a threat to human health.

Keywords: Black sea; Fish; Heavy metal; Whiting; Red mullet; Pollution

Mezgit (*Merlangius merlangus*) ve Barbunya (*Mullus barbatus*) Balıklarında Ağır Metal Düzeylerini Etkileyen Faktörler

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ÖZET

Bu çalışmada, Doğu Karadeniz'de (Türkiye) ekonomik öneme sahip en önemli iki demersal balık türü olan barbunya ve mezgit balıklarındaki ağır metal birikim düzeylerinin tespit edilmesi ve metal birikim düzeylerinin balık türü, örnekleme

yeri, avlanma dönemi ve boy grubu gibi faktörlerle ilişkilerinin ortaya konulması hedeflenmiştir. Balık kas dokularında krom (Cr), mangan (Mn), kobalt (Co), nikel (Ni), bakır (Cu), çinko (Zn), arsenik (As), kadmiyum (Cd) ve kurşun (Pb) derişimleri indüktif eşleşmiş plazma kütle spektrometresi (ICP-MS) ile ölçülmüştür. Barbunya ve mezgit balıklarının kas dokularındaki Co, Zn, As ve Cd birikim düzeyleri farklılığı istatistiksel olarak önemli bulunmuştur ($P<0.05$). Her iki balık türünün kas dokusundaki metal düzeylerinin de genellikle yaz ve sonbahar döneminde daha yüksek olduğu belirlenmiştir. Çalışmada mezgit balığı kas dokusundaki As ve Pb derişimleri farklılığının, barbunya balığı kas dokusunda ise Co, Cu ve Pb derişimleri farklılığının avlandıkları lokasyonlar yönünden istatistiksel olarak önemli olduğu tespit edilmiştir. Tespit edilen metal derişimleri Türk Gıda Kodeksi (TFC 2011), Avrupa Birliği Komisyonu Tüzüğü (EC 2006) ve Gıda ve Tarım Örgütü (FAO 1983) gibi çeşitli yasal limitler ile karşılaştırılmış ve balık kas dokularındaki metal düzeylerinin insan sağlığı açısından tehdit oluşturabilecek limitlerin altında olduğu belirlenmiştir.

Anahtar Kelimeler: Karadeniz; Balık; Ağır metal; Mezgit; Barbunya; Kirlilik

1. Introduction

Metals are among the most detrimental elemental contaminants in aquatic ecosystems due to their toxic effects and accumulation by entering the food chain (Tepe 2009; Boran & Altinok 2010). Some elements such as iron (Fe), copper (Cu), zinc (Zn), manganese (Mn) and selenium (Se) are considered as essential for their important roles in biological systems and nickel (Ni), vanadium (V), cobalt (Co) are known as probably essential metals. Such metals as lead (Pb), cadmium (Cd) and mercury (Hg) are non-essential metals and even very low amounts of these metals may have toxic effects (Canlı & Atlı 2003; Tüzen 2003; Uluozlu et al 2007; Turan et al 2009; Mendil et al 2010; Özden et al 2010). Industrial wastes, mining activities and marine sediment geochemical structure are potential sources of heavy metals affecting aquatic ecosystem (Balkıs et al 2007; Mendil et al 2010; Alkan et al 2012). Fish, major components of aquatic ecosystems, are protein-rich foodstuffs (Fındık & Çiçek 2011) containing high amounts of unsaturated fatty acids. Moreover, they are very important both economically and ecologically due to their key roles in food webs dynamics. Fish accumulate heavy metals as they are in the upper levels of the food chain. Therefore, fish especially demersal fishes are used as indicators of ecosystem contamination in the monitoring programs for the determination of metal pollution in seas (Has-Schon et al 2008; Harmelin-Vivien et al 2009; Mendil et al 2010; Özden et al 2010; Alkan et al 2012). Red mullet and whiting are generally known as demersal fish species. Nevertheless, though red mullet inhabits in more shallow waters compared to whiting and is an entirely bottom feeding species, whiting is a bathi-pelagic species. Heavy metal accumulation levels in fish may change depending on species, size groups (Canlı & Atlı 2003), tissues, seasons and geographic regions (Mendil et al 2010).

The Eastern Black Sea where almost 60% of the total fishing takes place has an important role in Turkish fisheries. The contributions of Eastern Black Sea to the total fishing of red whiting and red mullet were 68% and 19%, respectively (Turkish Statistical Institute 2011). The decrease in fish stocks due to overfishing and pollution made it necessary to determine the quality level and usability of the available resources.

In the present study, it is aimed to determine the levels of heavy metal accumulation in the muscle tissue of economically important fish species in Turkey, whiting and red mullet and evaluate the effects of fish species, fishing locations, fishing season and size groups on heavy metal accumulation levels.

2. Material and Methods

The study area fed by Kızılırmak, Yeşilırmak and Melet rivers is more densely populated particularly Samsun and its vicinity, in terms of industrial and agricultural activities.

A total of 668 whiting and 519 red mullet analyzed specimens were collected from six stations in the Eastern Black Sea, which were located in Samsun (S1, S2, S3) where trawl fishery are permitted and in Ordu (O1, O2, O3) not permitted (Table 1 and Figure 1).

S2, S3, O1 and O2 stations are more affected by the industrial and urban pressures compared to others. Sampling was carried out with trawl nets in July, October, January and April corresponding to summer, autumn, winter and spring seasons, respectively. The fishes were grouped as small, medium and large sizes following the separation of species (Table 1) and the length and weight were measured and muscle tissues were taken. Metal analysis in tissues is usually done on the dry weight since the legal limits are given as wet weight which requires converting wet into dry weights. Muscle tissues of fish samples were dried under vacuum with freeze dryer (Eyela, Japan) until tissues reached constant weight. About 0.5 g sample was taken from dried and homogenized samples for digestion in a sensitive manner after weighing. The samples were digested with microwave system (Milestone Ethos 1, Italy) and 7 mL ultrapure HNO_3 (65% Merck, Darmstadt, Germany) and 1 mL H_2O_2 (30% Merck, Darmstadt,

Table 1- Average lenght, weight and muscle wet/dried ratio of whiting and red mullet

Çizelge 1- Mezgit ve barbunya balıkları için ortalama boy, ağırlık ve kas doku yaş/kuru ağırlık oranı

Species	*Size group*	*N*	*Length (cm)*		*Weight (g)*		*Wet/Dried Ratio*
			Mean	*Std. dev*	*Mean*	*Std. dev*	
Merlangius merlangus (Whiting)	Small	261	9.8	1.3	7.2	2.9	5.8
	Medium	235	13.2	1.4	18.8	6.3	5.7
	Large	172	16.4	1.6	38.3	13.4	5.6
Mullus barbatus (Red mullet)	Small	216	8.8	1.3	7.1	3.5	4.6
	Medium	182	11.6	1.2	16.4	4.9	4.3
	Large	121	14.0	1.7	30.8	11.0	4.0

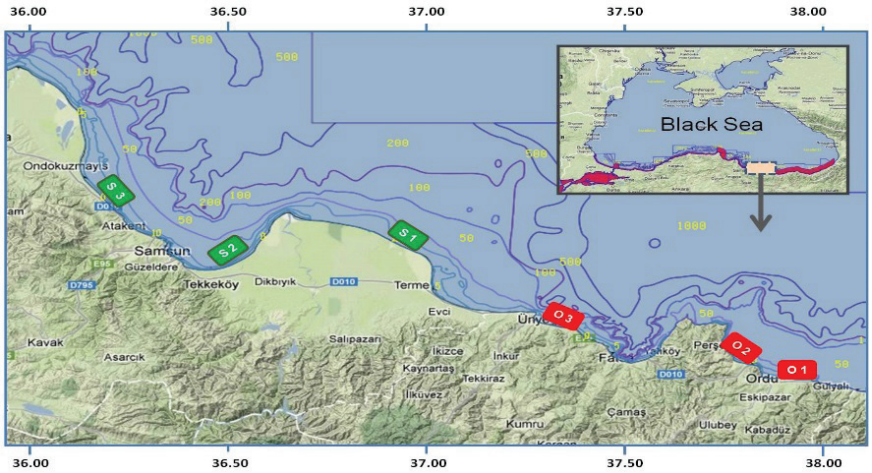

Figure 1- Map of sampling stations

Şekil 1- Örnekleme istasyonları

Germany) was used according to (Milestone 2011) procedure at 200 °C in 15 min. The solution was diluted to 25 mL with ultrapure water obtained from deionized water system (Barnstead Nanopure, USA) following digestion. Heavy metal analyses were performed using Varian 820 model ICP-MS (Melbourne, Australia) according to EPA (1994) Working conditions of the instrument were given in Table 2. Scandium (Sc) and Indium (In) elements were used as internal standard in the measurements. In order to validate digestion procedure and method of analysis, DORM 3 (National Research Council, Canada) certified reference material was digested and analyzed with the same procedure.

Student t-test was applied for statistical differences of the measured parameters between fish species. One-Way ANOVA, followed by Tukey post hoc test, was used to test difference in the metal accumulation levels among the size groups, sampling locations and sampling stations of both species. In order to determine the factors affecting metal accumulation levels, factor analysis was applied to the data using principle component analysis.

3. Results and Discussion

The analysis results of DORM 3 certified reference material are given in Table 3. The results of the recovery metal values as percentage were within the acceptable limits as specified on the certificate.

The mean concentrations of metals in each fish species are summarized in Table 4. In the muscle tissues, the mean concentrations of the heavy metals were determined as Zn>As>Cu>Mn>Cr>Ni>Cd>Co>Pb for whiting and Zn>As>Cu>Mn>Cr>Ni>Co>Pb>Cd for red mullet. The differences in the mean concentrations of metals (Zn: 21.5 mg kg^{-1}, As: 6.34 mg kg^{-1}, Co: 0.03 mg kg^{-1} and Cd: 0.031 mg kg^{-1}) for whiting and red mullet tissues (Zn: 19.7 mg kg^{-1}, As: 14.7 mg kg^{-1}, Co: 0.11 mg kg^{-1} and Cd: 0.018 mg kg^{-1}) were statistically significant ($P<0.05$). The mean concentrations of Co and As of the red mullet were higher than those of the whiting (Table 4). Cr, Mn, Ni and Cu concentrations in muscle tissues of whiting and red mullet were not statistically significant ($P>0.05$).

Table 2- Instrument parameters for Varian 820 ICP-MS

Çizelge 2- Varian 820 ICP-MS için cihaz parametreleri

Parameter	*Value*
Flow parameters (L min^{-1})	
Plasma flow	18
Auxiliary flow	1.65
Sheath gas	0.23
Nebulizer flow	0.87
Torch Alignment (mm)	
Sampling depth	6.5
Other	
RF power (kW)	1.4
Pump rate (rpm)	4
Stabilization delay (s)	20
Ion Optics (volts)	
First extraction lens	-1
Second extraction lens	-169
Third extraction lens	-204
Corner lens	-206
Mirror lens left	39
Mirror lens right	40
Mirror lens bottom	32
Entrance lens	1
Fringe bias	-1.5
Entrance plate	-50
Pole bias	0
CRI (mL min^{-1})	
Skimmer gas source	H_2
Sampler gas source	OFF
Skimmer flow	75
Sampler flow	0

Table 3- Concentration of metals found in certified reference material DORM 3

Çizelge 3- DORM 3 sertifikalı referans materyali analizinde bulunan metal derişimleri

Metal	*Certificated value (μg g^{-1})*	*Observed value (μg g^{-1})*	*Recovery (%)*
As	6.88±0.3	6.54±0.4	95.1
Cd	0.29±0.02	0.29±0.02	100.0
Cr	1.89±0.17	1.93±0.23	102.1
Cu	15.5±0.63	14.78±0.78	95.4
Ni	1.28±0.24	1.33±0.17	103.9
Pb	0.395±0.05	0.383±0.11	97.0
Zn	51.3±3.1	48.5±1.9	94.6

Table 4- Average heavy metal concentration of *Merlangius merlangus* (whiting) and *Mullus barbatus* (red mullet) species in this study, results of the previous study and legal limits (mg kg^{-1})

Çizelge 4- Bu çalışmadaki mezgit ve barbunya balıkları için ortalama ağır metal derişimleri, daha önceki çalışmalara ait sonuçlar ve yasal limitler (mg kg^{-1})

	Metal concentration (mg kg^{-1})									
	Cr	*Mn*	*Co*	*Ni*	*Cu*	*Zn*	*As*	*Cd*	*Pb*	*References*
Whiting	0.97	1.96	-	1.92	1.25	48.6	-	0.55	0.93	Uluozlu et al (2007)[1]
	0.14	0.08	-	1.36	-	6.03	-	0.19	0.5	Turan et al (2009)[2]
	0.80	-	0.03	0.27	1.02	22.76	5.65	0.04	0.08	Alkan et al (2012) [1]
	0.82	3.6	0.25	-	1.8	20.6	-	0.18	0.46	Mendil et al (2010) [2]
	-	-	-	3.78	3.72	31.34	-	0.002	0.58	Nisbet et al (2010) [1]
	0.69	0.74	0.10	0.90	1.03	13.52	0.29	0.03	0.26	Özden et al (2010) [2]
	0.86	7.63		1.14	1.32	65.4	0.17	0.21	0.53	Tüzen (2009) [2]
	-	-	-	-	-	-	0.03	0.22	13	Balkıs et al (2012)[1]
	1.5	-	0.04	0.31	2.5	18	4.96	0.03	0.05	Ergül & Aksan (2013)[1]
	0.62	0.92	0.03	0.61	1.56	21.5	6.34	0.031	0.024	This study[1]
Red mullet	1.63	6.54	-	-	0.98	106	-	0.45	0.84	Uluozlu et al (2007) [1]
	1.06	0.005	-	0.66	-	7.57	-	0.21	0.73	Turan et al (2009) [2]
	0.62	-	0.12	0.18	1.12	27.36	13.95	0.02	0.10	Alkan et al (2012) [1]
	0.99	2.05	0.38	-	1.4	17.8	-	0.23	0.40	Mendil et al (2010) [2]
	-	-	-	2.47	3.14	23.71	-	0.02	0.92	Nisbet et al (2010) [1]
	1.83	1.31	0.17	0.57	0.96	17.38	0.44	0.05	0.15	Özden et al (2010) [2]
	1.35	2.76	-	1.55	0.96	75.5	0.11	0.17	0.36	Tüzen (2009) [2]
	0.33	-	0.05	0.05	1.0	14.6	12.7	0.70	0.02	Ergül & Aksan (2013)[1]
	0.56	1.05	0.11	0.46	1.36	19.7	14.75	0.018	0.020	This study[1]
Legal limits								0.05	0.30	TFC (2011)
					30	30		0.50	0.50	FAO (1983)
								0.05	0.50	EC (2006)

[1], based on dry weight; [2], based on wet weight

The small, medium and large length groups of the whiting were determined as 9.8±1.3 cm, 13.2±1.4 and 16.4±1.6 cm, respectively (Table 1). The differences in Mn, Co, Cu, Zn and Cd accumulation levels among size groups of the whiting were statistically significant ($P<0.05$), whereas the differences in Cr, Ni, As and Pb accumulations levels among size groups of the whiting fish were statistically insignificant ($P>0.05$). Cu and Zn concentrations of small size whiting were higher than those of medium and large sizes (Table 5).

In the study the small, medium and large length groups of the red mullet were determined as 8.8±1.3 cm, 11.6±1.2 cm and 14±1.7 cm, respectively (Table 1). The differences in Mn and Cd accumulation in the red mullet fish size groups were statistically significant ($P<0.05$); however, the differences in Cr, Co, Ni, Cu, Zn, As and Pb accumulation levels were statistically insignificant ($P>0.05$). Cd concentrations of the small size group of red mullet were found to be higher than those of medium and large size groups. Mn concentrations of small and medium size red mullet were significantly higher than those of the large size group (Table 5).

When metal accumulation levels were evaluated according to sampling location (Samsun-Ordu), it

Table 5- Average heavy metal concentrations of *Merlangius merlangus* (whiting) and *Mullus barbatus* (red mullet) according to different length groups, (mg kg^{-1})

Çizelge 5- Farklı boy gruplarına göre mezgit ve barbunya balıkları ortalama ağır metal derişimleri, (mg kg^{-1})

Heavy metals	*Size groups*					
	Whiting			*Red mullet*		
	Large	*Medium*	*Small*	*Large*	*Medium*	*Small*
Cr	0.49	0.64	0.72	0.65	0.50	0.55
Mn	0.64	0.80	1.28	0.79	0.89	1.38
Co	0.02	0.03	0.05	0.11	0.10	0.11
Ni	0.61	0.41	0.82	0.48	0.43	0.47
Cu	1.04	1.59	1.96	1.18	1.33	1.52
Zn	18.78	20.59	24.83	19.06	18.89	20.99
As	4.92	7.12	6.73	13.43	17.87	12.61
Cd	0.01	0.03	0.05	0.01	0.01	0.03
Pb	0.02	0.02	0.03	0.02	0.02	0.02

was found that the difference in accumulations levels between locations for the whiting was statistically insignificant (P>0.05), but was significant for Cr, Cu and Pb accumulation levels between sampling location (Samsun-Ordu) for red mullet (P<0.05). The length and weight differences among fishing stations for the red mullet were statistically significant (P<0.05 level), but insignificant for the whiting. The stations dependent mean concentrations of Cr, Mn, Co, Ni, Cu, Zn and Cd in muscle tissues as well as length and weight were statistically insignificant. Arsenic (As) concentrations of S1 station which is under the influence of Yeşilırmak were higher than that of O3 station. Pb concentrations in O1 station may be related to geological origin and were higher than all stations (Table 6). The stations dependent mean concentrations of Cr, Mn, Ni, Zn, As and Cd in red mullet muscle tissues were statistically insignificant (P>0.05). Co concentrations determined in S3 station which was affected by urban pollution were higher than those obtained in S1, S2 and O2 stations and Cu concentrations in S3 station were higher than O2 and O3 stations. Pb concentrations may be related to geological origin as it was obtained in O1 station and the difference was statistically significant (P<0.05) and higher than all stations for red mullet muscle (Table 6).

Table 6- Average heavy metal concentration of *Merlangius merlangus* (whiting) and *Mullus barbatus* (red mullet) according to sampling stations, (mg kg^{-1})

Çizelge 6- Örnekleme istasyonlarına göre mezgit ve barbunya balıkları ortalama ağır metal derişimleri, (mg kg^{-1})

Heavy metals	*Sampling stations*											
	Whiting						*Red mullet*					
	O1	*O2*	*O3*	*S1*	*S2*	*S3*	*O1*	*O2*	*O3*	*S1*	*S2*	*S3*
Cr	0.70	0.54	0.50	0.45	1.02	0.45	0.44	0.46	0.53	0.63	0.83	0.60
Mn	0.87	1.19	0.79	0.89	1.09	0.77	1.26	1.01	1.19	0.86	0.89	0.96
Co	0.03	0.05	0.02	0.04	0.03	0.03	0.09	0.09	0.11	0.12	0.07	0.16
Ni	0.68	1.19	0.09	0.32	0.96	0.44	0.26	0.41	0.44	0.55	0.64	0.57
Cu	1.71	1.61	1.03	1.66	1.65	1.52	1.34	1.08	1.07	1.40	1.33	1.81
Zn	21.47	21.95	19.57	22.52	21.08	22.14	21.45	18.77	17.64	18.98	18.53	21.17
As	5.59	6.98	3.76	9.67	5.97	5.60	12.28	18.51	14.08	17.35	11.16	14.89
Cd	0.04	0.02	0.02	0.04	0.03	0.03	0.02	0.01	0.01	0.02	0.02	0.02
Pb	0.05	0.01	0.01	0.02	0.02	0.02	0.04	0.01	0.02	0.01	0.01	0.01

Seasonal differences can cause changes in tissue weights, fat contents/composition and water content of aquatic organism because of variation in food supply, reproduction, behavior and other physiological function all of which affect tissue contaminant concentrations (UNEP 1993). In the study, the samplings were carried out seasonally. Although seasonal differences in the mean length and weight of the whiting and red mullet were found to be insignificant (P>0.05), the mean length and weight taken from the samples in autumn and winter periods were found higher (Table 1). The seasonal difference in Cr, Co, Cu, Cd and Pb accumulation levels of the whiting and Co, Cu, Zn, As and Cd accumulation levels of the red mullet were statistically significant (P<005). Even though Mn and Ni accumulation levels observed in autumn were higher than those of other seasons for whiting, the differences were found to be statistically insignificant (P>0.05) (Table 7). The mean accumulation levels of Cu, Zn, As, Cd and Pb were detected higher than the mean levels in summer for the whiting. The mean metal accumulation levels of Mn, Cu, Zn, Cd and Pb values for red mullet were higher in summer and Cr and Ni levels were higher in winter. Co and As accumulation levels among sampling seasons for the red mullet were statistically significant (P<0.05). The lowest accumulation levels of were obtained for Co in spring and for As in summer (Table 7).

Table 7- Average heavy metal concentration of *Merlangius merlangus* (whiting) and *Mullus barbatus* (red mullet) according to sampling seasons, (mg kg^{-1})

Çizelge 7- Örnekleme mevsimine göre mezgit ve barbunya balıkları ortalama ağır metal derişimleri, (mg kg^{-1})

Heavy metals	*Seasons*							
	Whiting				*Red mullet*			
	Summer	*Autumn*	*Winter*	*Spring*	*Summer*	*Autumn*	*Winter*	*Spring*
Cr	0.40	1.03	0.68	0.45	0.45	0.62	0.68	0.40
Mn	1.01	1.11	0.85	0.69	1.02	1.31	1.01	0.95
Co	0.04	0.05	0.02	0.03	0.13	0.13	0.10	0.07
Ni	0.35	1.49	0.22	0.45	0.27	0.42	0.57	0.49
Cu	2.12	1.60	1.23	1.10	2.11	1.39	1.18	1.08
Zn	22.91	20.34	20.55	21.87	22.88	19.34	18.09	20.16
As	7.00	6.94	6.73	4.52	5.34	12.84	16.54	20.57
Cd	0.05	0.04	0.02	0.01	0.02	0.04	0.01	0.01
Pb	0.04	0.03	0.01	0.01	0.03	0.02	0.01	0.02

Correlation matrix for whiting and red mullet were given in Table 8 and Table 9. Very high correlation coefficients between length and weight of both species were obtained. A high inverse correlation coefficient was found between fish length and Zn concentration in whiting and positive high correlation coefficient was found between Mn and Co. Positive high level correlation coefficients were obtained between Cr, Ni and Cu, Cd metals in red mullet.

The data were evaluated by the factor analysis to express the relationships among variables. A small number of unrelated but conceptually significant new variables (factors, dimensions) from a large number of variables were obtained and new findings were gathered from these data (Kalaycı 2010). Factors were evaluated in terms of their contribution to total variance and the number of influential factors was determined. The variances expressed by three factors were about 73% for whiting and 71%

Table 8- Correlation matrix for whiting

Çizelge 8- Mezgit balığı için korelasyon matrisi

	Length	*Weight*	*Cr*	*Mn*	*Co*	*Ni*	*Cu*	*Zn*	*As*	*Cd*	*Pb*
Length	1.00										
Weight	0.97	1.00									
Cr	-0.05	-0.06	1.00								
Mn	-0.54	-0.47	0.14	1.00							
Co	-0.49	-0.48	0.10	0.74	1.00						
Ni	-0.03	-0.02	0.53	0.33	0.45	1.00					
Cu	-0.51	-0.50	0.05	0.45	0.62	0.10	1.00				
Zn	-0.77	-0.68	-0.16	0.68	0.53	0.10	0.44	1.00			
As	-0.17	-0.24	0.08	0.11	0.33	0.02	0.37	-0.01	1.00		
Cd	-0.59	-0.53	0.21	0.58	0.48	0.29	0.42	0.62	0.13	1.00	
Pb	-0.35	-0.31	0.14	0.45	0.37	0.30	0.44	0.38	0.08	0.64	1.00

Table 9- Correlation matrix for red mullet

Çizelge 9- Barbunya balığı için korelasyon matrisi

	Length	*Weight*	*Cr*	*Mn*	*Co*	*Ni*	*Cu*	*Zn*	*As*	*Cd*	*Pb*
Length	1.00										
Weight	0.97	1.00									
Cr	0.05	0.10	1.00								
Mn	-0.49	-0.45	0.08	1.00							
Co	-0.03	-0.02	0.22	0.26	1.00						
Ni	-0.05	-0.03	0.88	0.11	0.19	1.00					
Cu	-0.48	-0.39	-0.01	0.33	0.31	-0.11	1.00				
Zn	-0.36	-0.29	-0.12	0.46	0.34	-0.07	0.56	1.00			
As	0.18	0.08	0.05	-0.23	-0.14	0.25	-0.46	-0.31	1.00		
Cd	-0.49	-0.36	0.15	0.49	0.23	0.04	0.71	0.38	-0.46	1.00	
Pb	-0.11	-0.10	-0.03	0.55	0.05	0.04	0.27	0.44	-0.12	0.32	1.00

for red mullet (Figure 2). While factor 1 in whiting is related to fish length in relation to the Zn, Mn and Cd, factor 2 in whiting is related to sampling stations in relation to Cr (maximum in S2 station) and Ni (maximum in O2 station) and Factor 3 is related to sampling season (maximum in summer) in relation to arsenic. The first factor in red mullet was the sampling season and was positively correlated with Cu and Cd (maximum in summer) and negatively correlated with arsenic. Second factor was related to the sampling stations as it was in whiting. Fish length in red mullet was related to Pb and Mn (large<medium, small) indicating the factor 3.

In this study, the results relating to metal levels of the fish muscle tissue were given in terms of wet/dried ratio. The wet/dried conversion factor was used 5.7 for whiting and 4.3 for red mullet

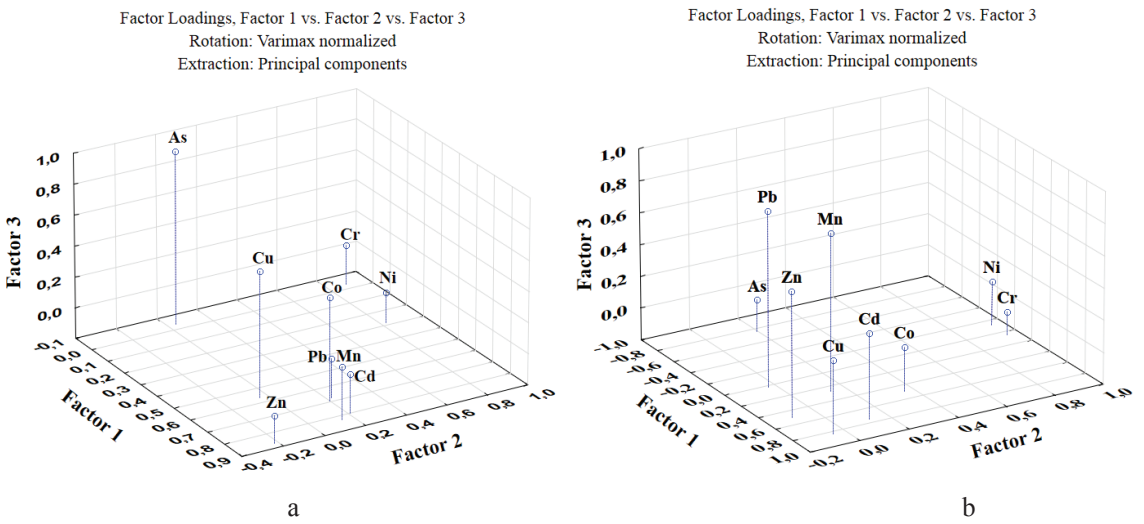

Figure 2- Factor analysis for whiting, a and red mullet, b fish species

Şekil 2- Mezgit, a ve barbunya, b balık türleri için faktör analizleri

(Table 1) and made it possible comparison with the previous studies (Table 4). The maximum metal concentrations in the whiting and red mullet were found below the limit values set by TFC (2011), EC (2006) and FAO (1983) (Table 4).

The Cr concentrations in the muscle tissues of whiting were significantly lower than same species fish Cr concentrations obtained by Tüzen (2009), Özden et al (2010) and Mendil et al (2010). On the other hand red mullet muscle tissue Cr concentrations significantly lower than determined by Turan et al (2009), Tüzen (2009), Mendil et al (2010) and Özden et al (2010). The determined Mn concentrations in muscle red mullet and whiting were lower than all of the studies except for the research conducted by Turan et al (2009). In this research, Co levels in the whiting and red mullet muscle tissues were lower than whiting Co levels determined by Özden et al (2010) and Mendil et al (2010). It was also determined that Ni concentrations in this study were lower than Ni concentrations obtained by Turan et al (2009), Tüzen (2009), Özden et al (2010) and Nisbet et al (2010) in whiting and red mullet. Cu concentrations determined by Tüzen (2009), Nisbet et al (2010), Mendil et al (2010) and Özden et al (2010) and in whiting and red mullet were relatively higher than the results of this study. Arsenic (As) concentrations determined in this study for the whiting and the red mullet were higher than all the values detected in the previous studies except for the results by Alkan et al (2012) and Ergül & Aksan (2013). In this study Cd concentrations were lower than the values from other studies except Alkan et al (2012) and Nisbet et al (2010) and Pb concentrations were more lower than the values other than Alkan et al (2012) and Ergül & Aksan (2013). Pb concentrations in whiting muscle tissue were determined by Balkıs et al (2012) and were higher than the our values and the others (Table 4). The mean length and weight differences of three different size groups of fishes (small, medium, large) were statistically confirmed ($P<0.05$). The difference in the water content of the muscle tissue of the both fishes was statistically significant ($P<0.05$).

The average metal concentrations determined in this study for the whiting and red mullet, the results of the previous studies that have been made other

researchers and the limit values set by the various regulatory authorities are given in Table 4. None of the metals measured in this study in terms of average values exceeded the limits established by the legal authorities such as TFC (2011), EC (2006) and FAO (1983).

4. Conclusions

In this study, metal levels of the muscle tissues of the two fish species (whiting and red mullet) were determined by ICP-MS which has high sensitivity and lower detection limits. Chromium (Cr), manganese (Mn), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd) and lead (Pb) concentrations in the muscle tissues of fishes were found to be below the limits set by the Turkish Food Codex (TFC 2011), European Communities Commission Regulation (EC 2006) and Food and Agriculture Organization (FAO 1983) (Table 4).

Whiting and red mullet fish in the Eastern Black Sea region which occupies an important place in the country's fishery potential are safe for human health.

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TARIM BİLİMLERİ DERGİSİ — JOURNAL OF AGRICULTURAL SCIENCES 22 (2016) 360-369

Hamsi Balığı (*Engraulis encrasicolus*) Dönerinin Soğuk Depolama Sırasındaki Kalite Değişimleri

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ÖZET

Bu çalışmada, hamsi balığından döner yapılması ve kalite özelliklerinin belirlenmesi amaçlanmıştır. Hamsi balığı dönerinde % 52.17 su, % 24.79 ham protein, % 18.62 ham yağ ve % 4.28 oranında ham kül saptanmıştır. Muhafaza süresinin sonunda hamsi döner örneklerinde doymuş yağ asitleri (DYA) içerisinde $C_{16:0}$, tekli doymamış yağ asitleri (TDYA) içerisinde $C_{18:1\ n-9}$ ve çoklu doymamış yağ asitleri (ÇDYA) içerisinde ise $C_{22:6\ n-3}$'ün en yüksek orana sahip olduğu tespit edilmiştir. Genel olarak, hamsi dönerler örneklerinde ∑n6/∑n3 oranında ve DHA/EPA (dekosahegzaenoik asit, $C_{22:6\ n-3}$/eikosapentaenoik asit, $C_{20:5\ n-3}$) oranında önemsiz bir değişim tespit edilmiştir (P>0.05). Depolama sonunda hamsi döner örneklerinde pH, tiyobarbitürik asit (TBA), toplam uçucu bazik azot (TVB-N) ve trimetilamin azot (TMA-N) değerleri sırasıyla 6.25, 3.53 mg MDA kg^{-1}, 34.03 mg 100 g^{-1} ve 5.25 mg 100 g^{-1} olarak saptanmıştır. Hamsi döner örneklerinde toplam mezofilik aerob bakteri (TMAB) ve toplam psikrofilik aerob bakteri (TPAB) sayısı depolama ile birlikte artarak muhafaza süresi sonunda sırasıyla 4.82 logkob g^{-1} ve 4.39 logkob g^{-1} değerlerine ulaşmıştır. Maya-küf ve koliforma ise rastlanılmamıştır. Duyusal analiz sonuçlarından panelistlerce hamsi dönerin beğenildiği anlaşılmaktadır. Bu çalışmada, hamsiden üretilen döner örneklerinin 63.günde bozulduğu belirlenmiştir.

Anahtar Kelimeler: Hamsi; Balık döner; Besin bileşenleri; Yağ asidi; Raf ömrü

Quality Changes of Anchovy (*Engraulis encrasicolus*) Döner During Cold Storage

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ABSTRACT

In this study, döner producing from anchovy and determination of quality properties of anchovy döner were aimed. Proximate composition of anchovy döner have been determined as 52.17% moisture, 24.79% crude protein, 18.62%

crude fat and 4.28% crude ash. $C_{16:0}$ among saturated fatty acids (SFA) and $C_{18:1\ n-9}$ among monounsaturated fatty acids (MUFA) and $C_{22:6\ n-3}$ among polyunsaturated fatty acids (PUFA) were determined the highest rates at the end of storage. Generally, ∑n6/∑n3 and DHA/EPA (decosahexaenoic acid, $C_{22:6\ n-3}$/eicosapentaenoic acid, $C_{20:5\ n-3}$) rates of anchovy döner were showed insignificant (P>0.05) changes at the end of storage. At the end of storage period pH, thiobarbituric acid (TBA), total volatile basic nitrogen (TVB-N) and trimethylamine nitrogen (TMA-N) values of anchovy döner were found as 6.25, 3.53 mg MDA kg^{-1}, 34.03 mg 100 g^{-1} and 5.25 mg 100 g^{-1}, respectively. The total mesophilic aerobic bacteria (TMAB) and total psychrophilic aerobic bacteria (TPAB) counts of anchovy döner were increased during storage and reached to 4.82 logcfu g^{-1} and 4.39 logcfu g^{-1}, respectively. Yeast-mould and coliform bacteria in anchovy döner were not detected. It was found that the anchovy döner was enjoyed by panelists according to results of sensory analysis. In this study, the results showed that deterioration of the döner samples produced from anchovy were determined on 63rd days.

Keywords: Anchovy; Fish döner; Nutritional components; Fatty acid; Shelf life

1. Giriş

Su ürünleri besleyici değerinin oldukça yüksek olması bakımından insanlık için önemli bir besin kaynağıdır. Geçmişte genellikle taze olarak tüketilen su ürünleri günümüzde gelişen teknolojiyle birlikte farklı şekillerde işlenebilmekte ve insanlar için seçenekli besin grupları haline dönüştürülebilmektedir. Su ürünlerinin gelecekte insanlar için en önemli hayvansal protein kaynağı olacağı düşünülmektedir. Günümüz hızlı yaşam temposu içerisinde beslenme alışkanlıklarındaki değişimler göz önünde bulundurulduğunda avcılık ve yetiştiricilik yoluyla elde edilen ürünlerin damak tadına yenilikler sunması için gerçekleştirilecek çalışmalara önem verilmelidir. Deniz ve içsu kaynaklarından sağlanan su ürünleri, içerdiği proteinler, çoklu doymamış yağ asitleri, mineral madde ve vitaminler sayesinde beslenmemiz açısından önemli bir yere sahiptir (Turan et al 2006). Alternatif protein kaynakları ile kıyaslandığında, su ürünlerinin daha ekonomik besin kaynağı olduğu ve değişik yöntemlerle işlenerek depolandığında da zaman içinde protein değerini yitirmeden tüketilme özelliğine sahip olduğu da bilinmektedir (Kolsarıcı & Özkaya 1998). Diğer besinlerde bulunmayan ancak insan beslenmesinde önemli rolü olan Eikosapentaenoik asit (EPA) ve Dekosahegzaenoik (DHA) asit gibi çoklu doymamış yağ asitlerini bulundurması su ürünlerini daha özel bir besin haline getiren unsurlardan biridir (Kaya et al 2004; Turan et al 2006).Yapılan araştırmalar, insanların karşılaştığı birçok hastalığa besin maddelerinin ve beslenme alışkanlıklarının neden olduğunu ortaya koymaktadır. Bu nedenle daha sağlıklı olan doymamış yağ asitleri bakımından zengin gıdaların tüketilmesi önerilmektedir (Kaya et al 2004). Birleşik Krallık Sağlık Departmanınca ideal n6/n3 oranı maksimum 4 olarak tavsiye edilmiş, n6/n3 oranının maksimum değerden daha fazla olmasının sağlığa zararlı olduğu ve kalp-damar hastalıklarını da artırıcı olabileceği ifade edilmiştir (Moreira et al 2001). Hamsinin balık köftesi (Varlık et al 2000), marinat (Olgunoğlu 2007), dumanlama (Ayas 2006), surimi (Kaba 2006), hamsi keki (İnanlı et al 2011) ve hamsikuşu (Köse et al 2001) gibi ürünleri üzerine farklı araştırıcıların çalışmaları bulunmakla birlikte hamsiden döner yapımına ilişkin her hangi bir çalışmaya rastlanılmamıştır.

Toplam üretimimiz içerisinde 179615.2 ton ile ülkemiz su ürünleri üretiminin yaklaşık % 30'nu oluşturan hamsinin 76190.4 tonluk önemli bir kısmı balık unu ve yağı fabrikalarında yan ürün olarak değerlendirilmektedir (TÜİK 2013). Bu çalışma ile hamsiden yeni bir damak tadı oluşturarak tüketici için albenisi-beğenisi yüksek ve çağımızın ısıt-ye cinsi beslenme alışkanlıklarına uygun bir ürün grubu oluşturulmasının yanı sıra kalite özelliklerinin belirlenmesi hedeflenmiştir. Ayrıca bu şekilde katma değerinin daha da artırılması amaçlanmıştır.

2. Materyal ve Yöntem

Çalışmada, perakende satış noktasından temin edilen hamsi balığı (*Engraulis encrasicolus*) buzlu strafor kutularda 1 saat içerisinde laboratuvara getirilmiştir. İlk olarak baş, iç organ ve omurga

çıkartılarak filetoları elde edilmiş, şebeke suyu ile yıkanarak temizlenmiş, suyu sızdırılmış ve döner yapımı için hazır hale getirilmiştir. Döner yapımında kullanılacak katkıların oranları toplam balık fileto ağırlığı dikkate alınarak % olarak hesaplanmıştır. Buna göre ağzı kapaklı şeffaf temiz plastik bir kap içerisinde bulunan temizlenmiş ve suyu sızdırılmış hamsi filetolarının üzerine katkı maddeleri, toplam fileto ağırlığının % 2.00'si oranında tuz, % 0.44'ü oranında karabiber ve % 7.00'si oranında soğan suyu olacak şekilde ilave edilerek iyice karıştırılmıştır ve aroma oluşumu için 4±1 °C'de 120 dakika süre ile marine edilmiştir. Bu sürenin sonunda filetolar döner çubuğunun altında bulunan sirküler tablanın üzerine dizilmiştir. Marinasyon ve dizme işlemi sonrası pişirme işlemine geçilmiştir. Döner çubuğunun bağlı olduğu ve et bloğunun otomatik dönmesini sağlayan motor aparatı ile eşit pişirme sağlanmaya çalışılmıştır. Pişen yüzeyler döner bıçağı ile kesilmiştir. Kesilen parçalar döner tepsisinde oda sıcaklığına ulaşır ulaşmaz ağzı kapaklı plastik şeffaf kaplarda homojen bir karışım sağlanarak pişirme işleminin sonuna kadar 4±1 °C'de muhafaza edilmiştir. Daha sonra 100±10 g olacak şekilde döner örnekleri vakum paketlenerek 4±1 °C'de 63 gün süreyle depolanmıştır. Döner örneklerinden muhafaza süresince 1, 7, 14, 21, 28, 35, 42, 49, 56 ve 63. günlerde analizler gerçekleştirilmiştir.

2.1. Kimyasal analizler

Tüm örneklerde su, ham protein (AOAC 2000), ham yağ (Lovell 1975) ve ham kül (Lovell 1981) analizleri yapılmıştır. Yağ asidi analizi; örneklerden yağ çıkarma işlemi yapılmış (Bligh & Dyer 1959) ve sonrasında metilleştirme işlemi (Ichihara et al 1996) küçük bir modifikasyon ile gerçekleştirilmiştir. Gaz Kromotografisi (GC) Şartları; Yağ asitleri GC Clarous 500 cihazı (Perkin-Elmer, USA), alev iyonizasyon dedektörü ve silika kapiler kolon (30 m x 0.32 mm ID, 0.25 µm BP20 0.25 UM; USA) kullanılarak analiz edilmiştir. Enjektör ve dedektör sıcaklıkları sırası ile önce 220 °C'ye sonra 280 °C'ye ayarlanmıştır. Bu esnada fırın sıcaklığı 5 dakika 140 °C'de tutulmuştur. Sonrasında her dakika 4 °C arttırılarak 200 °C'ye kadar, 200 °C'den 220 °C'ye de her dakika 1 °C artırılarak getirilmiştir. Split 1:50 oranında kullanılmıştır. Yağ asitleri standart 37 bileşenden oluşan FAME karışımının gelme zamanlarına bağlı olarak karşılaştırılmasıyla tanımlanmıştır. GC analiz sonuçları ± standart hataları ile birlikte % olarak ifade edilmiştir.

Ayrıca, pH (Varlık et al 2007), tiyobarbitürik asit (TBA, mg MDA kg^{-1}) (Erkan & Özden 2008), toplam uçucu bazik azot (TVB-N, mg 100 g^{-1}) (Nicholas 2003), trimetilamin azot (TMA-N, mg 100 g^{-1}) (AOAC 1998) analizleri yapılmıştır.

2.2. Mikrobiyolojik analizler

Bütün örneklerde toplam mezofilik aerob bakteri (TMAB, logkob g^{-1}) ve toplam psikrofilik aerob bakteri (TPAB, logkob g^{-1}) sayısı ile koliform ve maya-küf mikroorgnizma sayılarını belirlemek için mikrobiyolojik analizler yapılmıştır (Harrigan & McCance 1976; ICMSF 1978; Refai 1979; Arslan et al 1997).

2.3. Duyusal özelliklerin analizi

Duyusal özelliklerin değerlendirilmesinde renk, koku, lezzet, tekstür ve genel beğeni özelliklerinden yararlanılmıştır (Taşkaya et al 2003; Tokur et al 2006; Kenar 2009). Fakültemiz personeli ve öğrencileri arasından seçilmiş eğitimli 12 panelistten ısıtılarak sunulmuş döner örneklerinin duyusal özelliklerini 1-9 puan arasında değerlendirmeleri istenmiştir. Değerlendirmede 9 tamamen tazeliği, ≤3 ise bozulmuşluğu göstermektedir. Duyusal özelliklerin belirlenmesine yönelik analizlere muhafaza süresince devam edilmiştir.

2.4. İstatistiksel analiz

Çalışmada elde edilen veriler, SPSS 9.0 istatistik paket programı ile varyans analizine (one-way ANOVA) tabi tutulup, önemli varyans kaynaklarına ait ortalamalar Duncan Çoklu Karşılaştırma Testi ile $P<0.05$ güven aralığında karşılaştırılmıştır.

3. Bulgular ve Tartışma

Çiğ hamsi (Ç), marine hamsi (M) ve hamsi döner (D) örneklerinin su, ham protein, ham yağ ve ham kül oranlarını belirlemeye yönelik besin bileşen analizleri yapılmıştır (Çizelge 1). Özellikle pişirme

işlemiyle birlikte ürün su içeriğinin önemli (P<0.05) miktarda azalmasına bağlı olarak ham protein ve ham yağ içeriğinde nispi olarak (P<0.05), ham kül miktarlarında ise yine su içeriğinin azalmasına ve kullanılan katkılara bağlı olarak son üründe (P<0.05) artış belirlenmiştir. Hamsinin aylara göre su içeriğinin belirlendiği bir araştırmada su içeriğinin % 64.93 ile % 74.32 aralığında olduğu (Öksüz & Özyılmaz 2010), benzer bir çalışmada da % 66.0 ile % 77.0 (Gökoğlu et al 1999) olarak bulunduğu, diğer çalışmalarda % 66.95 (Kocatepe & Turan 2012), % 69.76 (Özden 2005), % 68.21 (İnanlı et al 2010) ve % 61.45 ile % 77.10 (Karaçam & Düzgüneş 1988) olarak tespit edilmiştir. Alabalık, orkinos ve somon türlerinin döner olarak değerlendirildiği çalışmada su içeriğinin başlangıca göre düştüğü belirlenmiştir (Şimşek 2011). Hamsi üzerine yapılan farklı araştırmalarda, protein oranı % 16.31 (Kocatepe & Turan 2012), % 15.06 ile % 18.91 (Karaçam & Düzgüneş 1988), % 19.56 (Ayas 2006), % 16.94-% 17.36 (Kaya & Turan 2010), % 19.07 (İnanlı et al 2010), % 18.02 (Özden 2005) olarak belirlenmiştir. Farklı türlerden döner yapılan örnek gruplarında protein oranında artış saptanmıştır (Şimşek 2011). Hamside yağ oranını % 4.72 (Ayas 2006), % 5.1 ile % 13.6 (Gökoğlu et al 1999) % 6.49-% 16.32 (Öksüz & Özyılmaz 2010), % 10.04 (İnanlı et al 2010) olarak tespit edilmiştir. Alabalık, orkinos ve somon pişmiş döner örneklerinde yağ miktarında başlangıca göre artış saptanmıştır (Şimşek 2011). Yapılan çalışmalara göre, hamside kül miktarı % 1.39 (Ayas 2006), % 1.35 ile % 1.68 (Öksüz & Özyılmaz 2010), % 1.03 (Kocatepe & Turan 2012), % 1.62 (Özden 2005) olarak belirlenmiş olup elde edilen bu sonuçlar bulgularımızla paralellik göstermektedir.

Çizelge 1- Çiğ, marine hamsi ve hamsi döner besin bileşenleri (%)*, (x±SH)**

Table 1- Nutritional compenents of raw, marinated anchovy and anchovy döner (%), (x±SE)***

	Su	*Ham protein*	*Ham yağ*	*Ham kül*
Ç	67.91±0.29^{a}	17.68±0.08^{b}	12.80±0.86^{b}	1.27±0.05^{c}
M	71.05±2.13^{a}	15.78±0.16^{c}	10.38±0.75^{c}	2.38±0.06^{b}
D	52.17±0.41^{b}	24.79±0.11^{a}	18.62±0.29^{a}	4.28±0.04^{a}

*, aynı sütunda farklı harfler bulunduran değerler arasında istatistiki fark önemlidir (P<0.05); **, ortalama±standart hata; Ç, çiğ hamsi; M, marine hamsi; D: hamsi döner

Yağ asitleri analiz sonuçlarından da anlaşılacağı gibi çoklu doymamış yağ asitlerinden $C_{22:6\ n-3}$ ve $C_{20:5n-3}$ önemli miktarlarda belirlenmiştir (Çizelge 2). Analizi yapılan tüm örnek grupları içerisinde en fazla tespit edilen yağ asidi çoklu doymamış yağ asitlerinden DHA olmuştur. Ham maddeyi oluşturan çiğ hamside % 20.00 olarak tespit edilen DHA, marinasyon işlemiyle % 19.10'a depolamanın başlangıcında (1. gün) döner örneklerinde % 18.76'ya azalmıştır (P>0.05). EPA'da ise çiğ hamside % 10.66 olarak tespit edilen değer marinasyon işlemiyle % 9.94'e azalmış (P<0.05) depolamanın başlangıcında döner örneklerinde % 10.01'e artmıştır (P>0.05). Çiğ hamside ∑DYA, ∑TDYA ve ∑ÇDYA sırasıyla % 31.40, % 20.16 ve % 36.68 olarak, marine hamside ise sırasıyla % 29.98, % 22.03 ve % 35.34 olarak, 1. gün döner örneklerinde ise sırasıyla % 29.34, % 22.70 ve % 35.00 olarak saptanmıştır. Hamsi döner örneklerinde depolama süresince ∑DYA, ∑TDYA ve ∑ÇDYA küçük artış ve azalışlar tespit edilmiş olup depolamanın 1. günü ile depolamanın son günü (63. gün) ∑DYA'deki değişim önemli (P<0.05) bulunurken, ∑TDYA ve ∑ÇDYA için önemsiz (P>0.05) bulunmuştur. Depolamanın başlangıcında ve sonunda döner örneklerinin ∑n6/∑n3 oranı arasında önemli bir değişim gözlenmemiştir (P>0.05) (Çizelge 2). Hamside ∑DYA % 33.40-%37.91,∑TDYA%25.91-%31.51,∑ÇDYA%34.00-%36.18 (Öksüz & Özyılmaz 2010) olarak bulunurken, başka bir araştırmada ∑DYA % 35.07, ∑TDYA % 19.50 ve ∑ÇDYA % 32.43, DHA/EPA oranı 1.45 olarak saptanmıştır (Kocatepe & Turan 2012), Tufan et al (2011) aynı tür ile yaptıkları çalışmada ∑DYA % 29.81-% 37.58, ∑TDYA % 18.82-% 22.49 ve ∑ÇDYA % 31.95-% 38.52 arasında, ∑ÇDYA/∑DYA 0.86-1.29 ve ∑n6/∑n3 oranını ise 0.10-0.22 arasında tespit etmişlerdir. Zlatanos & Laskaridis (2007) hamsilerde önemli doymamış yağ asitlerinden $C_{22:6\ n-3}$'ü en düşük oranda % 12.23 Şubat ayında, en yüksek oranda ise % 32.46'lık oranla Haziran ayında belirlemiştir. Hamsi üzerine yapılan bir çalışmada yağ asidi kompozisyonunda DYA içinde $C_{16:0,}$ TDYA içinde $C_{18:1\ n-9}$ ve ÇDYA içinde de $C_{22:6\ n-3}$'ün en yüksek oranda olduğunu tespit edilmiştir (Tanakol et al 1999). Bu sonuçlar

Çizelge 2- Çiğ, marine hamsi ve hamsi dönerin yağ asidi kompozisyonu (%)*, (x±SH)**

Table 2- Fatty acid composition of raw, marinated anchovy and anchovy döner (%), (x±SE)***

YA	*Ç*	*M*	*1*	*7*	*14*	*21*	*28*	*35*	*42*	*49*	*56*	*63*
$C_{12:0}$	0.05±0^{a}	0.05±0^{a}	0.05±0^{a}	0.05±0,01^{a}	0.05±0^{a}	0.05±0^{a}	0.05±0^{a}	0.05±0^{a}	0.05±0^{a}	0.05±0,01^{a}	0.05±0^{a}	0.05±0,01^{a}
$C_{14:0}$	6.75±0.31^{a}	5.91±0.02^{b}	5.75±0.06^{bc}	6.00±0.03^{b}	5.81±0.01^{b}	6.00±0.06^{b}	5.61±0.07^{bc}	5.16±0.56^{c}	5.92±0^{b}	5.85±0.02^{b}	5.97±0.05^{b}	5.94±0.14^{b}
$C_{15:0}$	0.14±0.01^{a}	0.13±0^{a}	0.13±0^{a}	0.13±0^{a}	0.14±0.01^{a}	0.14±0.01^{a}	0.15±0^{a}	0.13±0.01^{a}	0.15±0^{a}	0.13±0^{a}	0.14±0.01^{a}	0.15±0.01^{a}
$C_{16:0}$	18,27±0.16^{a}	17.97±0.02^{abc}	17.73±0.01^{abc}	17.90±0.20^{abc}	17.37±0.27^{c}	17.76±0.02^{abc}	17.70±0.45^{abc}	17.76±0.24^{abc}	17.45±0.04^{bc}	17.76±0.05^{abc}	17.94±0.23^{abc}	18.11±0.14^{ab}
$C_{17:0}$	0.47±0.09^{a}	0.37±0.01^{b}	0.35±0.01^{b}	0.36±0.01^{b}	0.37±0.01^{b}	0.36±0.01^{b}	0.35±0.01^{b}	0.38±0.02^{b}	0.36±0.01^{b}	0.36±0.01^{b}	0.36±0.01^{b}	0.36±0.01^{b}
$C_{18:0}$	3.83±0.03^{ab}	3.83±0.06^{ab}	3.73±0^{b}	3.76±0,01^{b}	3.78±0.05^{b}	3.88±0.04^{ab}	3.82±0.06^{ab}	3.87±0.03^{ab}	3.80±0.03^{ab}	3.86±0.09^{ab}	3.84±0.01^{ab}	3.94±0.01^{a}
$C_{20:0}$	0.33±0.01^{a}	0.27±0.01^{b}	0.23±0.04^{b}	0.23±0.01^{b}	0.26±0.01^{b}	0.25±0.01^{b}	0.23±0.02^{b}	0.28±0.01^{b}	0.25±0^{b}	0.24±0.01^{b}	0.26±0.02^{b}	0.25±0^{b}
$C_{23:0}$	0.68±0.01^{abc}	0.61±0.02^{cd}	0.62±0^{cd}	0.63±0^{abcd}	0.65±0.01^{abcd}	0.64±0.01^{abcd}	0.70±0.06^{a}	0.69±0.01^{ab}	0.62±0.01^{bcd}	0.64±0.01^{abcd}	0.62±0.01^{cd}	0.60±0.01^{d}
$C_{24:0}$	0.86±0.02^{ab}	0.83±0.05^{ab}	0.73±0.12^{b}	0.87±0.01^{ab}	0.86±0.01^{ab}	0.89±0.01^{a}	0.84±0.05^{ab}	0.87±0.02^{ab}	0.88±0.01^{ab}	0.85±0.01^{ab}	0.87±0.01^{ab}	0.85±0.01^{ab}
∑DYA	31.40±0.28^{a}	29.98±0.14^{bc}	29.34±0.21^{c}	29.96±0.24^{bc}	29.31±0.34^{c}	29.99±0.10^{bc}	29.47±0.55^{bc}	29.22±0.22^{bc}	29.49±0.08^{c}	29.77±0.11^{bc}	30.06±0.27^{bc}	30.27±0.01^{b}
$C_{14:1}$	0.27±0.01^{a}	0.24±0.01^{a}	0.24±0.01^{a}	0.25±0.01^{a}	0.25±0.01^{a}	0.25±0.01^{a}	0.24±0.01^{a}	0.27±0.03^{a}	0.26±0^{a}	0.25±0.01^{a}	0.26±0^{a}	0.26±0.01^{a}
$C_{16:1}$	4.95±0.02^{bc}	5.48±0.37^{ab}	5.44±0.02^{ab}	5.51±0.03^{ab}	5.46±0.02^{ab}	5.21±0.36^{abc}	5.72±0.21^{a}	4.86±0.13^{c}	5.57±0.01^{a}	5.39±0^{abc}	5.49±0.06^{ab}	5.51±0.01^{ab}
$C_{17:1}$	0.07±0^{cd}	0.10±0^{a}	0.08±0^{abc}	0.08±0^{bcd}	0.09±0^{ab}	0.07±0^{cd}	0.07±0^{cd}	0.06±0.01^{d}	0.08±0^{bcd}	0.08±0^{bcd}	0.07±0.01^{cd}	0.08±0^{bcd}
$C_{18:1\ n-7}$	2.97±0.03^{a}	2.69±0.20^{ab}	2.37±0.06^{bc}	2.47±0.07^{bc}	2.45±0.04^{bc}	2.61±0.13^{abc}	2.19±0.28^{c}	2.66±0.16^{ab}	2.49±0.01^{bc}	2.49±0.01^{bc}	2.45±0.01^{bc}	2.54±0.09^{bc}
$C_{18:1\ n-9}$	11.35±0.89^{b}	12.98±0.44^{ab}	14.09±0.55^{a}	12.98±0.54^{ab}	12.58±0.57^{ab}	13.22±0.20^{ab}	12.81±0.42^{ab}	12.96±0.03^{ab}	13.09±0.03^{ab}	12.86±0.09^{ab}	13.12±0.25^{ab}	13.31±1.19^{a}
$C_{20:1}$	0.38±0.01^{a}	0.34±0.01^{ab}	0.31±0.01^{b}	0.29±0.01^{b}	0.33±0^{ab}	0.34±0.01^{ab}	0.31±0.04^{b}	0.33±0.04^{ab}	0.33±0.01^{ab}	0.34±0.02^{ab}	0.34±0.01^{ab}	0.34±0.01^{ab}
$C_{22:1\ n-9}$	0.15±0.01^{a}	0.18±0.01^{a}	0.14±0.02^{a}	0.17±0^{a}	0.15±0.03^{a}	0.16±0.01^{a}	0.20±0.03^{a}	0.15±0.01^{a}	0.15±0.02^{a}	0.16±0.01^{a}	0.14±0.01^{a}	0.17±0.01^{a}
∑TDYA	20.16±0.92^{b}	22.03±0.61^{ab}	22.70±0.44^{a}	21.77±0.43^{ab}	21.32±0.60^{ab}	21.88±0.02^{ab}	21.55±0.50^{ab}	21.31±0.02^{ab}	21.99±0.04^{ab}	21.58±0.14^{ab}	21.90±0.31^{ab}	22.23±1.07^{a}
$C_{18:2n-6}$	2.71±0.19^{a}	2.28±0.05^{b}	2.33±0.04^{b}	2.42±0.02^{b}	2.32±0.03^{b}	2.41±0.03^{b}	2.28±0.02^{b}	2.29±0.01^{b}	2.37±0.02^{b}	2.33±0.01^{b}	2.40±0.01^{b}	2.38±0.04^{b}
$C_{18:3\ n-3}$	1.58±0.11^{b}	1.78±0.02^{a}	1.58±0.01^{b}	1.60±0.04^{b}	1.59±0.02^{b}	1.54±0.04^{b}	1.59±0.01^{b}	1.62±0.07^{b}	1.58±0.03^{b}	1.52±0.01^{b}	1.51±0.05^{b}	1.54±0^{b}
$C_{20:2}$	0.99±0.28^{bc}	1.20±0.05^{ab}	1.27±0.03^{ab}	0.76±0.01^{c}	1.29±0.01^{a}	1.32±0.03^{a}	1.33±0.06^{a}	1.30±0.01^{a}	1.27±0.02^{ab}	1.27±0.01^{ab}	1.30±0.03^{a}	1.26±0.04^{ab}
$C_{20:3\ n-6}$	0.21±0.04^{a}	0.23±0.01^{a}	0.22±0^{a}	0.14±0^{b}	0.23±0.01^{a}	0.22±0.01^{a}	0.21±0^{a}	0.21±0.01^{a}	0.23±0.01^{a}	0.22±0.01^{a}	0.22±0.01^{a}	0.22±0.01^{a}
$C_{20:4\ n-6}$	0.26±0.03^{c}	0.54±0.01^{ab}	0.50±0.04^{ab}	0.54±0^{ab}	0.55±0.01^{a}	0.51±0.01^{ab}	0.48±0.01^{b}	0.52±0.01^{ab}	0.53±0.01^{ab}	0.50±0.01^{ab}	0.51±0^{ab}	0.50±0.01^{ab}
$C_{20:5\ n-3}$	10.66±0.33^{a}	9.94±0.18^{bc}	10.01±0.08^{bc}	10.18±0.01^{bc}	10.07±0.01^{bc}	10.09±0.11^{bc}	10.18±0.07^{bc}	10.35±0.01^{ab}	10.04±0.06^{bc}	9.96±0.18^{bc}	9.88±0.06^{bc}	9.82±0.16^{c}
$C_{22:2}$	0.25±0.07^{ab}	0.25±0.02^{ab}	0.32±0.01^{a}	0.30±0^{a}	0.29±0.02^{ab}	0.26±0.01^{ab}	0.31±0.02^{a}	0.21±0.01^{b}	0.28±0.01^{ab}	0.26±0^{ab}	0.28±0.01^{ab}	0.26±0.01^{ab}
$C_{22:6n-3}$	20.00±0.32^{ab}	19.10±0.71^{abc}	18.76±0.05^{bc}	19.33±0.39^{abc}	19.66±0.61^{abc}	19.07±0.29^{abc}	20.63±0.47^{a}	20.50±0.70^{a}	18.73±0.12^{bc}	19.52±0.33^{abc}	18.65±0.40^{bc}	18.23±0.66^{c}
∑ÇDYA	36.68±0.37^{ab}	35.34±0.97^{abc}	35.00±0.14^{bc}	35.79±0.35^{abc}	36.02±0.54^{abc}	35.44±0.49^{abc}	37.02±0.61^{a}	37.01±0.73^{a}	35.06±0.03^{abc}	35.61±0.50^{abc}	34.77±0.48^{bc}	34.23±0.90^{c}
∑ÇDYA/∑DYA	1.17±0^{cde}	1.18±0.03^{cde}	1.19±0.01^{bcde}	1.18±0.02^{cde}	1.23±0.03^{abc}	1.18±0.01^{cde}	1.25±0.01^{ab}	1.26±0.01^{a}	1.19±0^{bcde}	1.20±0,02^{bcd}	1.15±0.02^{de}	1.13±0.03^{e}
∑n6/∑n3	0.10±0.01^{ab}	0.10±0^{ab}	0.10±0^{ab}	0.10±0^{ab}	0.10±0^{ab}	0.10±0^{ab}	0.09±0^{b}	0.09±0.01^{ab}	0.10±0.01^{a}	0.10±0^{ab}	0.10±0.01^{a}	0.10±0.01^{a}
DHA/EPA	1.88±0.09^{ab}	1.92±0^{ab}	1.87±0.02^{ab}	1.90±0.05^{ab}	1.95±0.06^{ab}	1.89±0.01^{ab}	2.02±0.03^{a}	1.98±0.08^{ab}	1.86±0.02^{ab}	1.96±0^{ab}	1.89±0.03^{ab}	1.85±0.03^{b}

*, aynı satırda farklı harfler bulunduran değerler arasında istatistiki fark önemlidir (P<0.05); **, ortalama±standart hata; YA, yağ asidi; Ç, çiğ hamsi; M, marine hamsi

çalışmamızı genel olarak destekler niteliktedir. Ortaya çıkan farklılıkların hammadde ve çalışma koşullarından kaynaklanabileceği düşünülmektedir.

Çalışmamızda çiğ hamsi örneklerinde 6.61 olarak tespit edilen pH değeri marinasyon işlemiyle birlikte azalmış ($P<0.05$) depolamanın 1. gününde ise artmıştır ($P<0.05$) (Çizelge 3). Bir çalışmada, orkinos dışında alabalık ve somon döner örneklerinde 1. gün pH değerinde çiğ balık etine göre önemli ($P<0.05$) değişim bulunmuştur (Şimşek 2011). Balık etlerinde TBA değerinin 3-4 mg MDA kg^{-1}'ın üzerinde olmasının kalite kaybının göstergesi olduğu belirtilmiştir (Köse et al 2001). Varlık et al (1993) ve Cadun et al (2005) tüketilebilirlik değerinin 7-8 mg MDA kg^{-1} arasında olduğunu bildirmiştir. Araştırmamızda hamsi döner örneklerinin TBA değeri muhafaza süresince genellikle artış eğiliminde olmuştur (Çizelge 3). Yapılan bir araştırmada, tuzlanmış ve tuzlanmamış hamsiden elde edilen hamsikuşu, pişmiş ve pişmemiş olarak depolamış ve bu süre içinde TBA değerinin düzensiz bir değişim gösterdiği tespit edilmiştir (Köse et al 2001). Alabalık, orkinos ve somon döner örneklerinde TBARS değerinin depolamaya bağlı olarak arttığı saptanmıştır (Şimşek 2011). TVB-N su ürünlerinin bozulmasının belirlenmesinde yaygın kullanılan biyokimyasal metotlardan biridir (Ruiz-Capillas & Moral 2001). Huss (1988) ve Köse & Erdem (2004) TVB-N için kabul edilebilir limit değerini 30-35 mg 100 g^{-1}, Varlık et al (1993) ve Akkuş et al (2004) 35 mg 100 g^{-1} olarak bildirmişlerdir. Çalışmamızda hamsi dönerde TVB-N değeri depolamanın sonunda (63. gün) 34.03 mg 100 g^{-1}'a ulaşmıştır (Çizelge 3). Tuzlanmış ve tuzlanmamış hamsilerden yapılan hamsikuşunun pişirilerek -18 ^{o}C'de 150 günlük depolanması sonunda TVB-N değerleri sırasıyla 12.72 mg 100 g^{-1} ve 9.37 mg 100 g^{-1}'e ulaşmıştır (Köse et al 2001). Buzdolabı koşullarında depolanan hamsi balığının TVB-N değerinin depolamanın sonunda (5. gün) artarak 35.4 mg 100 g^{-1}-38.8 mg 100 g^{-1}'a ulaştığı bildirilmiştir (Köse & Erdem 2004). Varlık et al (1993) TMA-N sınır değerini 8 mg 100 g^{-1}, Huss (1988) ise 10-15 mg 100 g^{-1} olarak belirtmiştir. Araştırmamızda TMA-N çiğ hamside 0.84 mg 100 g^{-1} iken hamsi döner yapımıyla birlikte artmış ve depolamanın sonunda 5.25 mg 100 g^{-1}'a ulaşmıştır (Çizelge 3). Hamsi keki çalışmasında kekin pişirilmesi ile 3.14 mg 100 g^{-1} olan TMA-N değerinin 12 gün sonunda 4.11 mg 100 g^{-1}'a arttığı tespit edilmiştir (İnanlı et al 2011). Sonuçlar genel olarak bulgularımızla benzerlik göstermektedir.

Çizelge 3- Hamsi döner örneklerindeki pH, TVB-N, TBA ve TMA-N değerindeki değişimler*, (x±SH)**

Table 3- Changes of the pH, TVB-N, TBA ve TMA-N values in anchovy döner samples*, (x±SE)**

Gün	*pH*	*TBA, mg MDA kg^{-1}*	*TVB-N, mg 100 g^{-1}*	*TMA-N, mg 100 g^{-1}*
Ç	6.61±0.01^{a}	1.01±0.03^{ef}	10.67±0.36^{e}	0.84±0.12 ^{e}
M	6.29±0^{e}	0.79±0.05^{f}	11.17±0.44^{e}	0.62±0^{e}
1	6.40±0.03^{d}	1.13±0.02^{e}	28.40±0.22^{d}	4.22±0.06^{d}
7	6.48±0.02^{bcd}	1.91±0.01^{d}	31.34±0.50^{bc}	4.36±0.11^{d}
14	6.54±0.02^{ab}	1.86±0.05^{d}	31.68±0.88^{bc}	4.46±0.07^{cd}
21	6.52±0.06^{abc}	2.39±0.18^{bc}	32.94±0.88^{ab}	4.22±0.15^{d}
28	6.43±0.01^{cd}	2.43±0.06^{bc}	31.59±0.67^{bc}	4.57±0,19^{bcd}
35	6.51±0.02^{bc}	2.25±0.07^{c}	31.42±0.30^{bc}	4.71±0.09^{bcd}
42	6.43±0.02^{cd}	2.54±0.05^{bc}	30.58±0.22^{bc}	4.87±0.25^{abc}
49	6.45±0.03^{bcd}	2.68±0.09^{b}	31.76±0.14^{bc}	4.70±0.20^{bcd}
56	6.30±0.02^{e}	2.63±0.12^{b}	32.18±0.36^{bc}	4.96±0.05^{ab}
63	6.25±0.03^{e}	3.53±0.21^{a}	34.03±0.66^{a}	5.25±0.25^{a}

*, aynı sütunda farklı harfler bulunduran değerler arasında istatistiki fark önemlidir ($P<0.05$); **, ortalama±standart hata; Ç, çiğ hamsi; M, marine hamsi

Su ürünlerinin tüketilebilirliğinin belirlenmesinde kullanılan yöntemlerden biri de mikrobiyolojik analizlerdir. Aerobik bakteri sayısı için limit değer 7 logkob g^{-1} olarak bildirilmiştir (ICMSF 1986). Bu çalışmada, başlangıçta çiğ hamside maya-küf tespit edilmemiş olup, TMAB, TPAB ve koliform için sırasıyla 5.56 logkob g^{-1}, 3.61 logkob g^{-1} ve 1.87 logkob g^{-1} olarak saptanmıştır. Döner yapımı ile uygulanan ısıl işlemle TMAB sayısı 3.17 logkob g^{-1}'a düşerken TPAB ve koliform tespit edilememiştir. Ancak depolama süreci içerisinde koliform ve maya-küf dışında artış gösterdiği ve limit değerlere ulaşmadığı görülmüştür (Çizelge 4). Hamsiden kek üretimi ile ilgili bir araştırmada, hamsi filetolarında TMAB sayısı 2.30 logkob g^{-1}, TPAB sayısı 3.36 logkob g^{-1} ve maya-küf sayısı da 3.28 logkob g^{-1} olarak belirlenmiş olup kek yapımıyla elde edilen bu değerlerde düşüş, depolama ile birlikte de tekrar artış tespit edilmiştir (İnanlı et al 2011). Hamsi kuşlarının pişirilmesiyle birlikte mezofilik ve pisikrotrofik bakteri sayısında azalma (Köse et al 2001), farklı balık türleriyle döner yapılan araştırmada; alabalık, orkinos ve somondan yapılan döner örneklerinde 4 ^{o}C'de 1. günlük depolama sonrasında toplam mezofilik aerobik bakteri ve koliform sayısında çiğ balıketine göre önemli ($P<0.05$) azalma tespit edilmiştir (Şimşek 2011). Yukarıda bahsi geçen araştırma sonuçları ile çalışmamız sonuçları uyumludur.

Çizelge 4- Hamsi döner örneklerinin muhafaza süresince mikroorganizma yükü (logkob g^{-1})*, (x±SH)**

Table 4- Microbial load of the anchovy döner samples during storage (logcfu g^{-1})*, (x±SE)**

Gün	*TMAB*	*TPAB*	*Koliform*	*Maya-küf*
Ç	5.56±0.04^{a}	3.61±0.09^{c}	1.87±0.03	<1.0
M	3.59±0.01^{j}	3.63±0.01^{bc}	<1.0	<1.0
1	3.17±0.04^{k}	<1.0	<1.0	<1.0
7	4.62±0.03^{d}	<1.0	<1.0	<1.0
14	4.22±0.01^{g}	<1.0	<1.0	<1.0
21	4.39±0.01^{f}	2.70±0.03^{e}	<1.0	<1.0
28	4.51±0.03^{e}	2.47±0.03^{f}	<1.0	<1.0
35	4.73±0.02^{bc}	4.34±0.01^{a}	<1.0	<1.0
42	4.65±0.03^{cd}	4.38±0.01^{a}	<1.0	<1.0
49	3.95±0.05^{h}	3.48±0.01^{d}	<1.0	<1.0
56	4.25±0.03^{g}	3.75±0.07^{b}	<1.0	<1.0
63	4.82±0.03^{b}	4.39±0.05^{a}	<1.0	<1.0

*, aynı sütunda farklı harfler bulunduran değerler arasında istatistiki fark önemlidir ($P<0.05$); **, ortalama±standart hata; Ç, çiğ hamsi; M, marine hamsi

Hamsi döner örneklerinin duyusal analiz sonuçlarına bakıldığında, panelistlerce değerlendirilen parametrelerde yüksek puanlar aldığı, muhafaza süresince bu parametreye ilişkin puanların süreyle doğru orantılı olarak azaldığı, depolamanın 63. gününde ise tüketilemeyecek sınır değerlere ulaştığı görülmüştür (Çizelge 5). Şimşek (2011) çalışmasında alabalık, orkinos ve somon olmak üzere üç farklı balık türünden elde edilen dönerlerin panelistlerce kabul edilebilirliğinin yüksek olduğunu bildirilmiştir. Bu sonuçlar çalışmamız sonuçları ile benzerlik göstermektedir.

4. Sonuçlar

Çalışmada hamsi döner örneklerinin doymamış yağ asitleri, özelliklede DHA ve EPA gibi önemli çoklu doymamış yağ asitleri ve ∑n6/∑n3 oranı bakımından beslenme açısından önemli bir kaynak olabileceği düşünülmektedir. Çalışmada elde edilen bilgiler ışığında hamsi dönerinin tüketici beğenisine

Çizelge 5- Hamsi döner örneklerinin muhafaza süresince duyusal analiz sonuçları*, (x±SH)**

Table 5- Results of the sensory anaylysis of anchovy döner samples during storage, (x±SE)***

Gün	*Renk*	*Koku*	*Lezzet*	*Tekstür*	*Genel beğeni*
1	7.50±0.23^{a}	8.08±0.22^{a}	8.33±0.14^{a}	7.50±0.21^{a}	7.91±0.15^{a}
7	7.25±0.17^{a}	7.66±0.22^{ab}	8.16±0.20^{a}	7.66±0.25^{a}	7.91±0.14^{a}
14	7.50±0.26^{a}	7.58±0.28^{ab}	8.00±0.17^{ab}	7.83±0.24^{a}	7.83±0.16^{a}
21	7.08±0.19^{a}	7.66±0.28^{ab}	8.00±0.30^{ab}	7.75±0.25^{a}	7.83±0.24^{a}
28	7.25±0.21^{a}	7.25±0.32^{bc}	7.33±0.33^{bc}	6.91±0.19^{b}	7.08±0.19^{b}
35	6.83±0.16^{ab}	7.08±0.19^{bc}	6.66±0.18^{cd}	6.75±0.25^{b}	6.83±0.20^{b}
42	6.33±0.22^{b}	6.75±0.21^{c}	6.25±0.27^{d}	6.33±0.25^{b}	6.50±0.26^{b}
49	5.00±0.27^{c}	5.08±0.33^{d}	4.66±0.30^{e}	4.91±0.35^{c}	4.75±0.35^{c}
56	4.66±0.22^{c}	3.83±0.16^{e}	3.75±0.27^{f}	3.58±0.28^{d}	3.91±0.25^{d}
63	2.33±0.14^{d}	1.91±0.14^{f}	1.50±0.15^{g}	1.33±0.14^{e}	1.41±0.15^{e}

*, aynı sütunda farklı harfler bulunduran değerler arasında istatistiki fark önemlidir (P<0.05); **, ortalama±standart hata

sahip olduğu belirlenmiştir. Hamsi dönerinin depolama süresince kimyasal ve mikrobiyolojik olarak limit değerleri aşmadığı tespit edilmiştir. Hamsi döner örneklerinin duyusal analiz sonuçlarına bakıldığında, panelistlerce değerlendirilen bütün parametrelerin yüksek puanlar aldığı, muhafaza süresince bu parametre ilişkin puanların süreyle doğru orantılı olacak biçimde azaldığı, depolamanın 63. gününde ise tüketilemeyecek sınır değerlere ulaştığı belirlenmiştir.

Su ürünleri üretimimizin en önemli türlerinden olan hamsinin alternatif işleme tekniklerinden biriyle işlenerek farklı bir lezzette sunulması, hamsinin daha çok kişi tarafından tüketilmesini destekleyecektir. Ayrıca çalışmanın benzer konularda yapılacak AR-GE çalışmaları için de teşvik edici olacağı kanısındayız.

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Döl Tutma Problemi Olan Holştayn Irkı Sığırlarda Sitogenetik ve Moleküler Genetik Taramalar

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ÖZET

Sığır yetiştiriciliğinde repeat breeder sendromu olarak adlandırılan döl tutma problemi önemli bir sorundur. Holştayn ırkı sığırlarda bu problemin ortaya çıkmasında bakım-beslemenin yanı sıra Robertsonian translokasyon ve faktör XI yetmezliği (FXID) olarak adlandırılan genetik bozukluklarında rolü olduğu düşünülmektedir. Bu çalışmada Kayseri ilinde bir çiftlikte bulunan repeat breederlı Holştayn ırkı ineklerde Robertsonian translokasyon ve FXID varlığının araştırılması amaçlanmıştır. Yapılan çalışmada, repeat breeder tanısı konan 62 baş Holştayn ırkı inek incelenmiştir. Kromozomal inceleme sonucunda 62 hayvanın 58'inin normal karyotip (2n= 60 diploid), dördünün ise en sık görülen 1;29'dan farklı dört tip Robertsonian translokasyon [rob (1;21), rob (23;26), rob (24;26), rob (26;29)] profiline sahip olduğu saptanmıştır. Yapılan PCR analizi sonucunda, incelenen 62 örneğin hiçbirinde FXID'e neden olan mutasyona ait bant görüntüsü gözlenmemiştir. Çalışma sonunda, döl tutma problemi bulunan sığırlarda sitogenetik ve moleküler genetik taramaların yapılmasının kalıtsal nedenlerle gelişen repeat breeder sendromu gösteren damızlık adayların belirlenerek damızlık dışı bırakılmasına ve bu sayede özellikle damızlık yetiştiren işletmeler için çözüm yollarının aranmasına katkı sağlayacağı düşünülmüştür.

Anahtar Kelimeler: FXID; Holştayn; Repeat breeder; Robertsonian translokasyon

Cytogenetic and Molecular Genetic Screening in Holstein Cattle Breed which Showing Repeat Breeding Problems

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ABSTRACT

The infertility problem named Repeat Breeder Syndrome is an important issue in cattle breeding. Beside maintenance and feed techniques, some genetic disorders such as Robertsonian Translocation and factor XI deficiency (FXID) are thought to be involved some problems in Holstein cattle. In this study, it was aimed to investigate the presence of Robertsonian Translocation and FXID in repeat breeder Holstein cows which grown a farm that located in the province

of Kayseri. In the study 62 female Holstein cattle with Repeat Breeder Syndrome were examined. Chromosomal examination results indicated that 58 of 62 cows had a normal karyotype (2n= 60 diploid) and four had different of Robertsonian translocation [Rob (1, 21), rob (23, 26), Rob (24, 26), Rob (26, 29)] profiles. None of the 62 cows was displayed the band of mutation which is the cause of FXID. As a result of the study it was determined molecular and cytogenetical screening of cows with a fertility problem could contribute to understand the reasons of repeat breeder syndrome and could be useful for the breeders to select the female breeding candidates and finding the solution for this problem.

Keywords: FXID; Holstein; Repeat breeder; Robertsonian translocation

1. Giriş

Döl verimi, süt sığırı yetiştiriciliği yapan bir işletmenin ekonomik yapısını etkileyen önemli bir verim özelliğidir. Bu sebeple infertilite günümüzde süt sığırı yetiştiriciliğinde mastitisle birlikte en önemli sorunlardan biridir. Sığır yetiştiriciliğinde döl verimini olumsuz yönde etkileyerek, işletme için önemli ekonomik kayıplara neden olan durumlardan biride "repeat breeder" olarak adlandırılan döl tutma problemidir. Repeat breeder terimi; en az bir doğum yapmış, düzenli seksüel siklus gösteren, genital organlarda klinik muayenelerle herhangi bir patolojik bulgu ve anomali görülmemesine rağmen üç veya daha fazla sayıda tohumlandığı halde gebe kalmayan ve tohumlamayı takiben bir sonraki östrus periyodunda kızgınlık gösteren sığırlar için kullanılmaktadır (Alaçam 1997; Bage et al 2002).

Sığırlarda fertilite üzerinde direkt etkiye sahip genetik tabanlı patolojilerden biri kromozom sayısı ve yapısındaki değişiklikler olarak tanımlanan kromozomal mutasyonlardır (El-Bayomi et al 2011). Kromozomal mutasyonlar üreme sisteminde görülen fonksiyonel ve anatomik bozukluklara sebep olur (Iannuzzi et al 2001). Sığırlarda fertilite bozukluklarına neden olan Robertsonian translokasyon, mayoz bölünme esnasında kendiliğinden, kimyasal veya radyoaktif mutajenlerin etkisi sonucu (Klug & Cummings 2003) kısa kolları kaybolmuş olan iki akrosentrik kromozomun uç uca birleşmesi ile karyotipte markır bir kromozomun ortaya çıkması ile karakterizedir (Chaves et al 2000; Di Meo et al 2006). Sitogenetik analizler ile damızlık adaylarının kromozomal profilinin ortaya konulmasının kromozomal yönden mutasyonlu dişilerin belirlenerek yetiştirme dışı bırakılması ile işletmelerin ekonomik kazanım sağlanabileceği bildirilmektedir (Pinton et al 1997; Molteni et al 2005).

Faktör XI yetmezliği (FXID), Holştayn sığır ırkında heterozigot durumda dahi infertiliteye sebep olabildiği bildirilen kalıtsal bir hastalıktır (Kolgeci et al 2013). FXID taşıyıcılarında hastalığa özel klinik semptomlar görülmediği için hastalığın teşhisinde en etkili yöntemin Polimeraz Zincir Reaksiyonu (PCR) olduğu bildirilmiştir (Citek et al 2006; Kolgeci et al 2013).

Kalıtsal hastalıklar çiftlik hayvanları yetiştiriciliğinde damızlıkların üreme gücünde problemler oluşturmanın yanı sıra doğan yavruların yaşama gücünü düşürerek de işletmelerde önemli ekonomik kayıplara sebep olmaktadır (Wathes 1992). Yetiştirme programlarının başarısında, yetiştirilmesi planlanan ırklarda gen ve kromozom düzeyinde en yaygın görülen kalıtsal hastalıklar yönünden damızlık adayların taranması önemlidir.

Yapılan çalışmada repeat breeder'lı Holştayn ineklerde Robertsonian translokasyonu ve FXID'e neden olan mutasyonun varlığı/yokluğunun araştırılması amaçlanmıştır.

2. Materyal ve Yöntem

Çalışmanın hayvan materyalini, Kayseri ilindeki bir süt sığırcılığı işletmesinde bulunan, aralarında akrabalık ilişkisi olmayan, en az bir kez doğum yapmış ancak, işletme kayıtlarına göre hastalık geçmişi olmamasına rağmen gebe kalmadığı için işletme tarafından repeat breeder olarak kabul edilerek kesime sevk edilmiş 62 baş dişi Holştayn

sığır oluşturmuştur. Çalışılan sığırlarda her bir hayvan için sitogenetik analiz olarak, heparinli tüplere alınan kanlardan, her bir hayvan için 50 metafaz alanının incelendiği GTG-bantlama yapılmıştır. Faktör XI yetmezliğinin araştırılmasında EDTA'lı tüplere *V. jugularis*'ten alınan kanlardan elde edilen DNA'lar kullanılarak PCR analizi yapılmıştır.

Kromozom analizi için Pinton et al (1997) tarafından önerilen yöntem modifiye edilerek uygulanmıştır. Bu amaçla 1 mL penisilin, 20 mL fetal bovine serum ve 2.5 mL fitohemaglutinin içeren RPMI 1640 ortamı içine heparinize periferal kanlar eklenerek hazırlanan karışım % 5 CO_2'li etüvde 37 °C'de 72 saat kültüre alınmıştır. Etüvdeki tüplere 71. saatte 75 µL kolşisin ilave edilerek mitoz bölünme bloke edilmiştir.

Kültür sonrasında örnekler GTG-bantlama (Seabright 1971) yöntemi ile boyanarak her preparattaki 50 metafaz alanı "Cyt Vision Version 7.2" (Applied Imaging CytoVision™ Imaging System) programı ile analiz edilerek örnekler Robertsonian translokasyon varlığı/yokluğu yönünden değerlendirilmiştir.

Moleküler analiz için örneklere ait DNA'lar fenol-kloroform yöntemi ile izole edilmiştir (Sambrook et al 1989). İncelenen örneklerde FXID'e neden olan mutant alleli belirlemek için yapılan PCR işleminde forward: 5´- CCC ACT GGC TAG GAA TCG TT-3´; reverse: 5´- CAA GGC AAT GTC ATA TCC AC -3', olacak şekilde bir primer seti kullanılmıştır. PCR işlemi; 14 µL dH_2O, 5 µL $MgCl_2$, 2 µL 10 x PCR buffer, 1.1 µL dNTP, 0.4 µL (20 nmol) primer, 0.2 µL Taq polimeraz (5 U μL^{-1}) ve 3 µL DNA eklenerek hazırlanan karışımla yapılmıştır. Hazırlanan karışımın başlangıçta 95 °C'de 10 dakika tutulmasını takiben her bir döngüsü; 95 °C'de 30 saniye, 55 °C'de 1 dakika, 72 °C'de 30 saniye olacak şekilde 34 döngü olarak yapılmıştır. PCR işlemi son döngünün bitiminden sonra örnekler 72 °C'de 10 dakika tutularak tamamlanmıştır. İncelenen bireylerin FXID yönünden genotiplendirilmesi ve elde edilen PCR ürünlerinin değerlendirilmesi % 2'lik agaroz jel elektroforezi ile yapılmıştır.

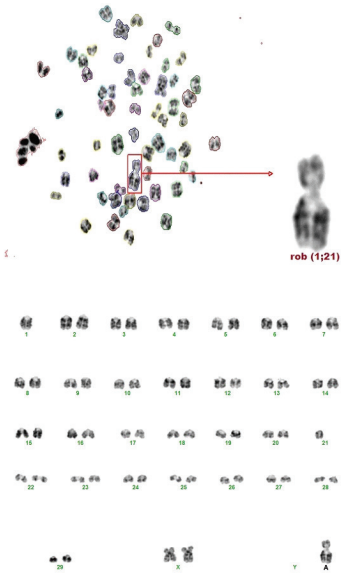
3. Bulgular ve Tartışma

Yapılan kromozomal inceleme sonucunda, 62 Holştayn ineğin 58'inin normal karyotipe (2n= 60 diploid) sahip olduğu, dört hayvanın ise farklı Robertsonian translokasyon [rob (1;21), rob (23;26), rob (24;26), rob (26;29)] profillerine sahip oldukları belirlenmiştir (Şekil 1, 2, 3, 4).

Yapılan PCR reaksiyonu sonunda, taşıyıcı bireyde 244 ve 320 bp'lik iki bant, homozigot normal bireylerde 244 bp'lik tek bant, homozigot hasta bireylerde ise 320 bp'lik tek bandın görülmesi beklenmiştir (Şekil 5). Ancak incelenen 62 örneğin hiçbirisinin homozigot veya heterozigot FXID'e neden olan mutasyona sahip olmadıkları gözlenmiştir.

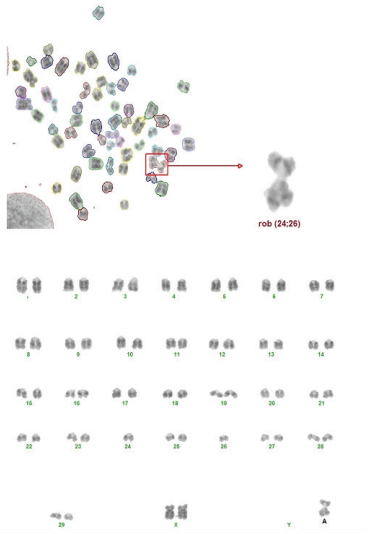
Sığır yetiştiriciliğinde, tohumlama sonrası gebeliğin şekillenmemesi ve erken embriyonik ölümler yılda bir yavru alınmasını engelleyerek işletme için önemli ekonomik kayıplara neden olmaktadır (Rubes et al 1996). Üç tohumlama sonunda gebeliğin şekillenmediği repeat breeder sendromu süt sığırı yetiştiriciliğinde oldukça önemli bir sorundur. Bu sendromun gelişmesinde beslenme ve çevre sıcaklığı gibi çevresel faktörlerin yanı sıra FXID olarak adlandırılan bir gen mutasyonu ve Robertsonian translokasyon gibi bazı kromozomal mutasyonların etkili olduğu bildirilmiştir (Wathes 1992; Joerg et al 2001; Gustafsson & Emanuelson 2002; Akyüz 2013). Repeat breeder'ın gelişmesinde etkili olan bakım-besleme gibi çevresel faktörlerin minimize edilebilmesi için çalışmanın hayvan materyalinin aynı işletmeden temin edilmesi yoluna gidilmiştir. Çalışma materyali seçilirken işletmenin döl verim kayıtları dikkate alınarak genital sistem hastalıkları yönünden daha önce herhangi bir hastalık geçirmeyen hayvanlar seçilmiştir.

Genetik kusurlar içerisinde önemli bir yer tutan kromozomal bozuklukların sığırlarda döl tutma problemlerine sebep olduğu bildirilmiştir (King 1990). Sayısal ve yapısal kromozom anomalilerinin embriyoda anormal gelişmeye veya gebeliğin ilk üç aylık döneminde embriyonel ölüme neden olabildiği bildirilmiştir (Joerg et al 2001). Düve ve ineklerde embriyoların % 20'sinin gebeliğin ilk



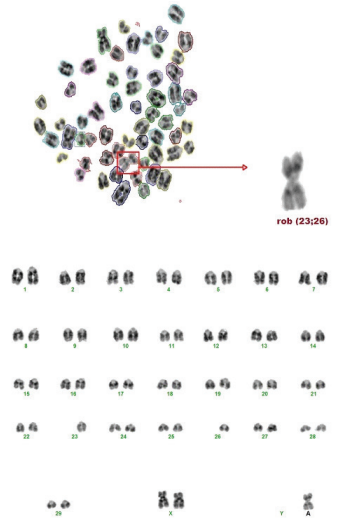
Şekil 1- Rob (1;21) translokasyon metafaz ve karyotip görüntüsü

Figure 1- Rob (1;21) translocation metaphase and karyotype image



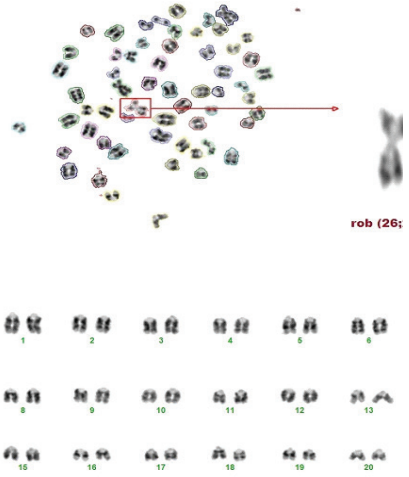
Şekil 3- Rob (24;26) translokasyon metafaz ve karyotip görüntüsü

Figure 3- Rob (24;26) translocation metaphase and karyotype image



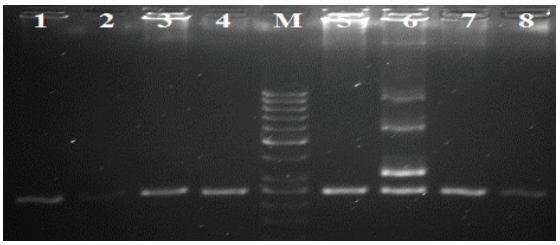
Şekil 2- Rob (23;26) translokasyon metafaz ve karyotip görüntüsü

Figure 2- Rob (23;26) translocation metaphase and karyotype image



Şekil 4- Rob (26;29) translokasyon metafaz ve karyotip görüntüsü

Figure 4- Rob (26;29) translocation metaphase and karyotype image



Şekil 5- FXID yönünden yapılan PCR sonuçlarının % 2'lik agaroz jel görüntüsü; M, 50 bç'lik DNA merdiveni; 5, homozigot normal kontrol (244 bç); 6, heterozigot kontrol (244 bç, 320 bç); 1, 2, 3, 4, 7 ve 8 homozigot normal bireyler

Figure 5- PCR results of FXID on 2% agarose gel image; M, 50 bpDNA Ladder; 5, homozygous control (244 bp); 6, heterozygous control (244 bp, 320 bp); 1, 2, 3, 4, 7 ve 8 homozygous normal subjects

12-16. günleri arasında dejenere olabildiği, ancak repeat breeder sendromu gösteren hayvanlarda ise embriyonik kayıpların gebeliğin 4-7. günleri arasında şekillendiği bildirilmiştir (Seguin et al 2000).

Gerçek sığır (*Bos taurus*) karyotipi 29 çift akrosentrik otozomal kromozom ve bir çift submetasentrik gonozomal kromozom olmak üzere toplam 30 çift kromozomdan oluşmaktadır (Chaves et al 2000). Akrosentrik kromozomlarda görülen kromozom füzyonu sonucu oluşan Robertsonian translokasyon sığırlarda en sık görülen kromozomal anomalilerinden biri olarak bildirilmektedir (Joerg et al 1999). Sığırda tanımlanan ilk Robertsonian translokasyonu, tek heterokromatin bloğa sahip 1. ve 29. kromozomlar arasındaki sentrik füzyon kaynaklı rob (1;29) translokasyonudur (Parvatti et al 1985). Heterozigot Robertsonian taşıyıcılığı görülen dişi hayvanlar genellikle normal fenotipe sahiptir. Ancak bu bireylerde erken embriyonik ölüm şekillenmesinden dolayı fertilitelerinde % 3 ile % 5 arasında bir azalma olduğu bildirilmiştir (Roberts 1986). Robertsonian translokasyon taşıyıcısı hayvanlarda fertilite problemlerinin normal hayvanlara göre daha fazla görüldüğü ve translokasyonun jenerasyonlar arasında segrege olabilen özellikte olduğu bildirilmiştir (Pinton et al 1997; Nicolae 2007). Belirtilen sebeplerle bu kromozomal anomaliyi taşıyan hayvanların belirlenerek yetiştirme dışı bırakılmasının yetiştiricilik açısından önemli bir kazanım olabileceği ifade edilmektedir (De Lorenzi et al 2008). Yapılan bu çalışmada Robertsonian translokasyon varlığının araştırılmasında tabloyu kesin olarak ortaya koyan, aynı zamanda benzer amaçla kullanılan Floresan Insituhibridizasyon (FISH) yöntemi gibi daha pahalı yöntemlere göre ucuzluğu nedeniyle avantajlı olan GTG-bantlama yöntemi kullanılmıştır.

Sığırlarda Robertsonian translokasyon tiplerinin tespit edilmesi ile ilgili yapılan farklı çalışmalarda İngiliz etçi sığır ırkları, Holştayn, Jersey, Normande sığır ırklarında rob (1;29) translokasyon tipinin görülmediği ortaya konmuştur (Seguin et al 2000; De Luca et al 2002). Miyake et al (1991) yaptıkları çalışmada sığırlarda rob (1;21) translokasyonu; Iannuzzi et al (2001) yaptıkları çalışma sonucu sığırlarda rob (26;29) varlığını bildirmişlerdir.

Kayseri ilinde yetiştirilen 62 baş repeat breederlı Holştayn ineğin incelendiği bu çalışmada da yapılan kromozomal tarama neticesinde repeat breeder gösteren hayvanların % 6'sının farklı kromozomal yapıya sahip olduğu gözlenmiştir. Sitogenetik taramalarda rob (1;29) translokasyona rastlanılmamış ancak, incelenen hayvanların dördünde, dört farklı Robertsonian translokasyonunun varlığı belirlenmiştir. Yapılan literatür taramasında, bu çalışmada belirlenen rob (1;21), rob (23;26), rob (24;26), rob (26;29) translokasyonlara yaygın olarak rastlanılmadığı gözlenmiş, dolayısı ile görülen bu translokasyonların nadir tipler olduğu düşünülmüştür. Çalışma bulguları neticesinde, sığır yetiştiriciliğinde önemli bir döl verimi problemi olan repeat breeder sendromunun ortaya çıkmasına neden olan faktörlerin daha kesin olarak belirlenebilmesi için sitogenetik taramaların da göz önünde bulundurulmasının gerekli olduğu düşünülmüştür.

Holştayn sığır ırkında görülen bir nokta mutasyon, kan pıhtılaşma faktörlerinden XI yetmezliğine (FXID) neden olarak, bu

mutasyon yönünden heterozigot bireylerde dahi döl tutma problemlerine neden olarak repeat breeder sendromunun gelişmesine etkisi olduğu bildirilmiştir (Ghanem et al 2005). Ghanem et al (2005) tarafından yapılan çalışmada, döl tutma problemi olan hayvanlar arasında FXID prevalansının % 2.5 olduğunu bildirilmiştir. Benzer şekilde Polonya'da farklı çiftliklerden toplanan ve 28'inde repeat breeder, 9'unda ise tekrarlayan mastitis gösteren bireylerinde bulunduğu rastgele 140 baş Holştayn inek seçilerek FXID yönünden incelenmiştir. Çalışma sonunda rastgele seçilen ve herhangi bir problemi bulunmayan 103 baş örnekte FXID alleline rastlanılmamışken, repeat breederlı 28 örneğin bir tanesinin FXID taşıyıcı olduğu belirlenmiştir (Gurgul et al 2009). Benzer şekilde Akyüz et al (2012) tarafından normal fertilite gösteren 118 baş ve repeat breeder senromu gösteren 43 baş toplam 161 baş Holştayn ineğin incelendiği bir çalışmada FXID prevalansının normal fertilite gösteren grupta % 0.85 olarak bulunmuşken, repeat breeder sendromu gösteren grupta % 2.33 olarak bulunmuştur.

4. Sonuç

Repeat breeder sendromu gösteren 62 baş Holştayn ineğin incelendiği bu çalışmada elde edilen sonuçlar, farklı Robertsonian translokasyon tiplerinin repeat breeder sendromu gösteren Holştayn ırkı ineklerde bulunma şansının olabileceğini göstermiştir. Çalışmada incelenen repeat breeder tanısı konulmuş örneklerde FXID'e neden olan mutasyona rastlanılmamıştır. Ancak repeat breeder sendromunun gerçek sebebinin belirlenmesi çalışmalarında daha önce yapılan ve FXID ile repeat breeder sendromu arasında ilişki olabileceğini bildiren çalışmaların sonuçlarının (Ghanem et al 2005; Gurgul et al 2009; Akyüz et al 2012) dikkate alınması gerektiği düşünülmektedir. Ayrıca, gerek erkek gerekse dişi damızlık adaylarının farklı Robertsonian translokasyon tipleri ve FXID yönünden değerlendirilmelerinin yetiştiriciler için avantajlı olacağı düşünülmektedir. Daha kesin sonuçlar için daha çok örneğin inceleneceği çalışmalar planlanmalıdır.

Bu çalışma sonuçlarına göre süt sığırı yetiştiriciliğinde, oluşumunda birçok faktörün etkili olduğu repeat breeder sendromunun sebebine yönelik çalışmalarda genetik faktörlerinde düşünülmesinin gerekli olduğu sonucuna varılmıştır. Dolayısıyla damızlık adayı boğaların seçimi yanında, döl tutma problemi olan dişilerde de sitogenetik ve moleküler genetik tanı yöntemleri kullanılarak genetik sebeplerden kaynaklanan repeat breeder'ın elimine edilmesi düşünülmelidir.

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Assessment of Inverse Distance Weighting (IDW) Interpolation on Spatial Variability of Selected Soil Properties in the Cukurova Plain

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ABSTRACT

This study attempts to evaluate interpolation technique for mapping spatial distribution of some soil characteristics at the Lower Seyhan River Basin in Cukurova (Turkey). These soil characteristics may help to improve agricultural land management practices. In the study area, 7 parallel transects each having 150 m of length were selected at 5 m intervals, and 104 soil samples were collected. In these samples, calcium carbonate, organic matter, cation exchange capacity and clay content (from particle size distribution) were determined. Inverse distance weighting (IDW) interpolation and employing of GIS technology were applied on the results. Calcium carbonate, organic matter, cation exchange capacity and clay content values derived from IDW interpolation were consistent with the results of the soil analysis. The verity of the interpolation technique was tested by employing cross validation. Interpolation of organic matter values showed a high mean error in 30-60 cm depth (2.82%) while this high deviation was not the case with the other parameters studied.

Keywords: Geographic information systems; Geostatistic; Inverse distance weighing; Cukurova (Turkey); Spatial variability

Ağırlıklı Ters Uzaklık İnterpolasyon Yöntemiyle Çukurova'da Kimi Toprak Karakteristiklerinin Konumsal Dağılımının Tahmini

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ÖZET

Bu çalışmada Çukurova Aşağı Seyhan Nehir Havzasındaki kimi toprak karakteristiklerinin konumsal dağılımının belirlenmesi için interpolasyon yöntemi kullanılmıştır. Bu toprak karakteristikleri tarımsal arazi yönetimini geliştirmede katkı sağlamaktadır. Çalışma alanında 150 m uzunluğa sahip, 5 m aralık ile 7 paralel transect seçilerek ve 104 adet toprak örneği alınmış ve bu örneklerde kalsiyum karbonat, organik madde, katyon değişim kapasitesi ve kil (tane büyüklüğü

dağılımından) belirlemesi yapılmıştır. Sonuçlara ağırlıklı ters uzaklık interpolasyon yöntemi (ATU) ve CBS teknolojisi uygulanmıştır. ATU interpolasyon yönteminden elde edilen kalsiyum karbonat, organik madde, katyon değişim kapasitesi ve kil değerleri ile toprak analiz sonuçları benzerlik göstermiştir. İnterpolasyon tekniğinin doğruluğunu belirlemek için çapraz doğrulama yapılmıştır. Organik madde değerlerinin 30-60 cm derinliğindeki interpolasyonu, en yüksek ortalama değişim değeri (% 2.82) göstermiş, diğer parametrelerde bu durum gözlenmemiştir.

Anahtar Kelimeler: Coğrafi bilgi sistemleri; Jeoistatistik; Ağırlıklı ters uzaklık; Çukurova (Türkiye); Konumsal değişkenlik

1. Introduction

It is known that precision farming or site-specific management aims to improve production efficiency within the field for agricultural planning and policy making both in regional and national levels. Geospatial measurements consist of spatial characterization of soil variability including calcium carbonate content, particle size distribution (Piikki et al 2013), cation exchange capacity and organic matter content (Frogbrook & Oliver 2001) which have recently become more useful and therefore gained particular interest. Soil properties may vary greatly depending on parent material, topography, vegetation cover and climate. These all factors affect the spatial distribution of the soil properties (Shi et al 2009). Namely, critical important relationship between the yield and soil properties and topographic characteristics for precision agriculture was reported (Drummond et al 2003). Dengiz (2010) reported that alluvial soils, formed by rivers as accumulated sediment deposited at different times, showed large variation in their properties over short distances. Geospatial measurement of some soil properties has become one of the most useful tools for rational agricultural practices (Corwin 2005). There have been a number of conflicting reports on the use of statistics to predict interpolation methods and their parameters as well. For example, Mabit & Bernard (2010), studied spatial distribution and content of soil organic matter (SOM) in an agricultural field in eastern Canada using ordinary kriging and inverse distance weighting power two. Gotway et al (1996) obtained better results when using inverse distance weighting (IDW) than kriging for soil organic matter and nitrogen contents distribution.

Cross validation method was employed in this study using the *Pronet* software program. Given the variability of the results obtained by the previous studies mentioned, in this study it is aimed to identify the spatial variability of various soil parameters at the study area and to evaluate the accuracy of IDW interpolation for determining the values related to these parameters because of the inadequate sample points available around the study area. It is supposed that this would enable the identification of the areas where remediation is required for improving the crop growth, and for applying appropriate land management processes.

2. Material and Methods

2.1. Description of the study area

This study was carried out at Lower Seyhan Basin, an alluvial plain of southern Turkey. The study area included 104 ha of irrigated agricultural land which was located within a multi-directional drainage system (WGS84; E 679312-681014, N 4079399-4081100) (Figure 1). Detailed information about study area and its climate characteristics was clearly described in Tunçay et al (2013). Seven parallel transects each having 150 m of length were designated at 5 m intervals within the study area. In total, 104 soil samples were collected at different soil horizons from 24 different points (as being 0, 50, 100 and 150 m in the 1st, 3rd, 5th and 7th transects; at 25, 75 and 125 m in the 2nd and 6th transects; and at 50 and 100 m in the 4th transect) (Tunçay et al 2013).

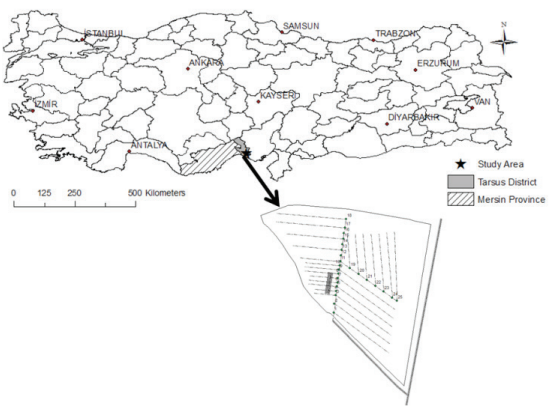

Figure 1- The research area

Şekil 1- Araştırma alanı

2.2. Sampling design, soil analysis and spatial prediction methods

The study area is accommodated on an alluvial plain, and it is conspicuous that the soil properties may vastly display significant spatial variability in short distances at alluvial soils. Soil samples from each horizon were individually taken, air dried, crushed and sieved (2 mm). Particle size distribution was determined by using hydrometer method (Sheldrick & Wang 1993), calcium carbonate ($CaCO_3$) by Sheibler calcimeter (Çağlar 1949), organic matter (OM) by Walkey Black method (Richards 1954), cation exchange capacity (CEC) by using NH_4OAc (pH 7.0) and NaOAc (pH 8.2) (Rhoades 1982). IDW via using the GemcomSurpac 3D software program was used for evaluating the results. For each sample point, soil samples were carried to a depth of 150 cm and employed for availing five different depths (from 30 to 150 cm) of soil layer maps for each individual property and parameter p (p; 2). The accuracy of IDW is established on the number of definite samples those were employed for estimation. The allocation of close sample locations were fixed at 24, and each soil sample point was evaluated with 4-5 soil horizons, determined by the soil profile properties within the context of this research. The interpolation procedures are abundant in the literature (Franzen & Peck 1995; Gotway et al 1996). Estimated values are interpolated based on the data from surrounding locations using Equation 1.

$$Z^*(xo) = \sum_{i=1}^{n} wiZ(xi) \quad (1)$$

Where; wi, weight assigned to the value at each location; $Z(\chi_i)$ and n, number of close neighboring sampled data points used for estimation. Weights are established using Equation 2.

$$wi = \frac{1/d_i^p}{\sum_{i=1}^{n} 1/d_i^p} \quad (2)$$

Where; d_i, denotes the distance between point i and the unknown point; p, exponent parameter. Weighting is remarkably dependent on p, such that, an increase in distance would cause an exponential decrease in weighting. In this study, a power of 2 and a skewness value of <1 was employed in IDW (Agris 1998).

3. Results and Discussion

3.1. Descriptive statistics result of the soil properties

Soil analysis revealed that the clay content of the study area ranged between 41.2-84.4% and increased with increasing depth. Organic matter content ranged between 0.11-2.76% (Table 1).

Table 1- Descriptive statistics for selected soil properties

Çizelge 1- Seçilen toprak özelliklerinin tanımlayıcı istatistikleri

Variable	*Min*	*Max*	*Mean*	*Median*	*Skewness*	*Kurtosis*	*SD*	*CV (%)*
$CaCO_3$ (%)	21.3	34.6	29.19	29.65	-0.33	-1.13	3.46	11.87
OM (%)	0.11	2.76	0.97	0.75	0.90	-0.14	0.62	64.30
CEC (meq 100 g^{-1})	21.8	45.2	35.10	35.42	-0.31	-0.33	4.66	13.28
Clay (%)	41.2	84.4	61.83	61.89	0.18	-0.05	8.89	14.39

SD, standart deviation; CV, coefficient of variation

3.2. Selected soil parameter related inverse distance weighting process, resulting maps and cross validation of the results

Organic matter content values revealed that the greatest variability of the different soil parameters analyzed had the ratio of 43.42% for the coefficient of variation. The mean overall clay content was 61.43% ranging between 49.1-75.9%. These conditions were attributed to the inferior drainage properties and high clay content, especially in the subsurface horizons that restricting the downward movement of water. Table 2 displays the descriptive statistics of the selected soil properties via using IDW method. As the sediment charges occupying the alluvial plain formed from materials carried by the Seyhan River and Tarsus Stream from Taurus Mountains that have calcareous parent material (Öner et al 2005; Atalay 2011), the content of free carbonates was found above 20% almost everywhere and every depth of the studied area. While the calcium carbonate calcium carbonate contents in the research area changed between 24.3-33.3%, it was higher than 28% at 60-90 and 90-120 cm depths (Figure 2). Due to the steady slow precipitation of the fine fluvial material at the rather flat soil surface, the clay content was always more than 49% in the studied area. While the organic matter content was barely below 1% in the surface soil, it was only between 0.2 and 0.9% after 60 cm depth (Figure 3).

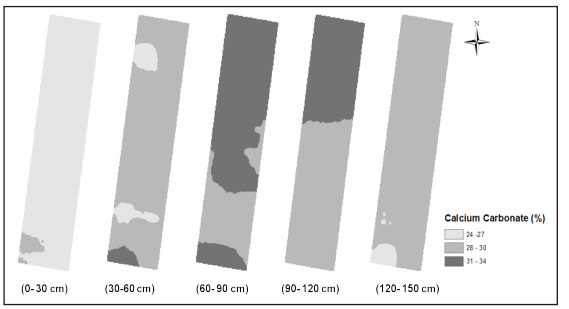

Figure 2- Soil layer mapping of estimated calcium carbonate contents

Şekil 2- Toprak tabakasında tahmin edilen kireç değerleri haritası

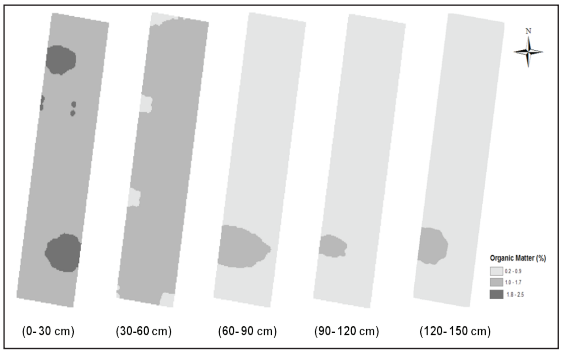

Figure 3- Soil layer mapping of estimated organic matter contens

Şekil 3- Toprak tabakasında tahmin edilen organik madde değerleri haritası

3.3. Clay content (using particle size distribution)

The particle size distribution suggested relatively narrow particle fractionation in the research area. Almost no coarse fraction was detected in the analyzed soil samples. In the top four layers (0-30, 30-60, 60-90 and 90-120 cm, respectively), clay contents generally varied between 49-68%. The deepest layer (120-150 cm) contained between 68-75% clay mostly (Figure 4). Langella et al (2012) reported that obtained interpolation surface using

Table 2- Descriptive statistics of some soil properties using inverse distance weighting (IDW) method

Çizelge 2- Bazı toprak özelliklerinin ağırlıklı ters uzaklık kullanılarak elde edilen tanımlayıcı istatistikleri

Variable	*Min*	*Max*	*Mean*	*Median*	*Skewness*	*Kurtosis*	*SD*	*CV (%)*
$CaCO_3$ (%)	24.3	33.3	29.33	29.54	-0.50	-0.55	2.08	7.10
OM (%)	0.24	2.28	0.98	0.86	0.54	-0.74	0.43	43.42
CEC (me 100 g^{-1})	27.6	40.8	34.90	35.15	-0.21	-0.41	2.31	6.62
Clay (%)	49.1	75.9	61.43	61.44	-0.01	0.02	4.37	7.13

inverse distance weighting is influenced mostly by nearby points. They also stated that the highest accuracy was obtained using 81 neighboring points in prediction of clay content distribution of topsoil. We have performed inverse distance weighting using 104 neighbor points in our research area.

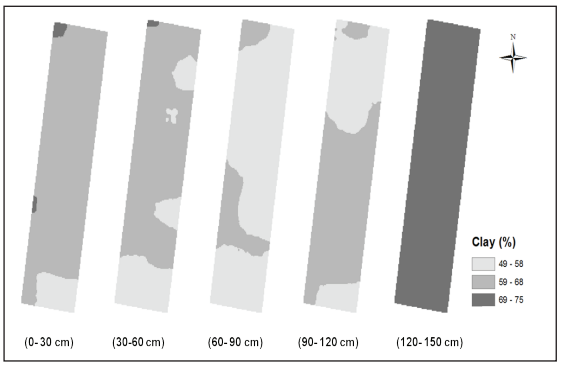

Figure 4- Soil layer mapping of estimated clay percentages

Şekil 4- Toprak tabakasında tahmin edilen kil değerleri haritası

3.4. Calcium carbonate and organic matter contents

Calcium carbonate content in the soil profiles in general were increased with the increased soil depth whereas decreasing contents were determined through the deepest two layers (90-120 and 120-150 cm). This sinusoidal change in lime contents may be attributed to different geological ages. Some 96% of the top soil layer contained 24-27% limestone while 88.05% of the just underlying layer had 28-30% calcium carbonate (Figure 2). Calcium carbonate contents changing relatively in a narrow range along the profile could be regarded as an indicator for the development of an indistinct clay accumulation zone in the soil. In this area, no steady change was observed in percentage of calcium carbonate contents along the profiles at sampling points and between the sampling locations in general. This finding suggested that the accumulation horizon has been still developing in the soil under the impact of "calcification" processes.

An irregular decrease along the profile was noted with the organic matter contents in the study area (Figure 3). According to the previous results obtained throughout the whole area, lime content, organic matter content and pH values distributed randomly (Tunçay et al 2013). The amounts of organic matter in the topsoil were significantly higher than in the deeper layers. The amount of organic matter was always less than three percent even in the surface soil, in spite of the favorable climate and soil characteristics for plant growth in the region, but not enough to support accumulation of organic matter more than a definite level. The pressure of intensive grazing at the region may also be responsible for this soil organic matter scarcity. Gotway et al (1996) obtained more reliable results than kriging for soil organic matter and nitrogen contents when using IDW. Inigo et al (2012) compiled the results for the comparison of mean values of paired up data on organic matter quantities at the surface and at depth for obtaining good interpretable values.

3.5. Cation exchange capacity (CEC)

Two important factors which are the most affecting parameters on cation exchange capacity of soils are clay content and organic matter amount. In addition to that, significant correlations between CEC and other soil properties including sand and silt percentages, pH, bulk density and EC, have been observed (Horn et al 2005; Jung et al 2006). Clay content in our study essentially ranged from 49-75% (Figure 4). The high amount of clay fraction explains relatively high CEC values in Figure 5 and when high clay content is coexisted with excess rate of exchangeable sodium, this may result in higher water saturation percentages and also explain the most frequently low hydraulic permeability which may be often close to zero in the field. This suggests that special precautions and measures should be taken to improve soil structure in eliminating those adverse physical properties. In addition to this fact, water ponding on land surface during preliminary surveys before the establishment of the experimental design was observed which most likely due to this high clay content and heavy seasonal precipitation.

Obviously, the available drainage system was not sufficiently effective. Salinity and sodification problems could not be avoided in deep soil despite the innovator underground drainage net established some 30-35 years ago. This might have resulted from the poor maintenance of the system, high clay content in the deep soil or the resulting low hydraulic permeability.

Clay content was between 49-68% in the upper soils (0-45 cm) which was less in the deeper layers (Figure 4), while clay content was again found higher at deeper parent material (>120 cm). The general high levels of cation exchange capacity were parallel to the content of clay colloids in soil. Accordingly, cation change capacity ranged between 33-36 meq 100 g^{-1} at 45-60 cm depth, 26-33 meq 100 g^{-1} at 60-105 cm and 33-42 meq 100 g^{-1} at 120-150 cm depth (Figure 5). The relative high levels of cation change capacity in the upper horizons could be depended on higher organic matter amount at the surface. Cross validation was performed including all of the variables in order to determine the accuracy of IDW interpolation for each different depth (Table 3). Mostly, the results of interpolation were consistent with those of soil analysis for $CaCO_3$, organic matter, CEC and clay contents. For the different parameters examined, organic matter had the highest mean error (2.82%) in 30-60 cm depth while it was 2.72% in 120-150 cm, and attributed to the variability of spatial stratification.

Soil $CaCO_3$ content gave the lowest mean error values ranging between 0.02-0.72% (Figure 2).

IDW performance and accuracy are the proximity in location and depth of the known soil characteristics such as organic matter, calcium carbonate contents, clay content and cation exchange capacity (Robinson & Metternicht 2006). It was observed that the majority of data with low skewness delivered the best results with a power of 2.

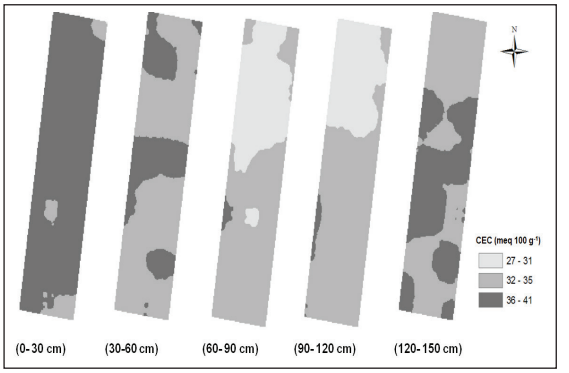

Figure 5- Soil layer mapping of estimated CEC values

Şekil 5- Toprak tabakasında tahmin edilen katyon değişim kapasitesi değerlerinin haritası

Table 3- Cross-validation results for four soil properties

Çizelge 3- Dört toprak özelliği için çapraz doğrulama sonuçları

$CaCO_3$ (%)	*MEV*	*MEP (%)*	*Organic matter (%)*	*MEV*	*MEP (%)*
0-30 cm	0.01	0.02	0-30 cm	0.01	0.75
30-60 cm	0.22	0.72	30-60 cm	0.02	2.82
60-90 cm	0.15	0.45	60-90 cm	0.01	1.72
90-120 cm	0.04	0.12	90-120 cm	0.01	1.44
120-150 cm	0.08	0.26	120-150 cm	0.02	2.72
CEC (meq 100 g^{-1})	*MEV*	*MEP (%)*	*Clay (%)*	*MEV*	*MEP (%)*
0-30 cm	0.16	0.42	0-30 cm	0.66	1.03
30-60 cm	0.08	0.25	30-60 cm	0.48	0.87
60-90 cm	0.14	0.46	60-90 cm	0.57	1.06
90-120 cm	0.06	0.17	90-120 cm	0.31	0.50
120-150 cm	0.21	0.56	120-150 cm	0.52	0.77

MEV, mean error value; MEP, mean error percent; CEC, cation exchange capacity

Kravchenko & Bullock (1999) reported that the data with high skewness (>2.5) were often best estimated with a power of four and for most of the soil properties with low skewness (<1) where a power of one yielded the most accurate estimates.

Estimating the spatial variability of physical and chemical soil properties is a prerequisite for soil and crop-specific management and construction of an ecological environment (Pal et al 2010; Sharma et al 2011; Wang & Shao 2013). Mueller et al (2001), reported that when the RMSE for IDW was minimized with small distance exponents, the field average approach performed well compared to other procedures (kriging, nearest neighbor interpolation).

4. Conclusions

Land use and land management are key parameters for sustainable crop production and desirable, productive soil properties which integrate a variety of environmental processes and human practice in landscape. It is extremely important defining a suite of indicators for site specific management. These indicators must be focused on and be targeted improvement of the physical, biological and chemical properties of the soils in the research region. This paper is focused on spatial interpolation and it is integrated within a GIS to provide and to help developing environmental models especially fitting into in alluvial plains. In addition, the distribution pattern of soil characteristics was mapped in the study area using geostatistical methods. Inverse distance method was employed and evaluated for analyzing the features of some soil characteristics, and its parameters such as minimum and maximum sample numbers, maximum radius etc. Mean error and mean error percentages for interpolation accuracy along with limiting soil sample point all over the study area were computed.

Calcium carbonate, organic matter, cation exchange capacity and clay content values obtained from IDW interpolation were consistent with the soil analysis results, thus enabling the extension of the obtained values to any similar none-sampled region. On the whole, the data obtained from the study can be utilized for site-specific management, inclusive of the establishment parameters estimation and testing the performance of the present irrigation and drainage systems and also evaluating the land-use practices.

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Farklı Sulama Programlarının Krizantemin Kalitesi Üzerine Etkileri

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ÖZET

Bu çalışma, farklı sulama aralıkları (SA_1:2 gün, SA_2:4 gün ve SA_3:6 gün) ve sulama suyu miktarlarının (S_1:T_r×1.50, S_2:T_r×1.25, S_3:T_r×1.00, S_4:T_r×0.75, S_5:T_r×0.50, S_6:T_r×0.25) sera koşullarında yetiştirilen krizantem bitkisinin kalite parametrelerine etkisini belirlemek amacıyla 2011 yılında yürütülmüştür. Çalışmada, *Chrysanthemum morifolium* Ramat türüne ait sprey krizantem çeşidi olan 'Bacardi' kullanılmıştır. Sera dışı radyasyon değerleri kullanılarak hesaplanan potansiyel bitki su tüketiminin (T_r) farklı oranları bitkilere sulama suyu olarak uygulanmıştır. Deneme konularına göre sulama suyu miktarı 192.1-469.4 mm arasında, ölçülen bitki su tüketimi (ET_a) ise 300.9-510.9 mm arasında değişmiştir. Farklı sulama suyu miktarları ve sulama aralıkları, çiçek sapı uzunluğunu, çiçek sapı kalınlığını, ikincil dal sayısını, bitki başına çiçek sayısını, dal ağırlığını, yaprak alan indeksini, vazo ömrünü ve kök uzunluğunu istatistiksel olarak önemli düzeyde etkilemiştir ($P<0.05$). Araştırmada, çiçek sapı uzunluğu, dal ağırlığı ve çiçek sapı kalınlıkları sırasıyla, 81.72-40.04 cm, 140.70-19.31 g ve 8.01-4.00 mm arasında değişmiştir. Dört gün aralıklarla hesaplanan potansiyel bitki su tüketimin 1.25 katının uygulandığı SA_2S_2 deneme konusundan en kaliteli krizantemler elde edilmiş ve bu konu sulama programı olarak belirlenmiştir.

Anahtar Kelimeler**:** Krizantem; Evapotranspirasyon; Sulama aralığı; Su kısıtı

Effects of Different Irrigation Schedulings on Quality of Chrysantmemum

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ABSTRACT

This study was carried out to determine the effects of different irrigation intervals (SA_1: 2-d, SA_2: 4-d, SA_3 6-d) and water amounts (S_1:T_r×1.50, S_2:T_r×1.25, S_3:T_r×1.00, S_4:T_r×0.75, S_5:T_r×0.50, S_6:T_r×0.25) on quality parameters of chrysanthemum grown in the greenhouse in 2011. The spray chrysanthemum (*Chrysanthemum morifolium* Ramat cv.

'Bacardi') plant was used as plant material in this study. Different ratios of the potential evapotranspiration (T_r), calculated using radiation values in outside the greenhouse, was applied as irrigation water. The irrigation water amounts applied to the experimental treatments ranged from 192.1 to 469.4 mm, and seasonal evapotranspiration (Et_a) measured from 300.9 to 510.9 mm. Different irrigation water amounts and irrigation intervals had statistically significant effects on flower stem length, stem diameter, the number of secondary lateral branches, the number of flowers, stem weight, leaf area index, vase life root length of chrysanthemum ($P<0.05$). In the study, flower stem length, stem weight and stem diameter varied between 81.72-40.04 cm, 140.70-19.31 g and 8.01-4.00 mm, respectively. The best quality chrysanthemums were obtained from SA_2S_2 on which about 1.25 times of the potential evapotranspiration calculated in two day intervals was selected as optimum irrigation program.

Keywords: Chrysanthemum; Evapotranspiration; Irrigation interval; Water deficit

1. Giriş

Krizantem çok yönlü kullanımı (kesme çiçek, saksılı ve dış mekan süs bitkisi) ve kontrollü iklim koşullarına sahip seralarda yıl boyu üretilmesi nedeniyle dünyadaki en önemli süs bitkilerinden biridir (Van der Ploeg & Heuvelink 2006). Dünyada 2013 yılı verilerine göre, 1573167 ha alan ve 50 milyar 275 milyon € değerinde süs bitkileri üretimi gerçekleştirilmektedir. Süs bitkileri içerisinde kesme çiçekler ve saksılı süs bitkilerinin üretim alanı 651800 ha, üretim değeri 28 milyar 192 milyon €'dur (Anonim 2013). Türkiye'de ise 45125.7 da alanda süs bitkileri üretilmekte olup bunun 11046.8 da'ını kesme çiçekler oluşturmaktadır. Türkiye'deki süs bitkileri ihracatının (71 milyon 345 bin $) % 49.06'sını (35 milyon $) kesme çiçekler oluşturmaktadır. Kesme çiçek türleri arasında krizantem üretim alanı bakımından (570 da), karanfil (4890 da), kesme gül (1612 da) ve gerbera (1131 da)'dan sonra 4. sırada yer almaktadır (TUİK 2014a; b). Dünyada kesme çiçek ticaretinin en fazla yapıldığı Hollanda çiçek mezatında (FloraHolland) ise krizantem, kesme gülden sonra en fazla satışı yapılan kesme çiçek türüdür (Anonim 2013).

Krizantemde fiyatlar büyük ölçüde görsel kalite özelliklerine (çiçek sapı uzunluğu, çiçek sapı kalınlığı, çiçek sapı direnci, çiçek sayısı, çiçek büyüklüğü ve pozisyonu, yaprak sayısı ve büyüklüğü) bağlı olduğundan üreticiler yıl boyunca yüksek kalitede çiçek yetiştirmeyi amaçlarlar (Carvalho & Heuvelink 2003). Süs bitkilerinin görsel kalitesi üzerinde ise fotosentez, biyokütle üretimi ve kuru maddenin önemli bir rolü vardır. Bitkilerin bu işlemlerinin olumsuz etkilenmemesi için su stresi içinde bulunmamaları gerekir (Jones & Tardieu 1998; Peri et al 2003). Bu nedenle süs bitkilerinde büyüme süreci ve görsel kalite üzerine suyun etkilerinin belirlenmesi için su yönetimini optimize etmek önemli bir adımdır (Carvalho & Heuvelink 2004; Lin et al 2011). Krizantemde iklim koşulları (özellikle sıcaklık ve ışık) ve dikim sıklığı üzerine çok sayıda araştırma yapılmış olmakla birlikte suyun büyüme ve görsel kalite üzerine etkilerinin belirlenmesine yönelik olarak yürütülen araştırma sayısı sınırlıdır (Lin et al 2011). Krizantem üreticileri üretim sırasında genellikle hem aşırı sulama (De Farias & Saad 2005) hem de yetersiz sulama ile verim ve kalite kayıpları ile karşılaşmaktadırlar (De Farias et al 2009). Bu nedenle, hem olası verim ve kalite azalmalarını önlemek hem de mevcut su kaynakları ile daha geniş alanların sulanabilmesi için toprak, bitki, su kaynağı gibi faktörlerin göz önüne alınması bir zorunluluktur. Ayrıca, bitkilerin, büyüme mevsimi boyunca yeterli ya da kısıtlı su koşullarında bitki su tüketimi değerlerinin bilinmesi ve buna göre su verim fonksiyonlarının oluşturulması gerekir. Bu veriler, her bitki için çok sayıda araştırma yapılarak sağlanabilir (Doorenbos & Kassam 1979). Sözü edilen bu verilerin oluşturulması için krizantem bitkisinde, Conover (1969), Harbaugh et al (1982), Parnell (1989), Kiehl et al (1992), Schuch et al (1998), Rego et al (2004), Conte e Castro et al (2005), Fernandes et al (2006), Budiarto et al (2007), De Farias et al (2009), Waterland et al (2010), Turan

(2013), Villalobos (2014) sulama ve çiçek kalitesi ile ilgili araştırmalar yapmışlardır. Sözü edilen bu araştırmaların büyük çoğunluğu saksı çalışmaları şeklinde olup, farklı toprak nemi gerilimlerinde bitki kalitesinin belirlendiği çalışmalardır.

Bu çalışmada, Akdeniz iklim kuşağında sera koşullarında toprakta yetiştirilen krizantem bitkisine uygulanan farklı sulama aralıkları ve su miktarlarının kalite parametrelerine olan etkisinin belirlenmesi amaçlanmıştır.

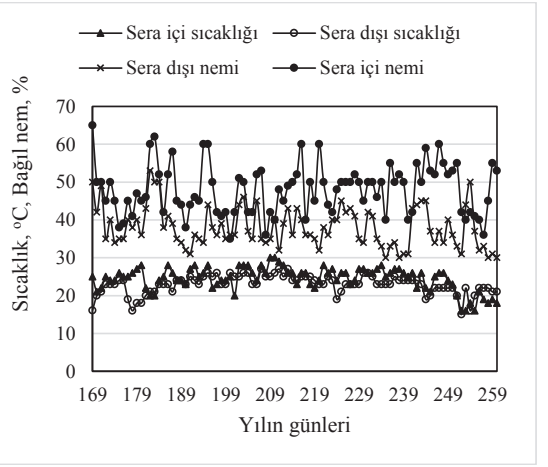
2. Materyal ve Yöntem

2.1. Araştırma alanının yeri

Araştırma, Süleyman Demirel Üniversitesi Ziraat Fakültesi Araştırma ve Uygulama Çiftliği'nde (Enlem: 37.83^0 N, Boylam: 30.53^0 E, Yükseklik: 1.020 m) bulunan 255 m^2'lik (6 m x 42.5 m) plastik örtülü serada, 2011 yılında yürütülmüştür. Denemenin yapıldığı sera toprağının tekstürü killi tın, hacim ağırlığı 1.32-1.41 g cm^{-3}, tarla kapasitesi % 24.80-27.01, solma noktası % 7.08-8.51 ve 0-60 cm'deki toplam su tutma kapasitesi 148.4 mm'dir (Çizelge 1). 2011 yılında sera içindeki günlük ortalama sıcaklık 20-30 ^{o}C, sera dışındaki sıcaklık ise 15-25 ^{o}C arasında değişmiştir. Bağıl nem ise sera içinde % 70-80 iken sera dışında % 50-70 arasında olmuştur (Şekil 1) (DMİ 2011).

2.2. Sulama uygulamaları

Sulama suyu damla sulama yöntemi ile uygulanmıştır. Damlatıcı aralığı 20 cm ve damlatıcı debisi ise 2 L s^{-1} olarak alınmıştır (Uçar at al 2011). Bitki kök bölgesindeki toprak nemi, toprak nem sensörleri (Irrometer, Model; Watermark200SS,



Şekil 1- Sera içi ve dışı sıcaklık ve bağıl nem değerleri

Figure 1- Temperature and relative humidity values in inside and outside of greenhouse

USA) yardımıyla izlenmiştir. Bu amaçla ilgili cihaz için arazide gerekli kalibrasyon işlemleri yapılmış ve her deneme konusuna 2 adet olmak üzere toprak yüzeyinden itibaren iki farklı derinliğe (15 ve 45 cm) yerleştirilmiştir.

Katsoulas et al (2006) tarafından geliştirilen Eşitlik 1 ve 2 yardımıyla potansiyel bitki su tüketimi hesaplanmıştır. Hesaplanan bitki su tüketiminin farklı oranları deneme konularına uygulanarak sulama konuları oluşturulmuştur.

$$T_r = r\,\zeta\,R_{Go} \quad (1)$$

$$\zeta = k_c\,\tau\,\alpha/\lambda \quad (2)$$

Burada; ζ, sera örtü malzemesi geçirgenlik oranı, evaporasyon katsayısı ve latent (gizli)

Çizelge 1- Sera toprağının bazı özellikleri

Table 1- Some properties of the greenhouse soil

Derinlik, cm	*Tarla kapasitesi, %*	*mm*	*Solma noktası, %*	*mm*	*Hacim ağırlığı, g cm^{-3}*	*Faydalı su kapasitesi, %*	*mm*	*Bünye sınıfı*
0-30	24.8	98.2	7.08	28.0	1.32	17.7	70.2	CL
30-60	27.0	114.2	8.51	36.0	1.41	18.5	78.2	CL
Toplam		212.4		64.0			148.4	

ısısına bağlı katsayı; T_r, hesaplanan potansiyel bitki su tüketimi, (mm); r, gölgeleme faktörü (0.75), (r= Ps/85<=1); R_{Go}, göz önüne alınan sulama aralığında solar radyasyon miktarı (kj m^{-2}) (Ölçülen radyasyon değerleri; deneme serasının yüksekliği (3.5 m), radyasyon ölçümü yapılan sensörün yüksekliği (2 m) ve çalışma alanının yüksekliği (1020 m) göz önüne alınarak, istasyon ile sera çatısı arasındaki 1.5 m'lik yükseklik farkına göre düzeltilmiş ve Tr hesaplamalarında düzeltilmiş değerler kullanılmıştır); k_c, bitki katsayısı (1.05; Baille 1999); τ, sera örtü malzemesinin solar radyasyon geçirgenlik oranı (0.75); α, evaporasyon katsayısı (0.6; Baille 1999); λ, latent gizli ısısı, (2450 kJ kg^{-1})'dır. Eşitliklerdeki hesaplamalar için gerekli olan solar radyasyon değerleri deneme serasına 500 m uzaklıkta bulunan tarımsal meteoroloji istasyonundan (Davis, Model ''Vantage Pro II Plus'', USA) alınmıştır.

2.3. Deneme konuları

Altı (6) farklı su düzeyi (S_1= T_r×1.50, S_2= T_r×1.25, S_3= T_r×1.00, S_4= T_r×0.75, S_5= T_r×0.50, S_6= T_r×0.25), 3 farklı sulama aralığı (SA_1= 2 gün, SA_2= 4 gün ve SA_3:6 günde bir sulama) olmak üzere 18 sulama konusu bölünen- bölünmüş parseller deneme desenine göre 3 tekrarlı olarak yürütülmüştür. Bitki su tüketimi, su bütçesi esasına göre Eşitlik 3 kullanılarak hesaplanmıştır (Kırnak et al 2013).

$$ET = I + P - DP \pm RO \pm \Delta S \quad (3)$$

Burada; ET, bitki su tüketimi (mm); I, sulama suyu (mm); P, yağış (mm); R, yüzey akışı (mm); ΔS, kök bölgesi nem içeriğindeki değişim (mm)'dir. Deneme sera ortamında yapıldığından P, sulama suyu damla sulama yöntemi ile uygulandığından R "0" kabul edilmiştir. Bitki su tüketimi hesaplamalarında 15. cm'ye yerleştirilen toprak nem sensörü değerleri dikkate alınmış, 45. cm derinlikteki toprak nem sensöründen ise derine sızmalar incelenmiştir. Toprak nem sensörlerinin okuma sınırının aşıldığı (199 kPa) durumlarda deneme konularından toprak örneği alınarak toprak nem içeriği gravimetrik yöntemle belirlenmiştir.

2.4. Kültürel işlemler

Araştırmada bitkisel materyal olarak *Chrysanthemum morifolium* Ramat. türüne ait sprey krizantem çeşidi olan 'Bacardi' kullanılmıştır. 'Bacardi' katalog verilerine göre 7 haftalık tepki süresine sahip beyaz renkli ve yalınkat petallere sahip bir çeşittir (Anonim 2014). Krizantem fideleri 20 Haziran 2011'de boyutları 1×1.5 m olan yataklara sıra arası 20 cm ve sıra üzeri 12.5 cm olmak üzere 5 sıralı olarak (40 bitki m^{-2}) dikilmiştir. Çalışmada bitkilere uç alma (pinç) işlemi uygulanmamış ve bitkiler tek gövdeli olarak yetiştirilmiştir.

Bitkilerin normal gelişiminin sağlanabilmesi için parsellere eşit miktarda gübreleme yapılmıştır. Bitkilerin sulama ve gübrelemesinde kullanılan besin çözeltisinin iyon içeriği (mg L^{-1}); N: 200, P: 20, K: 150, Ca: 80, Mg: 25, Fe: 3.0, Mn: 0.5, Cu: 0.02, Zn: 0.05, B: 0.5, Mo: 0.01'dir (Yoon et al 2000). Kısa gün koşullarını sağlamak ve erken çiçeklenmeyi teşvik etmek amacıyla bitkilere siyah renkli ışık geçirmez plastik örtüyle 17:00-08:00 saatleri arasında karartma uygulaması yapılmıştır. Kısa gün uygulamasına bitkiler 30 cm boya ulaştıklarında başlanmış ve çiçek tomurcukları renk gösterdiğinde son verilmiştir (Kofranek 1980; Kazaz et al 2010). Hasat, 15 Eylül 2011 tarihinde, dal üzerindeki çiçekler tamamen açtığında gerçekleştirilmiştir. Deneme süresince ana çiçek tomurcuğunun koparılması, destekleme sistemi, hastalık ve zararlılarla mücadele gibi standart kültürel uygulamalar yerine getirilmiştir.

2.5. Denemede incelenen özellikler ve istatistiksel analiz

Denemede farklı sulama konularına ilişkin bitki su tüketimi, çiçek sapı uzunluğu, dal ağırlığı, çiçek sapı kalınlığı, ikincil dal sayısı (birincil ana dallar üzerinde yetişen dallar), bitki başına çiçek sayısı, yaprak alan indeksi, kök uzunluğu ve vazo ömrü incelenmiştir. Kök uzunluklarını belirlemek için hasattan hemen sonra her deneme konusundan 3 bitkinin kök bölgesindeki toprak, içerisinde kökler olacak şekilde blok halinde alınmış ve laboratuvarda 0.1 N NaOH çözeltisinde 24 saat bekletildikten

sonra içerisindeki kökler ayıklanmış ve daha sonra kök uzunlukları ölçülmüştür (Böhm 1979).

Yaprak alan indeksi Eşitlik 4 yardımıyla hesaplanmıştır.

$$YAI = \frac{YA}{BA} \quad (4)$$

Burada; YAI, yaprak alan indeksi ($cm^2\,cm^{-2}$); YA, yaprak alanı (cm^2) [Yaprak alanlarının ölçülmesinde portatif yaprak alan ölçer kullanılmıştır (ADC BioScientific, Model: AM300, England)]; BA, her bir bitkiye ait birim alan (cm^2).

Çiçeklerin vazo ömrü; 21±1 °C sıcaklık, 1000 lüks ışık, % 70±5 nispi nem, 12 saat ışık ve 12 saat karanlık koşullarına sahip (Ferrante et al 2007; Lü et al 2010) vazo ömrü odasında belirlenmiştir.

Elde edilen verilere MINITAB 16 bilgisayar yazılımı yardımıyla varyans analizi yapılmış, ortalamaların karşılaştırılmasında MSTAT-C bilgisayar yazılımı yardımıyla LSD Çoklu Karşılaştırma testi uygulanmıştır.

3. Bulgular ve Tartışma

3.1. Sulama suyu ve bitki su tüketimi

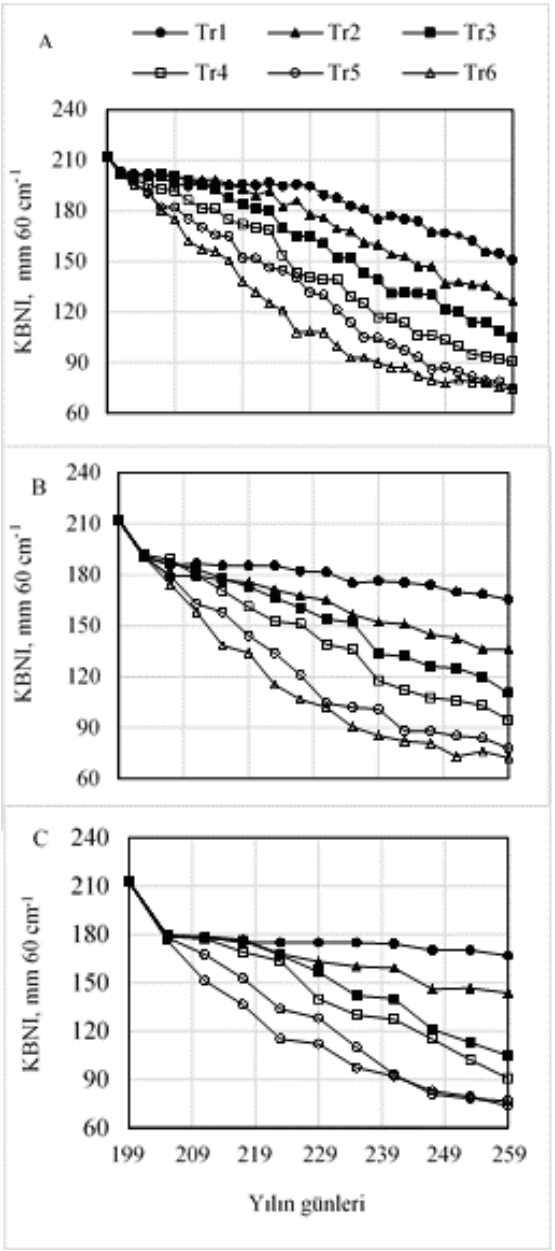
Denemede fidelerin gerek tutma oranının artırılması gerekse kök gelişiminin sağlanması amacıyla dikimden sonra 25 gün süre ile günlük sulama yapılmış ve hesaplanan Tr'nin tamamı (136.7 mm) sulama suyu olarak uygulanmıştır. S_1, S_2, S_3, S_4, S_5 ve S_6 konularına yetişme periyodu boyunca sırasıyla 469.4, 414.0, 358.5, 303.1, 247.6 ve 192.1 mm su uygulanmıştır (Çizelge 2). Çalışmada, en yüksek su tüketimi, T_r'nin 1.5 katının 2 ve 4 gün aralıklarla sulama suyu olarak uygulandığı SA_1S_1 (510.9 mm) ve SA_2S_1 (492.8 mm) konularında ölçülmüştür. Bunu 2 gün aralıklarla hesaplanan bitki su tüketiminin 1.25 katının uygulandığı SA_1S_2 (490.2 mm) konusu izlerken en düşük su tüketimi ise 6 gün aralıkla hesaplanan bitki su tüketiminin 0.25 katının sulama suyu olarak uygulanan SA_3S_6'da (300.9 mm) ölçülmüştür. Çizelge 2'den de görüleceği gibi aynı miktarda sulama suyunun farklı sulama aralıklarında uygulanması ölçülen bitki su tüketiminde farklılığa yol açmıştır. Daha fazla sulama suyu uygulanan deneme konularında, bitki kök bölgesindeki toprak nemi deneme süresince tarla kapasitesine yakın olduğundan bu konularda daha fazla bitki su tüketimi gerçekleşmiştir (Şekil 2, Çizelge 2). Ayrıca, sulama aralığı kısa olan konuların daha sık sulanması nedeniyle toprak yüzeyinin sürekli ıslak olması bu konulardaki bitki su tüketimi yüksekliğinin nedeni olarak gösterilebilir. Rego et al (2009), Wenbin et al (2011) ve Turan (2013) yaptıkları çalışmalarda sırasıyla 192.2-355 mm, 70-305 mm ve 249.7-517.9 mm arasında sulama suyu uygulamışlardır. Rego et al (2009) azalan sulama suyu uygulamasının sulama suyu kullanım etkinliğinin artırdığını bildirmişlerdir. Wenbin et al (2011) krizantemde bitki su tüketiminin 52.3-259.4 mm arasında değiştiğini belirtirlerken Turan (2013) ise 340.9-560.5 mm arasında değiştiğini bildirmiştir. Çalışmada uygulanan sulama suyu miktarları Rego et al (2009) ve Wenbin et al (2011)'dan oldukça farklı iken Turan (2013) ile uyumludur. Bitki su tüketimi ise Webin et al (2011) ile farklı Turan (2013) ile benzeşmektedir. Sulama suyu miktarındaki ve bitki su tüketimindeki bu farklılığın kullanılan çeşitten, vejetasyon dönemi farklılığından ve çevresel koşulların farklı olmasından kaynaklandığı düşünülmektedir.

Çizelge 2- Deneme konularına göre uygulanan sulama suyu ve bitki su tüketim değerleri

Table 2- Applied irrigation water and evapotranspiration values according to experimental treatments

Sulama programı	*Sulama suyu, mm*			*Bitki su tüketimi, mm*		
	S_a	S_b	S	SA_1	SA_2	SA_3
S_1		332.8	469.4	510.9	492.8	481.7
S_2		277.3	414.0	490.2	463.1	455.1
S_3	136.7	221.8	358.5	458.4	451.5	442.0
S_4		166.4	303.1	419.0	411.6	398.3
S_5		110.9	247.6	381.3	367.9	352.7
S_6		55.5	192.1	328.5	314.2	300.9

S_a, programlı sulamaya geçmeden önce deneme konularına uygulanan sulama suyu miktarı; S_b, programlı sulamaya geçtikten sonra uygulanan sulama suyu miktarı; S, toplam sulama suyu miktarı; SA_1, SA_2 ve SA_3, sulama aralığı 2, 4 ve 6 gün



Şekil 2- Deneme konularına göre kök bölgesi nem içerikleri (KBNI), (A, sulama aralığı 2 gün; B, sulama aralığı 4 gün; C, sulama aralığı 6 gün)

Figure 2- Root zone soil water contends according to treatments (A, irrigation interval 2-day; B, irrigation interval 4-day; C, irrigation interval 6-day)

3.2. Kalite parametreleri

Çalışmada bitkilere uç alma işlemi uygulanmamış ve bitkiler tek gövdeli olarak yetiştirilmiştir. Bu nedenle bütün deneme konularından bitki başına bir dal (40 bitki m^{-2}) hasat edilmiş verim yönünden bir karşılaştırma yapılmamıştır. Dikim tarihi ile çiçeklerin % 50'sinin hasat edildiği tarih arasında geçen süre olan çiçeklenme süresi S_1, S_2, S_3, S_4, S_5 ve S_6 konularında sırasıyla 67.3, 67.4, 67.9, 69.7, 70.3 ve 70.6 gün olarak gerçekleşmiştir. Farklı sulama suyu miktarlarının (S) ve sulama aralıklarının (SA), çiçek sapı uzunluğu, dal ağırlığı, çiçek sapı kalınlığı, ikincil dal sayısı, bitki başına çiçek sayısı, yaprak alan indeksi, kök uzunluğu ve vazo ömrü üzerine etkisi istatistiksel açıdan önemli bulunmuştur ($P<0.05$) (Çizelge 3). Çizelge 3'te görüldüğü gibi, S×SA interaksiyonu sap uzunluğunda % 5 düzeyinde, yan dal sayısı ve çiçek sayısı % 1 düzeyinde önemli çıkarken incelenen diğer parametrelerde önemsiz çıkmıştır. S×SA interaksiyonunun önemli çıkması, artan sulama suyu etkisinin sulama aralıklarına göre farklılık gösterdiğini ortaya koymaktadır.

3.2.1. Çiçek sapı uzunluğu

Artan sulama suyu miktarı ve daha sık sulama aralıkları çiçek sapı uzunluğunda istatistiksel olarak ($P<0.01$) önemli artışlar gerçekleştirmiştir (Çizelge 3 ve 4). Çalışmada en uzun çiçek sapları SA_1S_2'den (81.72 cm) elde edilirken bunu SA_2S_2 (81.24 cm), SA_2S_1 (81.03 cm) ve SA_3S_1 (80.08 cm) izlemiştir. En kısa çiçek sapları ise SA_3S_6 (40.04 cm), SA_2S_6 (42.46 cm) ve SA_3S_5'den (42.60 cm) elde edilmiştir. Çiçek sapı uzunluğu sulama suyu miktarı açısından değerlendirildiğinde; en fazla sulama suyunun uygulandığı S_1 konularında ortalama 80.02 cm ile en uzun çiçek sapı elde edilirken, bunu 78.45 cm ile S_2, 74.49 cm ile S_3, 59.15 cm ile S_4, 46.81cm ile S_5 ve 41.95 cm ile en az sulama suyunun uygulandığı S_6 izlemiştir. SA_1 ve SA_2 konularında artan sulama suyu uygulaması S_2 uygulamasına kadar çiçek sapı uzunluğunda artışa neden olurken S_1 uygulamasında istatistiksel olarak çiçek sapı uzunluğunda artışa neden olmamış aksine özellikle SA_1'de azalmaya neden olmuştur. Bu azalmaya aşırı su uygulamasının neden olduğu söylenebilir. SA_3'te ise artan sulama suyu uygulaması S_1'e kadar artışa neden olmuştur.

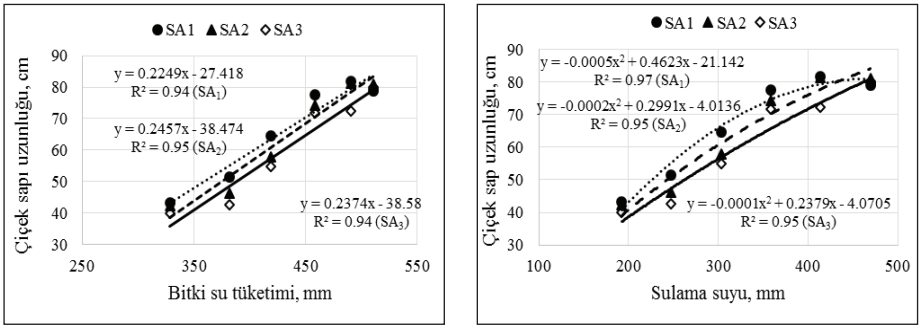
Çizelge 3- İncelenen parametrelerin ortalama değerlerine ilişkin varyans analiz sonuçları

Table 3- The results of variance analysis of the mean values of the investigated parameters

Varyasyon kaynakları	*SD*	*Kareler ortalaması*							
		ÇSU	*DA*	*ÇSK*	*İDS*	*BÇS*	*YAI*	*KU*	*VÖ*
Blok	2	6.17	95.0	0.14	0.71	6.76	0.03	5.59	2.74
Sulama aralığı (SA)	2	326.07**	691.0*	1.72**	14.33**	141.28**	0.81**	112.33**	19.24**
Su düzeyi (S)	5	12410.51**	89271.3**	97.99**	676.83**	6878.68**	62.16**	135.96**	18.95**
SA×S	10	182.61*	1259.0	1.89	68.50**	177.18**	0.17	18.23	5.62**
Hata	34	305.40	2608.3	3.89	16.39	138.08	0.67	65.87	0.94
Genel	54	13230.76	93924.6	105.61	776.47	7341.98	63.83	337.99	226.76

ÇDS, çiçek sapı uzunluğu, cm; DA, dal ağırlığı, g; ÇSK, çiçek sapı kalınlığı, mm; İDS, ikincil dal sayısı, adet bitki^{-1}; BÇS, bitki başına çiçek sayısı, adet bitki^{-1}; YAİ, yaprak alan indeksi; KU, kök uzunluğu, cm; VÖ, vazo ömrü, gün

Şekil 3'den de görüleceği gibi, çiçek sapı uzunluğu ile bitki su tüketimi arasında doğrusal, çiçek sapı uzunluğu ile sulama suyu arasında ise önemli eğrisel ($P<0.01$) ilişkiler elde edilmiştir. Çiçek sapı uzunluğu ile sulama suyu arasında eğrisel ilişkilerin elde edilmesi belirli bir değerden sonra sulama suyunun çiçek sapı uzunluğunu artırmadığı aksine azaltıcı etki yapması ile açıklanabilir. Genel anlamda uygulanan sulama suyu miktarı arttıkça çiçek sapı uzunluğunda artış sağladığı Harbaugh et al (1982) tarafından da vurgulanmıştır. Söz konusu çalışmada, 0.16 cm gün^{-1} konusunda bitki boyunu 62 cm, 0.24 cm gün^{-1} konusunda 76 cm, 0.31 cm gün^{-1} konusunda 86 cm, 0.40 cm gün^{-1} konusunda 92 cm, 0.47 cm gün^{-1} konusunda ise bitki boyunu 97 cm olarak belirtmişlerdir. Schuch et al (1998)'de benzer şekilde kısıtlı sulamanın tam sulamaya göre bitki boyunu % 12 oranında azalttığını bildirmişlerdir. Turan (2013) ise çiçek sapı uzunluğu ile uygulanan sulama suyu arasında önemli bir ilişkinin olduğunu vurgulamıştır. Bu veriler araştırmadan elde edilen sonuçları doğrular niteliktedir. Çiçek sapı uzunluğu ülkelere göre farklılık göstermekle birlikte sprey krizantemde genellikle 70-80 cm uzunluğundaki dallar tercih edilmektedir (Kazaz et al 2010). Ülkemizde ise sprey krizantemde ideal çiçek sapı uzunluğu 70 cm (Hatipoğlu 1987) iken bu değer İngiltere'de 50-70 cm'dir (Mengüç 1996). Dünyada en fazla kesme çiçek satışının yapıldığı Hollanda çiçek mezatında sprey krizantemler çiçek sapı uzunluğu bakımından 65, 70 ve 72 cm olmak üzere 3 gruba ayrılmaktadır (Anonim 2012). Çalışmada her üç sulama aralığındaki S_1, S_2 ve S_3 konularından 70 cm ve üzerinde çiçek sapı uzunlukları elde edilmiştir.



Şekil 3- Çiçek sapı uzunluğu ile bitki su tüketimi ve sulama suyu düzeyleri arasındaki ilişki

Figure 3- Relationship between flower stem length and evapotranspiration and between flower stem length and irrigation water levels

3.2.2. Dal ağırlığı

Dünyada krizantemlerin pazarlanmasında esas alınan en önemli kalite kriterlerinin başında dal ağırlığı gelmektedir. Çalışmada dal ağırlıkları hem farklı sulama aralıklarından hem de farklı sulama suyu miktarlarından önemli düzeyde etkilenmiştir (Çizelge 4). Farklı sulama suyu miktarları içerisinde en yüksek dal ağırlığı T_r değerinin 2 gün aralıkla 1.5 katının uygulandığı SA_1S_1 (140.70 g) konusundan elde edilmiş bunu aynı miktardaki suyun 6 gün aralıkla uygulandığı SA_3S_1 (135.24 g) konusu izlemiştir. Sulama aralıkları açısından ise en fazla dal ağırlığı SA_1'den (78.65 g) elde edilmiş, bunu diğer parametrelerde olduğu gibi SA_2 (76.53) ve SA_3 (70.23) izlemiştir. Sulama aralığı ve sulama suyu miktarı kombinasyonları birlikte değerlendirildiğinde, genel olarak daha çok sulama suyu uygulanan ve sulama aralığı kısa olan deneme konularından elde edilen dal ağırlıkları daha fazladır. Bu durum fazla sulama suyu uygulamasının çiçek sapı uzunluğundakine benzer şekilde dal ağırlığını da arttırmaktadır şeklinde yorumlanabilir.

Konuyla ilgili yapılan çalışmada, Harbaugh et al (1982), günlük farklı sulama suyu uygulamalarında 0.16 cm gün^{-1} konusunda bitki ağırlığını 93 g, 0.24 cm gün^{-1} konusunda 127 g, 0.31 cm gün^{-1} konusunda 138 g, 0.40 cm gün^{-1} konusunda 149 g, 0.47 cm gün^{-1} konusunda ise bitki dal ağırlığı 168 g olarak saptamışlardır. Dal ağırlığını Turan (2013) farklı sulama suyu düzeylerinde 123.61 g ile 32.48 g arasında değiştiğini bildirmiştir. Bu değerler, denemeden elde edilen sonuçlarla uyumludur. Hollanda çiçek mezatında sprey krizantemlerde çiçek sapı uzunluğuna (65, 70 ve 72 cm) bağlı olarak dal ağırlıkları 45-105 g arasında değişmektedir. Bununla birlikte optimal dal ağırlığı 70 g'dır (Anonim 2012). Dal ağırlığının 45 g'dan 70 g'a kadar yükselmesi durumunda satış fiyatında artış görülmekte, 75 gramın üzerindeki dal ağırlıkları artan nakliye masrafından dolayı tercih edilmemektedir. Japonya'da 80-90 cm uzunluğundaki sprey krizantemlerde boylama ve paketleme öncesinde dal ağırlığının 70 g, dalın dip kısmındaki (15-20 cm) yapraklar koparıldıktan sonra ise dal ağırlığının 50-55 g olması durumunda pazarda en kaliteli sınıfta yer almaktadır (Yoon et al 2000). Bu çalışmada, dal ağırlıkları bütün deneme konularında çiçek sapı uzunluklarına (40.04-81.72 cm) bağlı olarak 19.31-140.70 g arasında değişmiş ve her üç sulama aralığındaki (SA_1, SA_2 ve SA_3) S_1, S_2 ve S_3 konularından 70 g ve üzerinde dal ağırlıkları elde edilmiştir.

3.2.3. Çiçek sapı kalınlığı

Çiçek sapı kalınlığı dalın direncini belirlemede önemli bir kriterdir. Sulama suyu miktarları açısından en kalın çiçek sapı, S_1 konusunda ortalama 7.83 mm ile gerçekleşirken bunu, S_2, S_3, S_4, S_5 ve S_6 izlemiştir. Bu konularda belirlenen çiçek sapı kalınları sırasıyla 7.34 mm, 7.00 mm, 5.87 mm, 4.73 mm ve 4.19 mm'dir. Sulama aralıkları incelendiğinde ise en kalın çiçek sapı ortalama 6.35 mm ile SA_1'de belirlenmiş bunu SA_2 (6.22 mm) ve SA_3 (5.92 mm) izlemiştir. En kalın çiçek sapı SA_1S_1 kombinasyonundan elde edilirken en ince çiçek sapı en az sulama suyunun uygulandığı ve sulama aralığı 6 gün olan SA_3S_6 (4.00 mm) kombinasyonundan elde edilmiştir (Çizelge 4). Turan (2013), yaptığı araştırmada çiçek sapı kalınlıklarının 7.69-4.62 mm arasında değiştiğini artan su miktarlarının ve kısa sulama aralıklarının çiçek sapı kalınlıklarını artırıcı yönde etki yaptığını bildirmiştir. Araştırmadan elde edilen sonuçlar bu sonuçlarla uyum içerisindedir.

3.2.4. İkincil dal sayısı

İkincil dal sayısının artması bitki başına çiçek sayısını artırırken aynı zamanda dalın kompakt ve estetik görünüşünü de artırmaktadır. Bu nedenle ikincil dal sayısı sprey krizantemde önemli kalite parametrelerinden biridir. İkincil dal sayısı su düzeyleri açısından değerlendirildiğinde en fazla ikincil dal sayısı 15.34 adet ile S_1 konularından elde edilmiştir. Bunu S_2 (14.54 adet), S_3 (14.16 adet), S_4 (12.44 adet), S_5 (9.97 adet) ve S_6 (5.03 adet) konuları izlemiştir. S_2 ve S_3 konuları arasındaki fark istatistiksel olarak önemsiz iken diğer konular arasındaki fark önemlidir. İkincil dal sayısı sulama aralığı açısından değerlendirildiğinde ise en fazla ikincil dal sayısı SA_1 konularında ortalama 12.42 adet olarak bulunurken, bunu ortalama 12.12 adet ile SA_2 konuları ve ortalama 11.21 adet ile SA_3

Çizelge 4- Sulama suyu miktarı ve sulama suyu aralıklarının bazı kalite parametreleri üzerine etkileri

Table 4- Mean values and significance groups of investigated parameters of the chrysanthemum

Sulama programı	*Çiçek sapı uzunluğu, cm*			*Ortalama*	*Dal ağırlığı, g*			*Ortalama*
	SA_1	SA_2	SA_3		SA_1	SA_2	SA_3	
S_1	78.93^{ab}	81.03^{a}	80.08^{a}	80.02^{A}	140.70	119.57	135.24	131.84^{A}
S_2	81.72^{a}	81.24^{a}	72.38^{c}	78.45^{A}	117.29	120.16	102.98	113.47^{B}
S_3	77.45^{ab}	74.31^{bc}	71.70^{c}	74.49^{B}	94.27	97.14	84.33	91.91^{C}
S_4	64.60^{d}	57.91^{e}	54.92^{ef}	59.15^{C}	64.67	61.32	52.93	59.64^{D}
S_5	51.54^{f}	46.29^{g}	42.60^{gh}	46.81^{D}	34.71	38.02	26.59	33.11^{E}
S_6	43.34^{gh}	42.46^{gh}	40.04^{h}	41.95^{E}	20.29	22.98	19.31	20.86^{F}
Ortalama	66.27^{A}	63.87^{B}	60.29^{C}		78.65^{A}	76.53^{A}	70.23^{B}	
$LSD_{0.05}$	S:2.871	SA:2.30	S×SA: 4.972		S:8.390	SA:5.933	S×SA: öd	
	Çiçek sapı kalınlığı, mm				*İkincil dal sayısı, adet bitki^{-1}*			
S_1	8.01	7.59	7.90	7.83^{A}	15.89^{a}	14.82^{ab}	15.31^{ab}	15.34^{A}
S_2	7.43	7.74	6.85	7.34^{B}	14.71^{b}	14.38^{bc}	14.54^{bc}	14.54^{B}
S_3	7.18	6.89	6.92	7.00^{B}	14.91^{ab}	13.42^{c}	14.16^{bc}	14.16^{B}
S_4	6.35	5.79	5.47	5.87^{C}	14.49^{bc}	11.62^{d}	11.22^{d}	12.44^{C}
S_5	4.84	5.00	4.38	4.73^{D}	11.47^{d}	10.98^{d}	7.47^{e}	9.97^{D}
S_6	4.26	4.33	4.00	4.19^{E}	3.07^{g}	7.47^{e}	4.56^{f}	5.03^{E}
Ortalama	6.35^{A}	6.22^{A}	5.92^{B}		12.42^{A}	12.12^{A}	11.21^{B}	
$LSD_{0.05}$	S:0.4159	SA:0.2290	S×SA: öd		S:0.6651	SA:0.4703	S×SA: 1.152	
	Bitki başına çiçek sayısı, adet bitki^{-1}				*Yaprak alan indeksi*			
S_1	36.81^{a}	36.94^{a}	37.11^{a}	36.96^{A}	4.06	3.98	3.97	4.00^{A}
S_2	35.93^{a}	36.24^{a}	26.38^{bc}	32.85^{B}	3.80	3.63	3.41	3.61^{B}
S_3	28.88^{b}	29.00^{b}	26.58^{b}	28.15^{C}	3.04	2.99	2.73	2.92^{C}
S_4	23.11^{c}	17.36^{d}	15.56^{de}	18.67^{D}	2.49	2.26	2.06	2.27^{D}
S_5	12.38^{ef}	12.69^{ef}	10.09^{fg}	11.72^{E}	1.41	1.37	1.23	1.34^{E}
S_6	4.93^{h}	7.27^{gh}	4.60^{h}	5.60^{F}	1.30	1.20	0.93	1.14^{F}
Ortalama	23.68^{A}	23.25^{A}	20.05^{B}		2.68^{A}	2.57^{B}	2.39^{C}	
$LSD_{0.05}$	S:1.930	SA:1.365	S×SA: 3.343		S:0.1345	SA:0.09508	S×SA: öd	
	Kök uzunluğu, cm				*Vazo ömrü, gün*			
S_1	17.25	18.17	19.73	18.38^{D}	15.7^{ef}	15.3^{fg}	14.0^{g}	15.0^{C}
S_2	17.57	19.85	20.94	19.45^{CD}	13.7^{g}	16.3^{d-f}	17.7^{b-d}	15.9^{C}
S_3	17.88	21.71	22.08	20.56^{BC}	17.7^{b-d}	19.7^{a}	17.7^{b-d}	18.3^{AB}
S_4	18.13	22.50	22.26	20.96^{BC}	16.0^{ef}	17.3^{c-e}	20.3^{a}	17.9^{AB}
S_5	20.32	22.68	23.13	22.00^{AB}	17.0^{de}	18.7^{a-c}	20.3^{a}	18.7^{A}
S_6	21.27	24.99	23.39	23.22^{A}	16.7^{d-f}	16.6^{d-f}	19.0^{ab}	17.4^{B}
Ortalama	18.73^{B}	21.65^{A}	21.92^{A}		16.1^{C}	17.3^{B}	18.2^{A}	
$LSD_{0.05}$	S:1.333	SA:0.9428	S×SA: öd		S:0.9273	SA: 0.6557	S×SA: 1.606	

SA, sulama aralığı, gün; S, sulama suyu düzeyi. Gruplandırmalarda büyük harfler S ve SA'nın ortalamalarına ait gruplandırmaları, küçük harfler SxSA interaksiyonuna ait gruplandırmaları göstermektedir. öd, önemli değil

konuları izlemiştir. Sulama aralığı 2 ve 4 gün olan konulardan elde edilen ikincil dal sayıları arasındaki fark önemli değilken bu iki sulama aralığı ile sulama aralığı 6 gün olan konulardan elde edilen ikincil dal sayıları arasındaki fark istatistiksel açıdan önemli bulunmuştur. Hesaplanan T_r'nin 1.50 katının uygulandığı S_1 konusu ile 0.25 katının uygulandığı S_6 konusu arasında ikincil dal sayısı bakımından yaklaşık olarak % 80'lik bir azalma söz konusudur. Turan (2013), 2, 4 ve 6 gün aralıklarla A sınıfı buharlaşma kabından buharlaşan suyun 0.3, 0.6, 0.9 ve 1.2 katını sulama suyu olarak uyguladığı çalışmasında, farklı su düzeylerinin ve sulama aralıklarının ikincil dal sayısını istatistiksel olarak etkilediğini ve ikincil dal sayısının farklı su düzeylerine göre 15.60-9.67 adet arasında, sulama aralığına göre ise 14.51-13.23 adet arasında değiştiğini bildirmiştir. Araştırmadan elde edilen ikincil dal sayıları üst sınır açısından benzerlik gösterirken alt sınırlarda daha düşük yan dal sayılarının elde edildiği görülmektedir. Bu durumun uygulanan sulama programlarının farklılığından kaynaklandığı düşünülmektedir.

3.2.5. Bitki başına çiçek sayısı

Sprey krizantemlerde çiçek sapı uzunluğu ve dal ağırlığından sonra en önemli kalite parametrelerinden biri bitki başına çiçek sayısıdır. Bitki başına çiçek sayısı bakımından elde edilen veriler incelendiğinde hem sulama aralıkları hem de uygulanan sulama suyu miktarı açısından istatistiksel olarak önemli farklılıklar olduğu görülmüştür. Bitki başına en fazla çiçek sayısı ortalama 36.96 adet ile S_1'den elde edilmiş bunu uygulanan su miktarındaki azalmaya paralel olarak S_2 (32.85 adet), S_3 (28.15 adet), S_4 (18.67 adet), S_5 (11.72 adet) ve S_6 (5.60 adet) konuları izlemiştir. Bitki başına çiçek sayıları sulama aralıkları açısından değerlendirildiğinde ise en fazla çiçek sayısı SA_1'de ortalama (23.68 adet) belirlenmiş bunu SA_2 (23.25 adet) ve SA_3 (20.05 adet) takip etmiştir. SA_1 ve SA_2 arasında fark önemsiz iken bu iki konu ile SA_3 arasındaki fark ise önemlidir. Turan (2013) farklı sulama suyu düzeylerinin uygulanması ile çiçek sayısının 30.09 ile 10.60 adet arasında değişebileceğini bildirmiştir. Çalışmadan elde edilen sonuçlar bu sonuçlarla uyumludur. Hollanda çiçek mezatında sprey krizantemlerde bir dal üzerinde çiçek sayısının en az 5 adet ve üzerinde olması gerekmektedir (Anonim 2012). Çalışmada SA_1'de en az sulama suyu uygulanan S_6 (4.93 adet bitki^{-1}) deneme konusu ile SA_3'de yine S_6 (4.60 adet bitki^{-1}) deneme konusundan dal başına 5'er adedin altında çiçek elde edilirken, diğer bütün deneme konularında dal başına 5'er adedin üzerinde çiçek elde edilmiştir.

3.2.6. Yaprak alan indeksi

Bitkilerde yaprak alanı ve buna bağlı olarak hesaplanan yaprak alan indeksi vegetatif gelişmenin bir ölçüsü olarak değerlendirilir ve yaprak alanının buna bağlı olarak da yaprak alan indeksinin yüksek olması bitki su tüketimini artırıcı yönde etki yapar. Denemede yaprak alan indeksi hem sulama aralıklarından hem de su düzeylerinden istatistiksel olarak önemli düzeyde ($P<0.01$) etkilenmiş artan sulama suyu ve azalan sulama aralığı yaprak alan indeksini artırıcı yönde etki yapmıştır. En az sulama suyu uygulanan S_6 (1.14) ile en çok sulama suyu uygulanan S_1 (4.00) arasında yaprak alan indeksleri bakımından yaklaşık 3.5 kat fark oluşmuştur. Sulama suyunun 2, 4 ve 6 gün aralıklarla uygulandığı konularda yaprak alan indeksi sırasıyla 2.68, 2.57 ve 2.39 olarak belirlenmiştir (Çizelge 4). Çalışmadan elde edilen sonuçlarla uyumlu olarak Schuch et al (1998) 6 farklı krizantem çeşidinde tam sulamanın kısıntılı sulamaya göre yaprak alan indeksini artırdığını, Lin et al (2011) su stresinin yaprak alanlarında azalmaya yol açtığını bildirmiştir.

3.2.7. Kök uzunluğu

Bitkilere uygulanacak sulama suyu miktarını derinlik cinsinden ifade edebilmek için kök derinliklerinin bilinmesi gerekir. Literatürde krizantem bitkisinin kök derinliğine ilişkin bir bilgiye rastlanamamıştır. Bu nedenle çalışmada hasat sonunda bitki kök uzunlukları da belirlenmiştir. En uzun kökler en az sulama suyunun uygulandığı S_6'da (23.22 cm) belirlenirken en kısa kök uzunlukları ise en fazla suyun uygulandığı S_1'de (18.38 cm) belirlenmiştir.

Sulama aralıkları içinde ise en uzun kökler sulama aralığının en fazla olduğu SA_3'te (21.92 cm) belirlenmiştir (Çizelge 4). İncelenen diğer parametrelerin aksine sulama suyu ve sulama aralığı arttıkça kök uzunluğu artmamış aksine azalmıştır. Bir başka ifade ile sık ve fazla miktarda sulama suyu uygulamak kök gelişimini azaltmıştır. Bitkilerin su stresine girmemesi ve köklerin ihtiyaç duydukları suyu kolaylıkla alabilmeleri nedeniyle fazla su uygulanan konularda bitki köklerinin az su uygulanan konulara göre daha az uzadıkları düşünülmektedir.

3.2.8. Vazo ömrü

Kesme çiçeklerde en önemli kalite kriterlerinden biri vazo ömrüdür. Bütün kesme çiçek türlerinde olduğu gibi krizantemde de hasat sonrası ömrün uzun olması istenir. Vazo ömrü sadece tüketici memnuniyetini etkilemez aynı zamanda tüketicilerin çiçeklere olan talebini de etkiler (Onozaki et al 2001). Çalışmada en uzun vazo ömrü SA_3S_4 ve SA_3S_5 (20.3 gün) konularından elde edilirken en kısa vazo ömrü (13.7 gün) ise SA_3S_1'den elde edilmiştir. Sulama aralıkları açısından en uzun vazo ömrü ortalama 18.2 gün ile sulama aralığı 6 gün olan konularda belirlenmiştir. Bu konu ile sulama aralığı 2 gün (16.1 gün) ve 4 gün (17.3 gün) olan konular istatistiksel olarak birbirinden farklıdır. Sulama aralığına benzer şekilde, sulama miktarları da istatistiksel açıdan önemli düzeyde farklıdır. Su düzeyleri açısından en yüksek vazo ömrü ortalama 18.7 gün ile S_5'te gerçekleşirken en düşük vazo ömrü ise 15.0 gün ile S_1'de gerçekleşmiştir (Çizelge 4). Kesme çiçeklerde hasat sonrası dayanım süresini; hasat öncesi, hasat sırası ve hasat sonrası faktörler etkilemektedir. Toprak yapısı, çeşit, ışık, sıcaklık, nispi nem, sulama, gübreleme, hastalık ve zararlılarla mücadele, budama, uç alma, tomurcuk seyreltmesi gibi hasat öncesi kaliteyi artırıcı uygulamalar kesme çiçeklerde kuru madde miktarını artırarak hasat sonrası ömrü uzatırlar (Anonim 2002; Dole & Schnelle 2002). Halevy & Mayak (1981), su stresinin vazo ömrünü azalttığını bildirmesine karşın çalışmada genel olarak daha az sulama suyu uygulanan konulardan daha uzun vazo ömürleri elde edilmiştir. Bu durumun, vazo ömrünün sulama uygulamalarından çok vazo ömrünü etkileyen diğer parametrelerden daha fazla etkilenmesinden kaynaklandığı düşünülmektedir.

4. Sonuçlar

Dünyada ticareti yapılan kesme çiçekler arasında kesme gülden sonra ikinci sırada yer alan krizantem bitkisine farklı sulama suyu miktarlarının ve sulama aralıklarının etkisinin araştırıldığı bu çalışmada, sulama suyunun artması buna karşın sulama aralığının azalması çiçek sapı uzunluğunu, dal ağırlığını, çiçek sapı kalınlığını, ikincil dal sayısını, bitki başına çiçek sayısını ve yaprak alan indeksini artırırken kök uzunluğunu azaltmıştır. Ayrıca sera dışındaki radyasyon değerlerini kullanarak, sera içindeki bitkilerin bitki su tüketimlerini hesaplayan Katsaulas et al (2006) eşitliğinin krizantem bitkisinin sulama programının oluşturulmasında başarı ile kullanılabileceği sonucuna varılmıştır. Deneme sonucunda pazarlanabilir ürün açısından dünyada sprey krizantemlerde kabul edilen en önemli kalite kriterlerinden çiçek sapı uzunluğu ve dal ağırlığı dikkate alınarak yapılan değerlendirmede SA_2S_2 konusunun sulama programı olarak seçilebileceği, başka bir ifade ile hesaplanan T_r'nin 1.25 katının sulama suyu olarak uygulanması ile kaliteli çiçekler elde edilebileceği sonucuna varılmıştır.

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Kısaltmalar ve Semboller	
$S_1, S_2 .... S_6$	Sulama suyu düzeyleri, mm
SA_1, SA_2, SA_3	Sulama aralıkları, gün
kPa	Kilo paskal
da	Dekar

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Biological Control of Cotton Seedling Diseases by Fluorescent *Pseudomonas* spp.

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ABSTRACT

Seedling root rot seen in many plants including cotton is an important disease that leads to large economic losses. Human health and the environment are negatively affected as a result of using fungicides for disease control. The goal of this study was to determine the effects of fluorescent *Pseudomonas* (FP) bacteria against seedling root rot pathogens both *in vitro* and *in vivo* conditions. 59 FP isolates obtained from the rhizosphere of cotton and weeds on the field were tested by dual-culture assays *in vitro*. After applying effective FP isolates on the seeds, antagonistic effects against the seedling root rot pathogens were investigated in a climate chamber. Resulting of dual-culture tests, FP40 had maximum effect (49.60%) against *Rhizoctonia solani*. Besides, FP51, FP48 and FP35 had highest impact as 43.80%, 43.50%, and 43.10% against *Fusarium* sp., respectively. *Pythium deliense* was mostly effected by FP57 (59.80%), FP52 (57.80%) and FP56 (57.60%). While isolates FP35 and FP57 provided protection over 70% against all three pathogens in a climate chamber, they were as effective as commercial fungicides (Vitavax and Maxim) and biofungicide (Subtilex) and shown promising results.

Keywords: Biocontrol; Biofungicide; Seedling disease; Fluorescent *pseudomonas*

Fluoresan *Pseudomonas* spp. ile Pamuk Fide Kök Çürüklüğü Hastalıklarının Biyolojik Mücadelesi

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ÖZET

Fide kök çürüklüğü pamuk dahil pek çok bitkide görülen ve ekonomik kayıplara yol açan önemli bir hastalıktır. Fungisitler hastalığa karşı mücadelede kullanılması sonucu, çevre ve insan sağlığı olumsuz yönde etkilenmektedir. Çalışmada, fluoresan pseudomonas (FP) bakterilerinin fide kök çürüklüğü hastalık etmenlerine karşı *in-vitro* ve *in-vivo* koşullarda

etkilerinin belirlenmesi amaçlanmıştır. Pamuk ve tarladaki yabancı otların rizosferinden izole edilen 59 adet FP izolatı ile *in vitro*'da ikili kültür testleri yürütülmüştür. Daha sonra etkili bulunan FP izolatları tohuma uygulanarak fide kök çürüklüğü etmenlerine karşı antagonistik etkileri iklim odasında araştırılmıştır. İkili kültür testlerinde, *Rhizoctonia solani*'ye karşı en yüksek etkiyi FP40 (% 49.60); *Fusarium* sp.'ye karşı en yüksek etkiyi FP51 (% 43.80), FP48 (% 43.50) ve FP35 (% 43.10); *Pythium deliense*'ye karşı en yüksek etkiyi FP57 (% 59.80), FP52 (% 57.80) ve FP56 (% 57.60) izolatları göstermiştir. İklim odasında, FP35 ve FP57 izolatları her üç patojene karşı % 70'in üzerinde koruma sağlarken, ticari fungisitler (Vitavax, Maxim) ve biyofungisit (Subtilex) kadar etkili bulunmuş ve ümitvar sonuçlar elde edilmiştir.

Anahtar Kelimeler: Biyolojik mücadele; Biyofungisit; Fide hastalığı; Fluoresan *pseudomonas*

1. Introduction

Crop losses in agricultural production occurred in 9.1% by disease, 11.2% by pests and 14.7% by the weeds in the world. This amount is equivalent to one-third of the world agricultural production potential. Annual monetary value of these losses is about 550 billion dollars and the costs incurred to protect the product are about 455 billion dollars annually (Agrios 2005). The diseases caused yield losses with average 3.1% per year and 27% reduction in fiber production for 10 years study in the USA (Devay 2001). *Rhizoctonia* spp., *Pythium* spp. and *Thielaviopsis* spp. are seen as the most common and destructive damping off disease agents have been reported in the world (Agrios 1998).

These pathogens are seen in many plants including cotton and causes large economic losses. Cotton seedling root rot inducing factors can cause the seedling root and root collar to decay and let them to die especially in infected and heavy soils during wet and cool seasons, thus leading major destruction in cotton fields and sometimes requiring replanting of the field (Agrios 2005). Despite their promise in prevention of the damping off diseases, fungicides have some problems because of phytotoxicity, environmental pollution and human health effects (Ramamoorthy et al 2002). Moreover, when disease effect is in the level of requiring replanting, there will be space in the field due to less seedlings and the farmers generally use more seeds than necessary to compensate for this risk. In replanting, the expenses for seed, seedbed preparation and soil cultivation cost increase and the yield decreases because of late planting.

Hoitink (1986) reported that chemical application is generally not successful for soil-borne pathogens whereas bio-control agents are well colonized in the rhizosphere and don't have the toxic effects on the leaves like chemicals, and they have not only control the disease but also have positive effects on plant development. On the other hand, *R. solani* was suppressed about 60% due to "chitinase enzyme" with the inoculated cotton seeds with isolates of antagonistic bacteria of *Bacillus cereus*, *B. subtilis* and *B. pumilus* in the greenhouse (Pleban et al 1995). After the treatment of cotton seeds with *Pseudomonas fluorescens* race 89B-61, antagonist bacteria colonized the roots of cotton well and protected the plant against soil-borne diseases (Quadt et al 1997). Wang et al (2004) reported that *Pseudomonas fluorescens* CS85 was previously isolated from the rhizosphere of cotton seedlings as a plant growth-promoting bacterium and biocontrol agent against *R. solani*, *Colletotrichum gossypii*, *F. oxysporum* f.sp. *vasinfectum*. Various biocontrol agents such as *Burkholderia cepacia* and *B. subtilis* have effective results throughout the world. Isolate GBO3 of *B. subtilis* and Dagger-G biofungicide of *P. fluorescens* were tested *in vitro* against *Pythium ultimum* and *Fusarium* spp. in cotton seeds and found that antagonists reduce the damage of bacterial diseases in cottonseed (Agile & Batson 1999). Nowadays, commercially named biofungicides Deny®, Subtilex® and Kodiak® are suggested against the seedling diseases (Gardener & Fravel 2002).

Works conducted against important damping off diseases using non-pathogenic *Pseudomonas* in tomato nurseries in the greenhouse and field showed that the isolates 10, 11, 23, 32 and 44 had an effect over 50% against *P. deliense* and *R. solani* in pot trials while isolates 23 and 44 were also effective against *Sclerotinia minor* and *Alternaria solani* in the field (Aşkın & Katırcıoğlu 2008). In another experiment directed by Mahmood Janlou et al (2008) conducted in the field during 2002-2003 in Iran with three isolates of *P. fluorescens* and two isolates of *Bacillus* spp. using two different fungicides (carbendazim and carboxin+thiram) and two different cotton varieties (Sahel and Siokra). Resulting that one isolate of *P. fluorescens* and two isolates of *Bacillus* spp. were effective against seedling root rot disease as fungicides in both years. They reported that it is possible to use combination of both, fungicides and antagonist bacteria against diseases in the field.

In the present study, the effects of fluorescent *Pseudomonas* strains against cotton seedling diseases were tested both *in vitro* and *in vivo* conditions.

2. Material and Methods

2.1. Plant material, pathogens and fluorescent Pseudomonas spp. strains

Delinted seeds of cotton (*Gossypium hirsutum* L.) cultivar Carmen were the plant materials. Fifty-nine fluorescent *Pseudomonas* strains isolated from cotton and weeds were used in this study that effective in the root zone of cotton as well as summer and winter weeds (Erdoğan & Benlioğlu 2010). Three pathogenic isolates of *Rhizoctonia solani* AG4, *Fusarium* sp. and *Pythium deliense* used in the experiment were originally isolated from the roots of cotton and tomato seedlings infected with damping-off disease. Isolation, purification and identification of these fungi were carried out at Adnan Menderes University, Mustafa Kemal University and Süleyman Demirel University, Faculty of Agriculture, Department of Plant Protection. Fungicides, active substances and application doses are given in Table 1.

Table 1- Fungicides, active substance and application doses

Çizelge 1- Fungisitler, etkili madde ve uygulama dozları

*Trade name**	*Company*	*Active substance and percentage*	*Formulation*	*Dose*
Vitavax 200 FF	Hektaş	Carboxin 205 g L^{-1} + Thiram 205 g L^{-1}	FF	400 mL 100 kg^{-1} seed
$MaximXL_{035FS}$	Syngenta	Fludioxonil 25 g + Mefenoxam 10 g	FS	300 mL 100 kg^{-1} seed
Subtilex Seed™	Bioglobal	*Bacillus subtilis* MBI 600	WP	18 g 100 kg^{-1} seed

*, Vitavax 200 FF and $MaximXL_{035FS}$, commercial fungicides; Subtilex Seed™, Biofungicide

2.2. Preparation of pathogen inoculums

Inoculum for seedling disease agents (*R. solani*, *Fusarium* sp. and *P. deliense*) was prepared by recommendation of Martin (2000) that is oat bran formulation (30 g Oat bran, 30 g vermiculite, and 60 mL of sterile water). Then, *R. solani* and *Fusarium* sp. cultures were developed in media of Yeast Dextrose Agar (YDA) and Potato Sucrose Agar (PSA) at 24±1 °C for one week. An agar disk from the edge of *P. deliense* culture produced on Corn Meal Agar (CMA) at 21±1 °C for one week was taken and mixed as 4-5 counts to each bag. Bags were closed tightly and incubated (24±1 °C and 21±1 °C) for three weeks and mixed at the end of the first week.

2.3. In vitro assay

In vitro inhibition zone tests for FP strains against *R. solani*, *Fusarium* sp. and *P. deliense* were performed according to the dual-culture assay in which FP strains were subjected to pre-selection against three damping-off agents (*R. solani*, *Fusarium* sp. and *P. deliense*) on Potato Dextrose Agar (PDA)

plates. Then, to determine the rate of inhibition by FP strains, *in vitro* experiment was conducted as randomized plot design with three replications on PDA plates. Each plate was inoculated with four droplets of 10 µL bacterial suspension (at 10^8 cfu mL^{-1} concentration) symmetrically placed on four sites at equal distances (2 cm) from the center of plate. As a control, 10 µL of sterile water was dropped into four separate points on PDA plate. After incubation of PDA in petri plates for one day at 24±1 °C, an agar disc of 5 mm diameter taken from the edge of ten days grown *R. solani* (AG4), *Fusarium* sp. and *P. deliense* cultures and planted into the middle point of the bacteria inoculated petri plates and the control petri plates. After seven days incubation period of media for *R. solani* (AG4) and *Fusarium* sp. at 24±1 °C, for *P. deliense* at 21±1 °C, colony diameters of *R. solani* (AG4), *Fusarium* sp. and *P. deliense* were measured separately and percent inhibition zones were determined by the Equation 1 (Weller & Cook 1986; Gamliel & Katan 1993).

$$\text{Inhibition Zone (\%)} = C\text{-}T/C \times 100 \quad (1)$$

Where; *C*, diameter (mm) in the petri plates used as a control; *T*, fungi colony diameter (mm) in petri plates with bacteria.

2.4. In vivo experiments

A local cotton variety cv. Carmen seeds delinted with sulfuric acid were used in pot experiments (Akpınar & Benlioğlu 2008). Subsequently, these seeds were tested for germination percentage in a growth chamber (at 24±1 °C; 50-70% relative humidity; a 12 h light/12 h dark). Germinations were in plastic containers (1000 mL) and each container received forty seeds (ten seeds for each replicate) in a completely randomized plot design in four replications. Firstly, biofungicides (Table 1) were stirred in 1 mL of water at recommended doses and after cotton seeds coated, they let to dry for 12 h at room temperature. The control seeds were coated with only 1% of carboxy-methyl-cellulose (CMC). To coat cotton seeds with FP strains, a 2.5% of NaOCl surface disinfection for 1 min performed with sterile water. In the trial, cotton seeds (totally forty seeds for each treatment) were inoculated with each FP isolates using 1% CMC. For this purpose, antagonistic bacteria strains (at 10^8 cfu mL^{-1} concentration) produced at Nutrient Broth (NB) for 24 h, and were suspended with 1% of medium viscosity of CMC (2 mL) to coat cotton seeds (Quadt et al 1997). Seeds were spread on the filter paper to be dried in a sterile cabinet at room temperature and planted in one liter of plastic containers containing 100 mg of *R. solani* (AG4), *Fusarium* sp., and *P. deliense* inoculum within 24 h. Approximately, seven days after planting, germinated seeds were counted and recorded. Seeds that were not germinated or germinated but later knocked down and intact seedlings were counted and evaluated. Percentage of disease incidence (DI) was calculated using the Equation 2 (Hassanein 2012). These trials were performed as randomized plot design with four replications in a growth chamber (at 24±1 °C; 50-70% relative humidity; a 12 h light/12 h dark).

$$\text{DI (\%)} = \text{no. of infected plants/total no. of plants} \times 100 \quad (2)$$

2.5. Statistical analysis

All data obtained in experiments were analyzed using JMP statistical software (PC version 5.0, SAS Institute, Cary, NC, for PC computer) with the 95% confidence level.

3. Results and Discussion

3.1. In vitro assay

In our study, the effects of fifty-nine fluorescent *Pseudomonas* strains isolated from the rhizosphere of cotton and weeds on mycelium growth of seedling root rot pathogens (*R. solani*, *Fusarium* sp. and *P. deliense*) were tested. Results of dual-culture assay *in vitro* against *R. solani* showed the highest inhibition rate (49.60%) by strain FP40. Maximum effects (43.80%, 43.50% and 43.10%) against *Fusarium* sp. were obtained from strains of FP51, FP48 and FP35, respectively. Strains of FP57, FP52 and FP47 had the highest impact against *P. deliense* as 59.80%, 57.80% and 57.60%, respectively (Table 2, 3 and 4). In a similar study, Waara et al (1993) concluded that *Pseudomonas*

species suppressed *R. solani*, *Pythium* spp., *Fusarium* spp. both *in vitro* and *in vivo*. Also, *P. fluorescens* isolated from cotton fields in Egypt was suppressed by *Pythium carolinianum in vitro* (Abdelzaher & Elnaghy 1998). The another research by Laha & Verma (1998) aiming to investigate the effects of the 58 different *P. fluorescens* isolates from cotton rhizosphere on root rot of cotton, 16 of them inhibited the development of *R. solani* by 10-36% in Pseudomonas agar in fluorescein (PAF) culture. Demir et al (1999) used 128 isolates of fluorescent pseudomonas isolated from healthy cotton seedlings and rhizosphere soils to test *in vitro* for their effect on *R. solani* and found that the application of dried xanthum gum (XG) formulations to cotton seeds were increased emergence, reduced disease incidence as compared to control seeds without bacteria. *P. fluorescens* (Gh/R 1810) was the most effective strain, resulting 16.36% greater emergence and 57.94% greater survival of cotton seedlings than the untreated control. The mycelia growth of fungi *Pythium aphanidermatum* and *R. solani* were inhibited by five of Pseudomonas isolates (Afsharmanesh et al 2006). In a research to determine antagonistic effects of six of *Pseudomonas* isolates and six of *Bacillus* isolates *in vivo* and *in vitro* against *Fusarium oxysporum* f. sp. *ciceris*, all isolates had antagonistic effect on pathogen as a result of *in vitro* dual-culture assay (Karimi et al 2012).

Table 2- Inhibition rates of FP strains against *R. solani in vitro*

Çizelge 2- In vitro'da fluoresan pseudomonas izolatlarının R. solani'yi engelleme oranları

Strains	*Origin*	*Fungus colony diameter (mm)**	*Inhibition rate (%)*
FP6	*G. hirsutum* (Nazilli 84 S)	14.41 cde	38.50
FP20	*Solanum nigrum*	13.33 def	43.20
FP30	*G. hirsutum* (Carmen)	17.40 b	25.70
FP35	*Convolvulus arvensis*	13.00 ef	44.40
FP40	*Malva sylvestris*	11.83 f	49.60
FP42	*Raphanus* sp.	16.80 b	28.20
FP43	*Malva sylvestris*	14.25 cde	38.90
FP45	*Raphanus* sp.	15.73 bc	32.90
FP47	*G. hirsutum* (Nazilli 84 S)	13.83 de	36.40
FP48	*G. hirsutum* (Carmen)	15.03 cd	35.90
FP53	*G. hirsutum* (Giza 45)	14.67 cde	32.60
FP59	*G. hirsutum* (Carmen)	14.33 cde	34.20
Control		23.40 a	00.00
CV %		6.70	

*, in the same column means with different letters indicate the significant difference (LSD test, P<0.05)

Table 3- Inhibition rates of FP strains against *Fusarium* sp. *in vitro*

Çizelge 3- In vitro'da fluoresan pseudomonas izolatlarının Fusarium sp.'yi engelleme oranları

Strains	*Origin*	*Fungus colony diameter (mm)**	*Inhibition rate (%)*
FP9	*Datura stramonium*	18.53 bcd	36.60
FP14	*Solanum nigrum*	18.17 bcd	35.50
FP20	*Solanum nigrum*	16.75 cd	41.50
FP21	*Datura stramonium*	17.83 bcd	36.70
FP23	*Portulaca* sp.	16.75 cd	41.50
FP25	*Chenepodium album*	20.00 b	31.50
FP30	*G. hirsutum* (Carmen)	19.57 b	32.90
FP35	*Convolvulus arvensis*	16.58 d	43.10
FP48	*G. hirsutum* (Carmen)	16.50 d	43.50
FP49	*G. hirsutum* (BA 119)	17.00 cd	41.30
FP51	*G. hirsutum* (Nazilli 143)	16.41 d	43.80
FP57	*G. hirsutum* (STN-8A)	19.17 bc	32.30
Control		29.20 a	00.00
CV %		7.20	

*, in the same column means with different letters indicate the significant difference (LSD test, P<0.05)

Table 4- Inhibition rates of FP strains against *P. deliense in vitro*

Çizelge 4- In vitro'da fluoresan pseudomonas izolatlarının P. deliense'yi engelleme oranları

Strains	*Origin*	*Fungus colony diameter (mm)**	*Inhibition rate (%)*
FP5	*Portulaca* sp.	18.53 bc	40.40
FP9	*Datura stramonium*	16.33 d	47.60
FP14	*Solanum nigrum*	16.40 d	47.40
FP19	*Chenepodium album*	17.25 bcd	44.70
FP20	*Solanum nigrum*	18.97 b	39.20
FP21	*Datura stramonium*	16.06 d	48.50
FP23	*Portulaca* sp.	16.25 d	47.90
FP28	*Xanthium strumarium*	15.93 d	48.90
FP30	*G. hirsutum* (Carmen)	16.73 cd	46.30
FP35	*Convolvulus arvensis*	16.83 cd	46.00
FP48	*G. hirsutum* (Carmen)	17.25 bcd	44.70
FP49	*G. hirsutum* (BA 119)	15.63 d	49.90
FP52	*G. hirsutum* (Nazilli 84)	13.17 e	57.80
FP56	*G. hirsutum* (Nazilli 84 S)	13.23 e	57.60
FP57	*G. hirsutum* (STN-8A)	12.53 e	59.80
Control		31.18 a	00.00
CV %		6.80	

*, in the same column means with different letters indicate the significant difference (LSD test, $P<0.05$)

3.2. In vivo experiments

The results of germination seven days after planting were given in Table 5, 6 and 7 for the experiment, conducted in the pots in a growth chamber in order to determine the effects of FP strains, commercial fungicides and biofungicides against seedling root rot agents in cotton. The FP strains were significantly different in pots trials. Although commercial fungicides Maxim (76.0%) and Vitavax (73.6%) as well as strains FP35 (73.2%) and FP48 (73.1%) had maximum effect against *R. solani*, they were in the same statistical group with biofungicide Subtilex (70.9%). The lowest antagonistic effect against *R. solani* was obtained from the strains FP45 (50.5%) and FP47 (51.9%). In addition, applications of Maxim, Vitavax, FP35, FP48 and Subtilex that showed highest effect against *R. solani*, also resulted the highest number of total germinated plants, 37, 36, 36, 36 and 36, respectively. Commercial fungicides Maxim (77.0%), Vitavax (73.3%) and strain FP57 (73.2%) had also maximum impact on *Fusarium* sp. and found in the same statistical grouping. In contrast, the lowest impact against *Fusarium* sp. was obtained from FP21 (35.0%). Total numbers of germinated plants were also obtained from Maxim, Vitavax and FP57 as 39, 37 and 35, respectively. *P. deliense* was affected by Maxim (79.1%) and Vitavax (76.1%) at most and followed by Subtilex (73.9%) and strains FP20 (73.9%), FP35 (73.8%) and FP57 (73.4%). The lowest impact against *P. deliense* was belonging to strain FP5 (31.6%). Moreover, the number of total germinated plants was also higher in the applications that had the highest impact on *P. deliense* (Table 5, 6 and 7). Prior to sedaxane, other fungicides, such as carboxin fungicides and several analogs, pyraccarbolid, fenfuram, methfuroxam, furrmetamid, and pyrazoles IIa and IIb were selectively effective in controlling *R. solani* in cotton in either *in vitro* or *in vivo* experiments. A seed treatment containing the active ingredient sedaxane is an innovative option for growers whose fields have a historic incidence of *R. solani* and have previously experienced soybeans losses due to the pathogen (Huppatz et al 1983). Dagger G, bioformulation of *P. fluorescens* had suppressed

both *Rhizoctonia* spp. and *Pythium* spp. in cotton (Bradow 1991). *P. flu*orescens strain BL915 was effective against *R. solani* by producing pyrrolnitrin (Hill et al 1994). In a study, Zaki & Kersten (1998) used *P. cepacia* D1 race, biofungicides such as Deny and Kodiak and fungicidal mixtures (metalaxyl, triadimenol and thiram) against *R. solani* in field trials in Arizona in 1995-1996. Study resulted that plants from the cotton seeds treated with D1 race and fungicidal mixtures were not infected with disease. Nemli & Sayar (2002) examined the effects of many fungicides and fungicide combinations against cotton seedling root rot and found that combinations of carboxin+thiram+metalaxyl and fluodioxinil+metalaxyl were more effective than other applications had. Akpınar & Benlioğlu (2008) used two of endophytic bacteria (*Burkholderia cepacia* F5), one of *Bacillus megaterium* (C5), one of biofungicide (*T. harzianum* KUEN-1565) and fungicides (Trilex, BYF 182, Vitavax 200 FF) against damping off diseases caused by *R. solani* in pot and field trials in cotton during 2006-2007. The best results of pot trials for pre-emergence damping off disease were obtained from seed treatment applications of BYF 182, Trilex, Vitavax and F5. In field trials, the lowest rate of damping off disease before emergence were obtained from fungicides Vitavax and BYF 182 in Söke and from fungicides Vitavax and Trilex in Nazilli. On the other hand, Ardakani et al (2009) reported that Bentonite-B1 application increased healthy seedlings and was more effective than applications of carboxin+thiram against *R. solani* at 15, 30, 45 and 60 days after planting in a study using *P. fluorescens* (talk and bentonite formulation) and one of fungicide (carboxin+thiram) with a cotton variety in a climate chamber in Iran.

4. Conclusions

As a result, *Pseudomonas* strains 35 and 57 were as effective as commercial fungicides (Vitavax and Maxim) and biofungicides (Subtilex) against especially all three pathogens (*R. solani*, *Fusarium* sp., and *P. deliense*) and had promising results. Coating seeds with the bacteria in the study was

Table 5- Effects of FP strains, commercial fungicides and biofungicide against *R. solani* in pot trials

Çizelge 5- Saksı denemelerinde fluresan pseudomonas, biyopreparat ve fungisitlerin R. solani'ye etkileri

Treatments	*Total emerged plants*	*Average of emerged plants (%)*	*Effect against R. solani (%)**
FP6	33	17.5	60.4 abc
FP20	33	17.5	58.1 abc
FP30	33	17.5	65.6 abc
FP35	36	9.0	73.2 a
FP40	33	17.5	61.9 abc
FP42	34	15.0	62.8 abc
FP43	33	17.5	59.1 abc
FP45	30	25.0	50.5 c
FP47	31	22.5	51.9 c
FP48	36	9.0	73.1 a
FP53	33	17.5	67.4 abc
FP59	32	20.0	54.8 bc
Control (+)	23	42.5	15.7 d
Vitavax (K)	36	9.0	73.6 a
Maxim (K)	37	7.5	76.0 a
Subtilex (K)	36	9.0	70.9 ab
CV %			32.03

*, in the same column means with different letters indicate the significant difference (LSD test, $P<0.05$)

Table 6- Effects of FP strains, commercial fungicides and biofungicide against *Fusarium* sp. in pot trials

Çizelge 6- Saksı denemelerinde fluresan pseudomonas, biyopreparat ve fungisitlerin Fusarium sp.'ye etkileri

Treatments	*Total emerged plants*	*Average of emerged plants (%)*	*Effect against Fusarium sp. (%)**
FP9	31	22.5	55.3 c
FP14	33	17.5	64.8 abcd
FP20	32	20.0	57.1 bcd
FP21	27	32.5	35.0 e
FP23	34	15.0	70.8 def
FP25	30	25.0	56.3 cd
FP30	33	17.5	67.6 abcd
FP35	34	15.0	70.9 abc
FP48	34	15.0	70.5 abc
FP49	28	30.0	55.4 c
FP51	33	17.5	64.5 abcd
FP57	35	12.5	72.0 ab
Control (+)	25	37.5	18.6 f
Vitavax (K)	37	7.5	73.3 a
Maxim (K)	39	2.5	77.0 a
Subtilex (K)	34	15.0	70.1 abc
CV %			26.40

*, in the same column means with different letters indicate the significant difference (LSD test, P<0.05)

Table 7- Effects of FP strains, commercial fungicides and biofungicide against *P. deliense* in pot trials

Çizelge 7- Saksı denemelerinde fluresan pseudomonas, biyopreparat ve fungisitlerin P. deliense'ye etkileri

Treatments	*Total emerged plants*	*Average of emerged plants (%)*	*Effect against P. deliense (%)**
FP5	28	30.0	31.6 f
FP9	33	17.5	62.6 bcde
FP14	35	12.5	71.9 abcd
FP19	33	17.5	67.3 abcde
FP20	36	10.0	73.9 abc
FP21	30	25.0	56.1 e
FP23	30	25.0	58.8 de
FP28	30	25.0	60.0 cde
FP30	34	15.0	70.7 abcd
FP35	36	10.0	73.8 abc
FP48	35	12.5	71.3 abcd
FP49	33	17.5	65.9 abcde
FP52	33	17.5	69.2 abcde
FP56	30	25.0	62.7 bcde
FP57	36	10.0	73.4 abc
Control (+)	24	40.0	20.3 f
Vitavax (K)	37	7.5	76.1 ab
Maxim (K)	37	7.5	79.1 a
Subtilex (K)	37	7.5	73.9 abc
CV %			28.20

*, in the same column means with different letters indicate the significant difference (LSD test, P<0.05)

carried out with simple laboratory facilities and the method used was effective and easy to apply commercially. On the other hand, field trials with these antagonistic bacteria and more detailed studies of bio-controlling mechanisms of action are needed. Since fungicides are polluting the environment and demand for organic cotton production, biological preparations can be used as an alternative to fungicides.

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Evaluation of Irrigation Water Quality in Gölbaşı District

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ABSTRACT

Gölbaşı district, located at 20 km south of Ankara city is one of the special environmental protection areas (SEPA) of Turkey. The water resources of Golbasi district are under the pressure of urbanization and agricultural activities. In recent years, the demand for groundwater has increased, however accesibility is limited by the quantity and quality of water. This study aims to evaluate the irrigation water quality in Golbasi SEPA. A total of 41 water samples were collected from existing wells and fountains in 11 villages of Golbasi SEPA and analyzed for relevant quality parameters to assess their conformity with irrigation water quality standards. Analysis of samples led to classification of samples into 19 groups with common characteristics. Among them, 20 samples in Group 1-5 had salinity and alkalinity class of C2-S1, and they had the best water quality. On the other hand, 15 samples in Groups 6-14 had salinity and alkalinity class of C3-S1. Since these waters have high level of salt, leaching and special soil tillage is required to avoid salinity problem on the long-term. Yield reduction up to 10-25% may be experienced with alfalfa and corn. Among the samples, only 6 waters had salinity class of C4, and alkalinity of S1, S2 or S4. These waters are not suitable for irrigation under normal conditions. In special cases, they can be used if salt resistant plants are selected, where drainage is good and excess leaching is applied. Land reclamation may be required on the long term. Yield reduction up to 25-50% may be experienced with alfalfa and corn due to salinity.

Keywords: Agriculture; Boron; Golbasi; Salinity; Water quality

Gölbaşı Bölgesi'nde Sulama Suyu Kalitesinin Değerlendirilmesi

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ÖZET

Ankara ilinin 20 km güneyinde yer alan Gölbaşı bölgesi, Türkiye'nin özel çevre koruma bölgelerinden (ÖÇKB) birisidir. Gölbaşı bölgesindeki su kaynakları kentleşme ve tarım faaliyetlerinin baskısı altındadır. Son yıllarda, bölgede yeraltı suyu talebi artmıştır, ancak erişilebilirlik suyun kalitesi ve miktarı ile sınırlıdır. Bu çalışmanın amacı, Gölbaşı ÖÇKB'nde

kullanılan sulama suyu kalitesinin değerlendirilmesidir. Gölbaşı ÖÇKB sınırları içinde bulunan 11 mahallede mevcut kuyu ve çeşmelerden 41 adet su örneği toplanmış ve ilgili kalite parametreleri ölçülerek sulama suyu kalite standartlarına uygunluğu değerlendirilmiştir. Örneklerin incelenmesi sonucunda ortak özelliklere sahip 19 grup ortaya çıkmış, bunlardan Grup 1-5 içinde yer alan 20 örneğin tuzluluk ve alkalilik sınıfı C2-S1 olarak bulunmuştur. Bu örnekler, sulama suyu olarak en iyi kaliteye sahip sulardır. Diğer yandan, Grup 6-14 içinde yer alan 15 örneğin tuzluluk ve alkalilik sınıfı C3-S1 olarak bulunmuştur. Bu sular, yüksek tuzluluğa sahip olduklarından uzun dönemde tuzluluk problemi yaratmamak için yıkama ve özel toprak işleme gerekmektedir. Tuzluluk nedeniyle yonca ve mısır gibi bitkilerde % 10-25'e varan verim kaybı gözlenebilir. Örnekler arasında yalnızca 6 örneğin tuzluluk sınıfı C4, alkalilik ise S1, S2 veya S4 olarak bulunmuştur. Bu sular, normal koşullarda sulama suyu olarak kullanılmaya uygun değildir. Özel durumlarda, tuzluluğa dayanıklı bitki türlerinin seçilmesi, drenajın iyi olduğu ve bol yıkama yapılan durumlarda kullanılabilir. Uzun dönemde arazi ıslahı gerekebilir. Tuzluluğa bağlı olarak yonca ve mısırda % 25-50'ye varan oranda verim kaybı gözlenebilir.

Anahtar Kelimeler: Bor; Gölbaşı; Su kalitesi; Tarım; Tuzluluk

1. Introduction

Turkey is under the risk of becoming a water-poor country by 2030 due to limited water resources and expected adverse impacts of population increase and climate change. As a candidate country to the European Union (EU), Turkey has to adopt the environmental policy of EU and transpose the related legislation such as the Water Framework Directive (WFD) (2000/EC/60) (Dalkılıç & Harmancıoğlu 2008). The WFD promotes integrated management of water resources to reduce problems associated with excessive water abstraction, pollution, floods and droughts (EC 2000). Therefore, Turkey has to use her water resources wisely to minimize water stress in the future.

Turkey gets an average of 643 mm precipitation per year, however some regions suffer from water scarcity due to lower precipitation levels. Golbasi district, located at a distance of 20 km south of Ankara city, is one of these regions. It gets an average of 400 mm precipitation per year and has a terrestrial climate. The weather is cold and rainy in winters, whereas it is hot and arid in summers. Annual average temperature is 11.7 °C (DSİ 2007). These conditions result in water scarcity in the region. In addition, water resources are polluted by natural and anthropogenic factors. Although Golbasi has been designated as a Special Environmental Protection Area (SEPA), it is not well protected due to the increasing pressures resulting from urbanization and agricultural activities. These activities adversely affect the quality of surface and groundwater resources in the district. Güngör (2010) reports that the main reason of groundwater pollution in the areas near Eymir and Mogan Lakes is the presence of Hançili geological formation, which results in natural pollution. However, pollution due to anthropogenic factors also threatens the water quality in the district.

Water quality is important for every type of cultivation. When used for irrigation, poor water quality may lead to reduced crop yield and economical losses. Therefore, irrigation water quality should be known in order to maintain long-term productivity. The effects of irrigation water on crop production and soil quality are described by salinity hazard, sodium hazard, pH, alkalinity and specific ions (CSU 2015). However, water salinity, as measured by electrical conductivity (EC) is the most influential water quality guideline on crop productivity. In irrigated agriculture, if salt accumulates in the crop root zone to a certain concentration, a salinity problem occurs, causing yield reduction. The salt originates either from the saline, high water table or the irrigation water (FAO 1994). The usual range of EC for irrigation water is given as 0-3 dS m^{-1} by FAO (1994). This range is divided arbitrarily into three degrees of severity: none, slight to moderate, and severe based on field studies, research trials and observations.

Sodium adsorption ratio (SAR) is used to define sodicity in terms of the relative concentration of sodium compared to the sum of calcium and magnesium ions in water. SAR assesses the potential for infiltration problems due to a sodium imbalance in irrigation water (CSU 2015). The usual range of SAR in irrigation water is given as 0-15 (FAO 1994). SAR values of 1-10 are low and 10-18 are medium. For medium SAR values, amendmends and leaching is required. SAR values of 18-26 are high and they are generally not suitable for continuous use (FAO 1994). Regarding infitration problem, SAR needs to be considered together with EC. This is because the swelling potential of low salinity waters is greater than high salinity waters at the same sodium content. Therefore, a more accurate evaluation of the infiltration/permeability hazard requires using EC together with SAR (CSU 2015).

The residual sodium carbonate (RSC) is important for carbonate-rich and bicarbonate-rich irrigation waters. RSC shows their tendency to precipitate calcium. As RSC increases above zero, sodium hazard to soil structure also increases since water adds more carbonates than divalent cations to the soil. When RSC is positive, calcium is lost from the soil solution. Water resources having RSC greater than 2.5 me L^{-1} cannot be used for irrigation without amendment. However, in general water samples having RSC less than 1.25 me L^{-1} can be used safely for irrigation (FAO 1994). Similarly, water resources containing high salinity (Class C3) and high alkalinity (Class S3) are not suitable for irrigation (USDA 1954).

In Golbasi SEPA, farmers mostly depend on groundwater resources, which are naturally contaminated with boron and salinity. The main reason of salinity is low precipitation and high evaporation in arid and semi-arid regions (Tas & Ozturk 2011). The salt content of irrigation water may adversely affect the yield by reducing the water availability to the crop. In addition, groundwaters in some regions contain high levels of boron as Turkey lands are rich in this element. Although boron is an essential element for plants, it becomes toxic at high concentrations for some plants. Some plants are more sensitive to boron than others. Sensitive plants can tolerate irrigation waters up to 0.3 mg L^{-1} boron, while resistant plants may be able to survive up to 4 mg L^{-1} boron in irrigation water (SKKY 1991; Kabay et al 2007).

Although chloride is essential to plants in very low amounts, it can cause toxicity to sensitive crops at high concentrations. Like sodium, high chloride concentrations cause more problems when applied with sprinkler irrigation. Leaf burn under sprinkler from both sodium and chloride can be reduced by night time irrigation or application on cool, cloudy days (CSU 2015).

In Golbasi SEPA, irrigated agriculture, although limited, is still practiced. Therefore, there is a need to determine the current quality of water resources in the district. For this purpose, the aim of this study is to evaluate the irrigation water quality in Golbasi SEPA. The most widely grown plants in the region, i.e., wheat, barley, alfalfa and corn, were considered for evaluation. Water quality of samples were evaluated in terms of salinity and alkalinity class, effect of salinity on yield, SAR, RSC, boron, chloride and sulfate contents.

2. Material and Methods

2.1. Sampling

In Golbasi SEPA (Figure 1), 11 villages (Ballikpinar, Gaziosmanpasa, Gokcehoyuk, Hacilar, Hacihasan, Karaoglan, Ogulbey, Orencik, Yaglipinar, Yavrucak, Yurtbeyi) were visited during the irrigation season (May-June) in 2012. The area of Gölbaşı SEPA is 274 km^2, which is almost one-third of the area of Golbasi district (738 km^2). It is known that irrigated agriculture is very limited in Golbasi district due to water scarcity. In Golbasi SEPA, the water resources used for irrigation were identified with the help of Golbasi Governorate District Directorate of Food, Agriculture and Livestock. A total of 41 samples were collected from several resources such as wells, lagoons and fountains. In choosing the sampling points, priority was given to the water resources that were already used for irrigation. Among the

samples collected, 10 of them were used only for irrigation, 24 of them were used only for livestock breeding, 3 of them were used for both purposes and 4 of them were not used for any purpose. Samples were collected in 1 L polyethylene bottles and immediately sent to the laboratory for analysis.

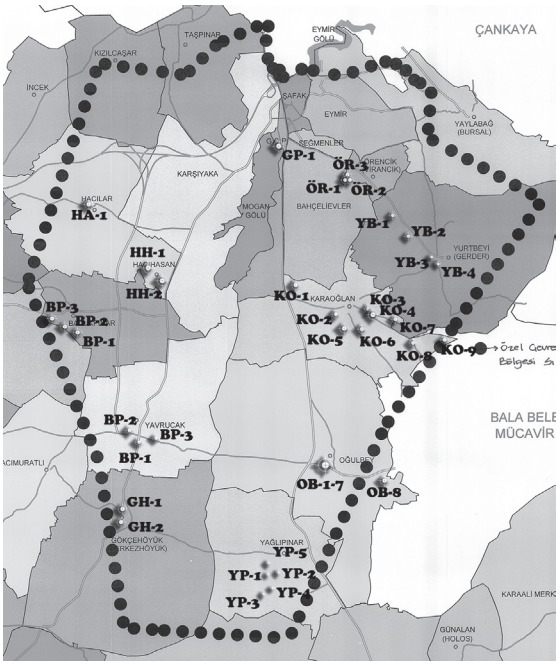

Figure 1- Map of Golbasi SEPA

Şekil 1- Gölbaşı ÖÇKB haritası

Before selecting the sampling points, the chemical analysis results of another study were examined; the study covered 65 samples collected from water resources belonging to private and corporate entities (DSİ 2007). However, after that time, it was found that some of these water resources could not be used or dried out. Therefore, it was possible to collect samples from 41 water resources in this study. Most of the samples belonged to families who deal with irrigated agriculture and livestock breeding. In evaluation of the water quality, the method of irrigation was assumed as sprinkler irrigation.

2.2. Water quality analyses

Water samples were analyzed for electrical conductivity (EC), sodium, calcium, magnesium, carbonate, bicarbonate, boron, chloride and sulfate (Table 1) (Richards 1954; Eltan 1998). Analyses were carried out at the Irrigation Water Quality Analysis Laboratory of Soil Fertilizer and Water Resources Central Research Institute (Ministry of Food Agriculture and Livestock).

Electrical conductivity was measured directly with a Jenway model electrical conductivity meter with temperature correction according to the method TS 9748 EN 27888. Sodium was measured by a flame photometer, where the color of the flame was measured at a wavelength of 589 nm according to the method TS 4530/T1. Calcium and magnesium were measured by titration with EDTA according to the

Table 1- Water quality parameters measured

Çizelge 1- Ölçülen su kalitesi parametreleri

Parameter	*Unit*	*Method*
Electrical conductivity (EC)	µS cm^{-1}	TS 9748 EN 27888
Sodium	me L^{-1}	TS 4530/T1
Calcium	me L^{-1}	TS 8196
Magnesium	me L^{-1}	TS 4474 ISO 6059
Carbonate	me L^{-1}	TS 8489
Bicarbonate	me L^{-1}	TS 8489
Boron	mg L^{-1}	TS 3661
Chloride	me L^{-1}	TS 4164 ISO 9227
Sulfate	me L^{-1}	Barium chloride method

methods TS 8196 and TS 4474 ISO 6059. Carbonate and bicarbonate were measured by titration with sulfuric acid according to the method TS 8489. Boron was measured by the Karmin method using a spectrophotometer according to the method TS 3661. Chloride was measured by Mohr method via titration with silver nitrate according to the method TS 4164 ISO 9227. Sulfate was measured according to barium chloride turbidimetric method.

Sodium adsorption ratio (SAR) was calculated from sodium, calcium and magnesium data. USA Salinity Lab class was determined for each sample by using SAR and electrical conductivity (EC) data. Residual sodium carbonate (RSC) was calculated using carbonate, bicarbonate, calcium and magnesium data.

The quality of water samples were evaluated based on the comparison with guidelines given in Table 2. The values in Table 2 are applicable under normal field conditions prevailing in most irrigated areas in the arid and semi-arid regions of the world (FAO 1994).

In terms of specific ion toxicity, sodium, chloride and boron limits are considered (Table 2) depending on the type of irrigation method. The usual range of use for boron is reported as 0-2 mg L^{-1} and it is 0-30 me L^{-1} for chloride, 0-20 me L^{-1} for sulfate and 6.5-8.4 for pH (FAO 1994).

3. Results and Discussion

The raw data are given in Table 3. As seen, pH of samples changed from 7.0 to 8.7, which is within the normal range of 6.0-8.5, except one sample, that is HA-1 in Hacilar village. This result agrees with previous findings in the district; Maral (2010)

Table 2- Irrigation water quality guidelines (FAO 1985)

Çizelge 2- Sulama suyu kalitesi kılavuz değerleri (FAO 1985)

Potential irrigation problem		*Unit*	*Degree of restriction on use*		
			None	*Slight to moderate*	*Severe*
Salinity (affects crop water availability)					
EC_W		dS m^{-1}	< 0.7	0.7-3.0	> 3.0
Infiltration (affects infiltration rate of water into the soil. Evaluate using ECw and SAR together)					
SAR	0-3	EC_W	> 0.7	0.7-0.2	< 0.2
	3-6		> 1.2	1.2-0.3	< 0.3
	6-12		> 1.9	1.9-0.5	< 0.5
	12-20		> 2.9	2.9-1.3	< 1.3
	20-40		> 5.0	5.0-2.9	< 2.9
Specific ion toxicity (affects sensitive crops)					
Na	Surface	SAR	< 3	3-9	> 9
	Sprinkler	me L^{-1}	< 3	> 3	
Cl	Surface	me L^{-1}	< 4	4-10	> 10
	Sprinkler	me L^{-1}	< 3	> 3	
B		mg L^{-1}	< 0.7	0.7-3.0	> 3.0
Miscellaneous effects (affects susceptible crops)					
Bicarbonate (HCO_3^-)	Overhead sprinkling only	me L^{-1}	< 1.5	1.5-8.5	> 8.5
pH				Normal range 6.5-8.4	

have found that pH of two samples collected in Golbasi are 7.7 and 7.8. Similarly, DSİ (2007) have found that pH of 34 samples collected from wells in Golbasi SEPA villages are 6.6-8.0, with very few samples having pH slightly higher than 8.0.

Electrical conductivity of samples varied between 0.4 dS m^{-1} and 4.0 dS m^{-1} (Table 3). These values are similar to those found by Maral (2010); EC of two samples collected in Golbasi were found as 1.3 dS m^{-1} and 1.9 dS $m^{-1,}$ respectively. Similarly, DSİ (2007) have found that EC of 34 samples changed from 0.3 dS m^{-1} to 4.5 dS m^{-1} in Golbasi SEPA.

US salinity and alkalinity classes of samples collected in Golbasi SEPA were determined. A total of 21 samples (51%) were C2-S1, 14 samples (34%) were C3-S1, and the remaining 6 samples (15%) were C4-S1, C4-S2 and C4-S4 (Table 3). So, only two samples were C4-S4, which are HA-1 and YC-3, respectively. HA-1 (drilling well with 200 m depth) is currently used for landscape irrigation in a school garden in Hacilar village and YC-3 (drilling well with 96 m depth) belongs to a private property in Yavrucak, which can not be not used at the moment. These data agree well with literature findings; Maral (2010) found the salinity class of two samples in Golbasi as C3. Similarly, DSI (2007) found that 16 samples (47%) were C2-S1, 11 samples (32%) were C3-S1, and the remaining 7 samples (21) were C1-S1, C3-S2 and C4-S4. Thefore, both the results of this study and literature findings clearly show that most water resources in Golbasi SEPA have moderate to high salinity and low alkalinity.

The Na^{+} concentration of samples changed from 0.1 me L^{-1} to 26.9 me L^{-1}. The usual range for Na^{+} is 0-40 me L^{-1} (FAO 1994). Therefore, all the samples contain acceptable Na^{+} concentrations. The values of Na^{+} determined by DSİ (2007) are also within the acceptable range. The Ca^{+2} and Mg^{+2} concentrations of 41 samples changed from 0.1 me L^{-1} to 7.1 me L^{-1} and from 0.1 me L^{-1} to 28.9 me L^{-1}, respectively. According to FAO (1994), the usual ranges for Ca^{+2} and Mg^{+2} in irrigation water are 0-20 me L^{-1} and 0-5 me L^{-1}, respectively. Therefore, it can be said that Ca^{+2} content of the samples are acceptable, however Mg^{+2} content of 14 samples (34%) are much higher than the acceptable range (Table 3). In Golbasi district, the origin of Mg^{+2} is the ophiolitic rocks. The surface and shallow waters become rich in Mg^{+2} and bicarbonate while permeating through the ophiolitic rocks and reach the aquifer formations. Therefore, in groundwaters Mg^{+2} content is often dominant as compared to the Ca^{+2} contents.

In magnesium dominated waters, i.e., Ca/Mg is less than 1, the potential effect of sodium may be slightly increased. This means a given SAR value will show slightly more damage if the Ca/Mg ratio is less than 1. The lower the ratio, the more damaging is the SAR (Maral 2010). When determining the suitability of a water for irrigation, there are insufficient data to make the Ca/Mg ratio an evaluation factor. However, if an irrigation water is used that has a Ca/Mg ratio less than 1, a further evaluation is needed. Such waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment (FAO 1994). In this study, Ca/Mg ratio of 23 samples (56%) is less than 1. These are BP-1, BP-2, GH-1, OB-1, OB-2, OB-3, OB-4, OB-5, OB-6, OB-7, OB-8, ÖR-1, ÖR-2, ÖR-3, YP-1, YP-2, YP-3, YP-5, YC-1, YC-2, YC-3, YB-2 and YB-4 (Table 3). According to the comments given in Table 4, further evaluation will be required regarding plant nutrition and addition of calcium as fertilizer or soil amendment in case of using these water resources for irrigation.

In most water samples, there is no carbonate. The carbonate content of only four samples are greater than zero; HA-1, KO-9, YP-3 and YC-3. They are between 0.6-5.2 me L^{-1}, which are higher than the FAO usual range of 0-0.1 me L^{-1}. On the other hand, bicarbonate content of samples is between 3.5-14.2 me L^{-1}, where FAO usual range is given as 0-10 me L^{-1} (1994). Therefore, only four samples have bicarbonate levels higher than FAO usual range; these are GP-1, HA-1, OB-8 and YC-4 (Table 3).

Table 3- Water quality data

Çizelge 3- Su kalitesi verileri

Village/Sample/Source		*pH*	*EC* ($dS\ m^{-1}$)	Na^{+1} ($me\ L^{-1}$)	Ca^{+2} ($me\ L^{-1}$)	Mg^{+2} ($me\ L^{-1}$)	*Ca/Mg*	CO_3^{-2} ($me\ L^{-1}$)	HCO_3^{-} ($me\ L^{-1}$)	*B* ($mg\ L^{-1}$)	Cl^{-1} ($me\ L^{-1}$)	SO_4^{-2} ($me\ L^{-1}$)	*SAR*	*RSC* ($me\ L^{-1}$)	*Salinity Class*
Ballikpinar															
BP-1	Fountain	7.75	0.53	0.43	2.03	2.93	0.7	0.00	4.35	0.9	0.33	0.76	0.27	0.00	C2-S1
BP-2	Dug well (12 m)	7.09	3.85	20.30	5.32	12.82	0.4	0.00	8.87	1.9	13.11	16.65	6.71	0.00	C4-S2
BP-3	Drilling well (80 m)	7.40	0.71	1.51	3.73	1.81	2.1	0.00	5.37	0.0	0.85	0.92	0.91	0.00	C2-S1
Gaziosmanpasa															
GP-1	Dug well (7 m)	7.42	1.63	4.40	7.13	5.80	1.2	0.00	10.34	0.7	5.69	1.45	1.73	0.00	C3-S1
Gokcehoyuk															
GH-1	Fountain 1	7.06	0.76	0.88	2.48	4.00	0.6	0.00	6.35	0.4	1.00	0.12	0.49	0.00	C3-S1
GH-2	Fountain 2	7.25	0.71	0.77	3.60	2.94	1.2	0.00	5.54	0.3	0.86	0.97	0.42	0.00	C2-S1
Hacilar															
HA-1	Drilling well (200 m)	8.72	2.36	23.90	0.18	0.13	1.4	4.46	12.21	6.8	6.34	1.23	61.07	16.36	C4-S4
Hacihasan															
HH-1	Dug well (10 m)	7.31	0.99	2.03	4.35	3.86	1.1	0.00	6.00	0.3	1.19	3.11	1.00	0.00	C3-S1
HH-2	Drilling well (80 m)	7.31	1.15	4.55	3.43	3.43	1.0	0.00	6.16	0.6	3.71	1.58	2.45	0.00	C3-S1
Karaoglan															
KO-1	Drilling well (110 m)	8.12	0.78	5.00	1.95	0.94	2.1	0.00	6.13	2.0	1.63	0.17	4.15	3.23	C3-S1
KO-2	Fountain	7.51	0.48	0.51	3.02	1.81	1.7	0.00	4.79	0.4	0.42	0.18	0.33	0.00	C2-S1
KO-3	Drilling well (130 m)	7.50	0.62	1.32	3.64	1.51	2.4	0.00	4.92	0.2	0.61	0.99	0.82	0.00	C2-S1
KO-4	Drilling well (125 m)	7.76	0.48	1.35	3.02	0.72	4.2	0.00	4.41	0.1	0.56	0.19	0.99	0.65	C2-S1
KO-5	Fountain	7.39	0.71	0.86	4.49	2.68	1.7	0.00	6.70	0.1	0.69	0.72	0.45	0.00	C2-S1
KO-6	Drilling well (110 m)	7.54	0.60	1.02	3.78	1.64	2.3	0.00	5.33	0.2	0.71	0.49	0.62	0.00	C2-S1
KO-7	Drilling well	7.93	0.64	3.45	1.89	1.17	1.6	0.00	5.90	0.9	0.62	0.09	2.78	2.82	C2-S1
KO-8	Drilling well	7.41	0.52	0.58	3.52	1.37	2.6	0.00	5.06	0.2	0.44	0.05	0.37	0.16	C2-S1
KO-9	Lagoon 2	8.39	0.44	0.33	3.24	1.26	2.6	0.63	3.52	0.0	0.30	0.43	0.22	0.00	C2-S1

Table 3- (Continued) Water quality data

Çizelge 3- (Devam) Su kalitesi verileri

Ogulbey														
OB-1	Drilling well (125 m)	7.90	1.27	2.49	1.48	9.12	0.2	0.00	7.56	0.8	2.72	3.00	1.08	0.00	C3-S1
OB-2	Drilling well (45 m)	7.90	3.20	2.60	3.66	28.87	0.1	0.00	7.15	0.0	10.74	17.70	0.64	0.00	C4-S1
OB-3	Drilling well (170 m)	7.89	0.72	0.74	0.59	6.02	0.1	0.00	4.64	0.0	1.22	1.60	0.40	0.00	C2-S1
OB-4	Old network	7.91	0.47	0.91	0.84	3.66	0.2	0.00	4.95	0.0	0.45	0.10	0.60	0.41	C2-S1
OB-5	Drilling well (110 m)	7.89	1.22	1.78	1.89	9.79	0.2	0.00	7.39	0.1	2.32	3.93	0.73	0.00	C3-S1
OB-6	Drilling well (120 m)	7.39	3.18	8.90	6.89	15.70	0.4	0.00	5.15	0.1	10.20	16.49	2.64	0.00	C4-S1
OB-7	Fountain	7.73	1.12	1.35	0.77	9.31	0.1	0.00	4.80	0.0	2.77	4.10	0.60	0.00	C3-S1
OB-8	Drilling well (75 m)	7.77	1.45	2.45	4.05	10.32	0.4	0.00	12.74	0.0	1.57	2.73	0.91	0.00	C3-S1
Orencik														
ÖR-1	Old network 1	7.58	0.64	0.45	2.73	4.05	0.7	0.00	5.99	0.0	0.66	0.64	0.24	0.00	C2-S1
ÖR-2	Old network 2	7.79	0.64	0.91	2.87	3.77	0.8	0.00	5.60	0.4	0.46	1.04	0.52	0.00	C2-S1
ÖR-3	Dug well (5 m)	7.07	1.32	2.55	4.51	5.51	0.8	0.00	8.64	0.2	1.85	3.32	1.14	0.00	C3-S1
Yaglipinar														
YP-1	Drilling well (72 m)	7.65	0.79	1.78	2.23	4.77	0.5	0.00	6.21	0.3	1.00	1.66	0.95	0.00	C3-S1
YP-2	Old network	7.91	1.45	5.10	2.48	8.54	0.3	0.00	9.49	0.5	2.37	4.42	2.16	0.00	C3-S1
YP-3	Creek	8.28	2.79	17.40	3.09	10.17	0.3	2.46	7.29	0.4	7.01	14.23	6.73	0.00	C4-S2
YP-4	Fountain 1	7.52	4.64	1.13	1.94	1.49	1.3	0.00	4.39	0.1	0.35	0.00	0.86	0.93	C2-S1
YP-5	Fountain 2	7.43	1.09	4.00	1.86	6.45	0.3	0.00	6.75	0.4	0.86	4.88	1.96	0.00	C3-S1
Yavrucak														
YC-1	Dug well (12 m)	7.18	2.05	8.60	3.53	8.12	0.4	0.00	6.42	1.1	8.65	5.37	3.55	0.00	C3-S1
YC-2	Old network	7.56	0.58	0.69	1.43	3.61	0.4	0.00	4.95	0.3	0.51	0.33	0.43	0.00	C2-S1
YC-3	Drilling well (96 m)	8.43	2.64	26.90	0.13	0.24	0.5	5.16	14.21	9.7	6.81	1.15	62.48	19.0	C4-S4
Yurtbeyi														
YB-1	Drilling well (50 m)	7.09	0.82	1.13	4.30	3.39	1.3	0.00	7.87	0.4	0.89	0.21	0.57	0.13	C2-S1
YB-2	Fountain 1	7.91	0.65	1.02	2.71	3.43	0.8	0.00	6.15	0.4	0.45	0.66	0.58	0.00	C2-S1
YB-3	Old network	7.41	0.45	0.14	3.84	0.76	5.0	0.00	4.33	0.4	0.26	0.17	0.09	0.00	C2-S1
YB-4	Fountain 2	7.67	0.40	0.51	1.57	2.07	0.8	0.00	3.81	0.0	0.40	0.04	0.38	0.14	C2-S1

On the other hand, bicarbonate contents of BP-2, ÖR-3 and YP-2 are very close to the upper limit of 10 me L^{-1}. Similarly, Maral (2010) have found that bicarbonate content of two samples collected in Golbasi were 6-13 me L^{-1}. In addition, DSI (2007) reports bicarbonate levels within 1.7-12.2. These data show that bicarbonate levels of samples analyzed in this study agree with literature.

According to FAO (1994), when using overhead sprinklers, there is no restiction on use of waters having HCO_3^- less than 1.5 me L^{-1}, but there is slight to moderate restriction on use of waters having HCO_3^- of 1.5-8.5 me L^{-1}, and severe restriction for HCO_3^- greater than 8.5 me L^{-1} (Table 1). Therefore, there is slight to moderate restriction on use of 34 water samples (83%), and severe restriction is required for 7 samples (17%) in case of using overhead sprinklers (Table 3 and Table 4).

RSC is zero for 31 samples and above the upper limit of 2.5 me L^{-1} for four samples, namely HA-1, KO-1, KO-7 and YC-3 (Table 3). These water samples cannot be used for irrigation under normal conditions. On the other hand, RSC is below the lower limit of 1.25 me L^{-1} for six samples, namely KO-4, KO-8, OB-4, YP-4, YB-1 and YB-4 (Table 3). Although RSC method had been used to evaluate potential infiltration problems, SAR is the most commonly used recent method (FAO 1994). SAR is within the usual range of 0-15 for all samples except HA-1 and YC-3, which are as high as 61-63. SAR and EC were evaluated together to assess the possible infiltration problems. The SAR of 35 samples (85%) are between 0-3, SAR of 2 samples are between 3-6, and that of 2 samples are between 6-12 (Table 3). There is no restriction on use of these 39 samples in terms of their EC contents. However, for 2 samples having SAR of 61-63, namely HA-1 and YC-3, there is severe restriction (Table 4).

In terms of specific ion toxicity, sodium, chloride and boron contents of samples were evaluated. The boron concentrations in the groundwaters of Golbasi district is of natural origin. For three samples; HA-1, KO-1 and YC-3, boron concentrations were higher than the usual range of 0-2 mg L^{-1}. In addition, boron concentration of BP-2 (1.9 mg L^{-1}) is very close to the upper limit. Boron contents of samples were evaluated regarding four plants that are commonly cultivated in Golbasi district, namely barley, wheat, alfalfa and corn. According to FAO (1994), barley and wheat are sensitive to boron; the acceptable range is 0.75-1 mg L^{-1}. Corn is moderately tolerant to boron; the acceptable range is 2-4 mg L^{-1}. On the other hand, alfalfa is tolerant to boron; the acceptable range is 4-6 mg L^{-1}. Therefore, BP-2 and YC-1 are not suitable for barley and wheat, whereas HA-1 and YC-3 are not suitable for any type of plant considered (Table 4). On the other hand, the remaining 37 samples (90%) are suitable for all types of plants considered in this study. These data are similar to those reported by Maral (2010) and DSI (2007); 82% of samples collected in Golbasi district had boron concentrations in the acceptable range of 0-2 mg L^{-1}. According to these results, boron does not seem to be a significant problem for irrigation, however it should be noted that most of the samples were collected from existing wells, which were probably drilled to the depth of safe boron limits.

Low amounts of chloride is essential for plants however it can be toxic to sensitive plants at high concentrations. When used with sprinkler irrigation, high chloride levels may cause more problems such as leaf burn (Maral 2010). Night time irrigation can be adopted to reduce this problem. The usual range for chloride is 0-30 me L^{-1} (FAO 1994). Wheat, alfalfa and corn are classified as moderately tolerant, whose leaves may show injury at chloride concentrations higher than 3.9 me L^{-1}. Barley is classified as tolerant, for which the lower limit of chloride for showing injury is 9.9 me L^{-1}. Another consideration with chloride is the type of irrigation; for sprinkler irrigation there is no restriction on use of waters having Cl^- concentration less than 3 me L^{-1} and there is slight to moderate restriction above this value. Based on these criteria, evaluation of results showed that Cl^- levels of all water samples are within the usual range set by FAO (1994). A total of 33 samples (80%) have Cl^- concentrations less than 3.9 me L^{-1}; which is the safe level for

Table 4- Evaluation of irrigation water quality

Çizelge 4- Sulama suyu kalite değerlendirmesi

Group	*Sample*	*Evaluation*
1	BP-3 GH-2 KO-5	These water resources can be used safely for irrigation of plants that are moderately sensitive to salinity (alfalfa, corn). However, leaching is required for those plants that are sensitive to salinity. They can be used for every type of plant and soil condition without any hazard.
2	KO-2, KO-3 KO-4, KO-6 KO-8, KO-9 YP-4, YB-3	These water resources can be used safely for irrigation of plants that are moderately sensitive to salinity (alfalfa, corn). However, leaching is required for those plants that are sensitive to salinity. In terms of Na^+ contents, these water resources can be used for every type of plant and soil condition without any hazard. When SAR and EC are considered together, there is slight to moderate restriction on use of these waters for irrigation.
3	OB-3 YC-2	These water resources can be used safely for irrigation of plants that are moderately sensitive to salinity (alfalfa, corn). However, leaching is required for those plants that are sensitive to salinity. In terms of Na^+ contents, these water resources can be used for every type of plant and soil condition without any hazard. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment.
4	BP-1, OB-4 ÖR-1, ÖR-2 YB-2, YB-4	These water resources can be used safely for irrigation of plants that are moderately sensitive to salinity (alfalfa, corn). However, leaching is required for those plants that are sensitive to salinity. In terms of Na^+ contents, these water resources can be used for every type of plant and soil condition without any hazard. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. When SAR and EC are considered together, there is slight to moderate restriction on use of these waters for irrigation.
5	KO-7	This water resource can be used safely for irrigation of plants that are moderately sensitive to salinity (alfalfa, corn). However, leaching is required for those plants that are sensitive to salinity. In terms of Na^+ contents, this water resource can be used for every type of plant and soil condition without any hazard. When SAR and EC are considered together, there is slight to moderate restriction on the use of this water for irrigation. It is not suitable for use in terms of RSC.
6	HH-1	This water resource contains high level of salt. If it is used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and this water should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity.
7	GH-1 OB-7 YP-1 YP-5	These water resources contain high level of salt. If they are used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and they should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment.
8	YB-1	This water resource contains high level of salt. If it is used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and this water should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. When SAR and EC are considered together, there is severe restriction on use of this water for irrigation.

Table 4- (Continued) Evaluation of irrigation water quality

Çizelge 4- (Devam) Sulama suyu kalite değerlendirmesi

9	GP-1	This water resource contains high level of salt. If it is used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and this water should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. A yield reduction of up to 10% can be observed for alfalfa and corn due to salinity. When sprinkler irrigation is used, there is slight or moderate restriction for the use of this water resource. Plants that are moderately tolerant to chloride (alfalfa, corn, wheat) may show injury. There is severe restriction on use of this water by overhead sprinklers due to its high bicarbonate content.
10	HH-2	This water resource contains high level of salt. If it is used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and this water should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. A yield reduction of up to 10% can be observed for corn due to salinity. When sprinkler irrigation is used, there is slight or moderate restriction for the use of this water resource.
11	KO-1	This water resource contains high level of salt. If it is used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and this water should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. When SAR and EC are considered together, there is slight to moderate restriction on use of these waters for irrigation. It is not suitable for use in terms of RSC.
12	OB-1 OB-5 ÖR-3	These water resources contain high level of salt. If they are used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and these waters should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 10% can be observed for corn due to salinity.
13	OB-8 YP-2	These water resources contain high level of salt. If they are used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and these waters should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 10% can be observed for alfalfa and corn due to salinity. There is severe restriction on use of these waters by overhead sprinklers due to their high bicarbonate content.
14	YC-1	This water resource contains high level of salt. If it is used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as salt resistant barley varieties) and this water should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 10% and 25% can be observed for alfalfa and corn, respectively, due to salinity. It is not suitable for plants (wheat, barley) that are sensitive to boron. Plants that are moderately tolerant to chloride (alfalfa, corn, wheat) may show injury.

Table 4- (Continued) Evaluation of irrigation water quality

Çizelge 4- (Devam) Sulama suyu kalite değerlendirmesi

15	OB-2, OB-6	These water resources are not suitable for irrigation under normal conditions. They can be used only under very special conditions. For example, they can be used for plants that are tolerant to salinity (salt resistant barley varieties) in areas with good drainage and when excess leaching water is used. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 25% and 50% can be observed for alfalfa and corn, respectively, due to salinity. Plants that are moderately tolerant to chloride (alfalfa, corn, wheat) may show injury.
16	YP-3	This water resource is not suitable for irrigation under normal conditions. It can be used only under very special conditions. For example, it can be used for plants that are tolerant to salinity (salt resistant barley varieties) in areas with good drainage and when excess leaching water is used. It can be used for oragnic soils having coarse textured and high permeability. Land reclamation may be required on the long term. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 25% and 50% can be observed for alfalfa and corn, respectively, due to salinity. Plants that are moderately tolerant to chloride (alfalfa, corn, wheat) may show injury.
17	BP-2	This water resource is not suitable for irrigation under normal conditions. It can be used only under very special conditions. For example, it can be used for plants that are tolerant to salinity (salt resistant barley varieties) in areas with good drainage and when excess leaching water is used. It can be used for organic soils having coarse textured and high permeability. Land reclamation may be required on the long term. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 50% can be observed for alfalfa and corn due to salinity. Plants that are moderately tolerant and tolerant to chloride (alfalfa, corn, wheat, barley) may show injury. It is not suitable for plants that are sensitive to boron (wheat and barley). There is severe restriction on use of this water by overhead sprinklers due to its high bicarbonate content.
18	HA-1	This water resource is not suitable for irrigation under normal conditions. It can be used only under very special conditions. For example, it can be used for plants that are tolerant to salinity (barley) in areas with good drainage and when excess leaching water is used. It can be used with the condition that leaching and chemical soil improvement are applied for soils having low salt content and high soluble Ca^{+2} content. Land reclamation may be required on the long term. A yield reduction of up to 25% can be observed for alfalfa and corn due to salinity. Plants that are moderately tolerant to chloride (alfalfa, corn, wheat) may show injury. It is not suitable for plants that are sensitive, moderately tolerant and tolerant to boron (wheat, barley, alfalfa, corn). When SAR and EC are considered together, there is severe restriction on use of this water for irrigation. It is not suitable for use in terms of RSC. There is severe restriction on use of this water by overhead sprinklers due to its high bicarbonate content.
19	YC-3	This water resource is not suitable for irrigation under normal conditions. It can be used only under very special conditions. For example, it can be used for plants that are tolerant to salinity (barley) in areas with good drainage and when excess leaching water is used. It can be used with the condition that leaching and chemical soil improvement are applied for soils having low salt content and high soluble Ca^{+2} content. Land reclamation may be required on the long term. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 25% and 50% can be observed for alfalfa and corn, respectively, due to salinity. Plants that are moderately tolerant to chloride (alfalfa, corn, wheat) may show injury. It is not suitable for plants that are sensitive, moderately tolerant and tolerant to boron (wheat, barley, alfalfa, corn). When SAR and EC are considered together, there is moderate restriction on use of this water for irrigation. It is not suitable for use in terms of RSC. There is severe restriction on use of this water by overhead sprinklers due to its high bicarbonate content.

alfalfa, corn and wheat. However, there is slight to moderate restriction on use of GP-1, HA-1, YP-3, YC-1 and YC-3 regarding irrigation of alfalfa, corn and wheat with sprinklers. The use of HH-2 have no restriction for plant types but there is restriction for sprinkler irrigation. On the other hand, there is slight to moderate restriction on use of BP-2, OB-2 and OB-6 for all type of plants considered in addition to sprinkler irrigation (Table 3 and Table 4). Similarly, Maral (2010) and DSİ (2007) have found that chloride content of water resources in Golbasi district are all in the usual range of 0-30 me L^{-1}.

The sulfate ion in irrigation water has fertility benefits. It is also a major contributor to salinity in many irrigation waters. The sulfate concentrations were within the usual range of 0-20 me L^{-1} for all samples analyzed (Table 3). The literature findings were also similar (DSİ 2007; Maral 2010). Therefore, it can be stated that Golbasi SEPA waters have enough sulfate levels.

According to the evaluation of all results, 41 samples were classifed into 19 groups based on their common characteristics, in the order of increasing problematic issues (Table 4). It was found that 20 samples (49%) in Groups 1-5 can be used safely for irrigation of alfalfa and corn, which are moderately sensitive to salinity. Three samples (BP-3, GH-2 and KO-5) in Group 1 can be used without any restriction. Eight samples in Group 2 (KO-2, KO-3, KO-4, KO-6, KO-8, KO-9, YP-4 and YB-3) can also be used safely for irrigation of these plants. However, there is slight to moderate restriction on use of these waters in terms of SAR and EC contents. Two samples (OB-2 and YC-2) in Group 3 have the same evaluation as Group 2, however further evaluation is needed regarding Ca/Mg ratio, which is less than 1. Detailed explanation about the possible further evaluations is given in Table 4. In Group 4, there are 6 samples (BP-1, OB-4, ÖR-1, ÖR-2, YB-2, YB-4) having basically similar characteristics with Group 3, but in addition, there is slight to moderate restriction for these waters in terms of SAR and EC. In Group 5, there is one sample (KO-7), which can be used as the samples in Groups 1-4 but KO-7 is not suitable for use in terms of RSC.

In Groups 6-14, 15 water samples (GP-1, GH-1, HH-1, HH-2, KO-1, OB-1, OB-5, OB-7, OB-8, ÖR-3, YP-1, YP-2, YP-5, YB-1 and YC-1), corresponding to 36% of all samples have high level of salt. If these waters are used continously, leaching and special soil tillage is required to avoid salinity problems. Yield reduction up to 10-25% may be observed for alfalfa and corn due to salinity. Specific reduction percentages for each group of samples are given in Table 4.

In Groups 15-19, six waters (BP-2, HA-1, OB-2, OB-6, YP-3, YC-3), which correspond to 15% of all samples, are not suitable for irrigation under normal conditions. They can be used under very special conditions such as selection of plants that are tolerant to salinity (such as salt resistant barley varities) in areas with good drainage, and application of excess leaching. Land reclamation may be required on the long-terms if these waters are used. Yield reduction up to 25-50% may be observed due to salinity. Chloride may be harmful for the leaves of moderately tolerant plants such as alfalfa, corn and wheat. The water sample BP-2 in Group 17 is not suitable for plants that are sensitive to boron (wheat and barley). Water samples HA-1 and YC-3 in Groups 18-19 are not suitable even for plants that are tolerant to boron (such as alfalfa).

4. Conclusions

This study figures out the existing situation in terms of water quality used for agriculture in Golbasi SEPA. The analysis of samples taken from 41 points revealed that almost half of the samples are suitable for irrigation, almost one-third of samples contain high levels of salt and need proper management to avoid salinity problems. Less than one-fifth of samples are not suitable for irrigation under normal conditions. Further research is required to determine the specific land reclamation requirements.

Golbasi Special Environmental Area is suffering from water scarcity and water quality problems. In recent years, there has been an increasing demand

for groundwater resources for irrigation. Indeed, drilling new wells is not allowed anymore in an attempt to protect the groundwater resources in the region. Salinity problems may adversely affect the agricultural activities in terms of finding suitable water resources for irrigation. It is suggested to switch to alternative water resources such as wastewater reuse and rainwater harvesting in order to minimize water extraction from groundwater resources.

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Density and Biomass of Fish Populations in Kirmir Stream of Sakarya River, Turkey

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ABSTRACT

In this study, Zippin's triple-catch removal method was used to estimate density and biomass of fish species in Kirmir Stream of Sakarya River, Central Anatolia Turkey. A total area of 1.5256 ha was sampled and 4167 fishes were caught using electrofishing between February 2007 and November 2007. A total of 9 fish species representing 2 families Cyprinidae and Cobitidae were recorded. Fish species identified are as follows: Chub (*Leuciscus cephalus* Linnaeus, 1758), barbel (*Barbus plebelejus escherichi* Heckel, 1843), *Capoeta tinca* Heckel, 1843, spirlin (*Alburnoides bipunctatus* Bloch, 1782), *Capoeta capoeta sieboldi* Steindachner, 1864, tirgis-nase (*Chondrostoma regium* Heckel, 1843), bleak (*Alburnus orontis* Sauvage, 1882), spined-loach (*Cobitis taenia* Linnaeus, 1758) and angora-loach (*Noemacheilus angorae* Steindachner, 1897). *A. orontis* was the most dominant species, constituting 1199 fish and 28.77% of the total fishes, followed by *C. tinca* (1173 fish and 28.15%), *B. p. escherichi* (584 fish and 14.01%), *L. cephalus* (454 fish and 10.90%), *A. bipunctatus* (322 fish and 7.73%), *C. regium* (245 fish and 5.88 %), *N. angorae* (107 fish and 2.57%) *C. c. sieboldi* (65 fish and 1.56%) and *C. taenia* (18 fish and 0.43%). The density and biomass values were estimated as 11456 fish ha^{-1} and 346.78 kg ha^{-1} in February 2007, 8982 fish ha^{-1} and 279.82 kg ha^{-1} in May 2007, 6320 fish ha^{-1} and 251.52 kg ha^{-1} in August 2007 and 2887 fish ha^{-1} and 168.87 kg ha^{-1} in November 2007, respectively. The lowest density and biomass values were observed in November 2007.

Keywords: Density; Biomass; Electrofishing; Kirmir stream; Ankara; Turkey

Sakarya Nehri'nin Kirmir Çayı'ndaki Balık Populasyonlarının Yoğunluğu ve Biyoması

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ÖZET

Bu çalışmada, İç Anadolu Bölgesi'ndeki Sakarya Nehri'nin Kirmir Çayı'nda balık türlerinin yoğunluk ve biyomas değerlerini tahmin etmek için üç avlı ayrılmaya dayalı metot kullanılmıştır. 1.5256 ha'lık alanda örnekleme yapılmış ve

Şubat 2007-Kasım 2007 tarihleri arasında 4167 adet balık elektroşok metoduyla avlanmıştır. Elde edilen örneklemelerde 2 familyaya (Cyprinidae ve Cobitidae) ait 9 balık türü (tatlısu kefali (*Leuciscus cephalus* Linnaeus, 1758), bıyıklı balık (*Barbus plebejus escherichi* Heckel, 1843), siraz balığı (*Capoeta tinca* Heckel, 1843), inci balığı (*Alburnoides bipunctatus* Bloch, 1782), saçaklı siraz (*Capoeta capoeta sieboldi* Steindachner, 1864), karaburun (*Chondrostoma regium* Heckel, 1843), anadolu inci balığı (*Alburnus orontis* Sauvage, 1882), taş ısıran balığı (*Cobitis taenia* Linnaeus, 1758) ve çöpcü balığı (*Nemachelius angorae* Steindachner, 1897) avlanmıştır. *A. orontis* toplam populasyon içerisinde 1199 birey ve % 28.77 ile en yoğun türdür ve bu türü sırasıyla *C. tinca* (1173 birey ve % 28.15), *B. p. escherichi* (584 birey ve % 14.01), *L. cephalus* (454 birey ve % 10.90), *A. bipunctatus* (322 birey ve % 7.73), *C. regium* (245 birey ve % 5.88), *N. angorae* (107 birey ve % 2.57) *C. c. sieboldi* (65 birey ve % 1.56) and *C. taenia* (18 birey ve % 0.43) takip etmiştir. Yoğunluk ve biyomas değerleri sırasıyla Şubat 2007'de; 11456 adet ha^{-1} ve 346.78 kg ha^{-1}, Mayıs 2007'de; 8982 adet ha^{-1} ve 279.82 kg ha^{-1}, Ağustos 2007'de; 6320 adet ha^{-1} ve 251.52 kg ha^{-1} ve Kasım 2007'de; 2887 adet ha^{-1} ve 168.87 kg ha^{-1} olarak tahmin edilmiştir. En düşük yoğunluk ve biyomas değerleri Kasım 2007'de gözlenmiştir.

Anahtar Kelimeler: Yoğunluk; Biyomas; Elektrikle avcılık; Kirmir çayı; Ankara; Türkiye

1. Introduction

A fish population is shaped by the geologic, chemical, physical, and biological factors within and surrounding the environment in which it lives. The relative quality of that environment affects the organisms living there, exerting positive or negative pressure on the population (Platts & McHenry 1988). The fluctuation of the fish population is really important for stock assessment and management. In this way, a major decline and rise in the population size or the population biomass can be detected, and appropriate management strategies can be adopted (Chen et al 2004). A relatively simple and inexpensive method of evaluating the health of lentic systems is to monitor the density and biomass of the fish population (Platts & McHenry 1988; Bohlin et al 1989).

Density and biomass estimates of targeted species by electrofishing capture data are most often generated using depletion (or sometimes referred to as removal) (Moran 1951; Zippin 1958; White et al 1982) or the mark-recapture method (Ricker 1975; Zubik & Fraley 1988). Because these methods are labour intensive, they have been recommended only when researchers require detailed knowledge of the target population. Typically, removal methods have been used in stream environments where fish capture is by electrofishing during two to four intensive sampling periods over a short time period (often within a day) (Kelso 1989).

It was clear that estimates of population density and biomass would be required if the interrelationships of the various species were to be evaluated (Williams 1965). Many authors in various regions of the world have been studied the density and biomass of fish or fishes per surface unit in rivers (Pires et al 1999; Penaz et al 2003; Dikov & Zivkov 2004; Namin & Spurny 2004; Vlach et al 2005; Kolev 2010). The principal aim of these investigations was to obtain population density and biomass estimates of most, if not all, of the fish species occurring at each site, and it is perhaps pertinent to consider the accuracy of the results obtained.

Little work has been done in Central Anatolia, Turkey on river populations parameters (i.e. density and biomass) of fish (Ölmez 1992; Korkmaz & Atay 1997; Korkmaz et al 1998; Korkmaz 2005). With this respect it is needed to establish the status of fish density and biomass in a number of localities and stream profiles in Central Anatolia, Turkey. As there is no data about density and biomass of fish in Kirmir Stream, the information obtained from Zippin's triple-catch removal method by electrofishing in the stream sections could be important. The objectives of this study were to determine density and biomass estimates, and habitat structure for fish populations in Kirmir Stream and to assess correlations between density and biomass.

2. Material and Methods

2.1. Study area

Kirmir Stream is a branch of the Sakarya River geographically located in the north-western part of the Central Anatolian Region of Turkey at 40-41° N and 32-33° E (Figure 1). The depth of the stream is generally shallow (30-50 cm), but reaches 2-3 m at some points. The bottom structure varies between sandy, stony and muddy (Kucuk & Alpaz 2008).

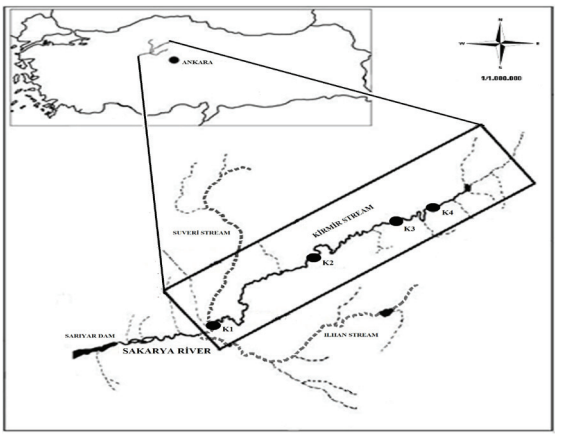

Figure 1- Study area and sampling sites

Şekil 1- Araştırma alanı ve örnekleme yerleri

The bottom of site 1 was covered with small rocky (5-10 cm), and the banks were occasionally wooded; the bottom of site 2 was covered with rocky (20-30 cm), sandy and standing water, and the banks were un-wooded and rocky; the bottom of site 3 was covered with rocky (30-70 cm), and the banks were occasionally wooded and standing water; the bottom of site 4 was covered rocky (30-50 cm) and big rocky, and the its around was reeds.

This study was carried out in Kirmir Stream of Sakarya River. Four sampling sites were assigned on Kirmir Stream (130 km long) for taking fish samples, water samples and measuring water characteristics. These sampling sites in Kirmir Stream were selected according to habitat structure, depth, water velocity, size and structure of substratum (Hankin 1984). At each sampling site, we took the measurement per 10-20 m to determine the mean stream width (m) over a 200 m standard reach length. Some physical and chemical characteristics of sampling sites were shown in Table 1. Width and depth of the stream varies 3.16-6.12 m and 0.12-0.89 m, respectively.

2.2. Sampling methods

Fish populations in Kirmir Stream were sampled approximately every 3 months between February 2007 and November 2007 using electrofishing (500-

Table 1- Some physical and chemical charecteristics of sampling sites

Çizelge 1- Örnekleme yerlerinin bazı fiziksel ve kimyasal özellikleri

Sampling times and sites		*pH*	*Water Temperature (°C)*	*Dissolved Oxygen (mg L^{-1})*	*Water velocity (m sec^{-1})*	*Conductivity (µmhos cm^{-1})*	*Depth (m)*	*Width (m)*	*Area (ha)*
February 2007	1	7.84±0.01	10.5±0.00	9.6±0.24	0.24±0.02	1540±1.70	0.63±0.08	5.16±0.05	0.1032
	2	7.81±0.02	10.5±0.00	10.2±0.08	0.45±0.01	1580±1.82	0.17±0.04	5.80±0.06	0.1160
	3	8.11±0.02	8.5±0.03	9.8±0.13	0.59±0.02	1696±1.73	0.51±0.04	3.33±0.06	0.0666
	4	7.89±0.01	9.0±0.00	11.5±0.17	0.42±0.02	1674±1.29	0.41±0.07	5.66±0.05	0.1132
May 2007	1	7.50±0.02	21.5±0.00	6.0±0.17	0.25±0.01	1486±1.71	0.53±0.05	5.08±0.05	0.1016
	2	7.51±0.02	23.5±0.03	8.8±0.17	0.45±0.02	1510±1.71	0.12±0.02	5.70±0.08	0.1140
	3	7.69±0.03	24.5±0.00	8.7±0.13	0.71±0.03	1688±1.29	0.38±0.05	3.16±0.04	0.0632
	4	8.07±0.02	25.0±0.00	7.7±0.15	0.50±0.01	1642±1.83	0.33±0.04	5.60±0.06	0.1120
August 2007	1	8.12±0.02	24.0±0.00	8.6±0.24	0.28±0.02	1897±1.29	0.29±0.05	3.27±0.07	0.0654
	2	8.17±0.02	22.0±0.03	7.3±0.01	0.40±0.01	1584±1.29	0.46±0.08	4.25±0.07	0.0850
	3	8.16±0.03	23.0±0.00	8.9±0.13	0.67±0.03	1966±1.83	0.37±0.06	3.28±0.07	0.0656
	4	8.24±0.01	24.5±0.03	7.9±0.13	0.43±0.02	1786±2.16	0.30±0.06	5.45±0.06	0.1090
November 2007	1	7.62±0.02	7.5±0.00	9.8±0.01	0.27±0.02	1300±3.59	0.82±0.08	6.12±0.04	0.1224
	2	7.76±0.02	5.0±0.00	10.1±0.18	0.50±0.02	1243±2.22	0.50±0.06	5.06±0.05	0.1012
	3	7.56±0.02	6.5±0.00	10.5±0.18	0.67±0.03	1278±1.29	0.89±0.07	4.05±0.08	0.0810
	4	7.83±0.01	7.2±0.03	9.7±0.18	0.53±0.02	1200±1.83	0.21±0.06	5.31±0.04	0.1062
Total sampling area (ha)									1.5256

700 V, 2 A, D.C). The electrofishing team consisted of three experienced crew members with one using the anode and the other two using dip nets to capture the fish. Each sampling site under study was closed at both ends with 8-10 mm mesh size nets (Lacroix 1989). Each fishing pass (with 1.5 hour) was carried out in an upstream direction. The time interval between passes was at least 30-60 minutes. Each sampling site was sampled three times with effort standardized among sampling. The depth and width of the sampling sites were measured per 10-20 m (Neves & Pardue 1983). Fish caught in each sample were anesthetized with MS 222 and mortality was not observed. Then, fishes were identified as to species and weighted (±0.01 g). Fish caught were returned to the water as alive in accordance with permission. In each sampling, the numbers and biomass of fish were determined. Then, in order to determine fish density (population size) according to species, it was used Zippin's triple-catch removal method (Zippin 1956; Seber & Whale 1970). Zippin's triple-catch removal method is described as in Equation 1.

$$\hat{N} = \frac{T}{(1 - \hat{q}^k)} = \frac{C_1 + C_2 + C_3}{(1 - \hat{q}^k)} \quad (1)$$

Where; $\hat{p}$ is the catch efficiency $(\hat{p}=1-\hat{q})$; T is total catch $(C_1+C_2+C_3)$; k is the numbers of removals; C_1 , C_2 ,C_3 are the catch in each consecutive removal; $\hat{N}$ is population density. The sampling variance and standard error of $\hat{N}$ were estimated from the Equation 2 and 3, respectively.

$$S^2_{\hat{N}} = \frac{\hat{N}.(1 - \hat{q}^k)\,\hat{q}^k}{(1 - \hat{q}^k)^2.(p.k)^2.\hat{q}^{k-1}} \text{ and } S_{\hat{N}} = \sqrt{S^2_{\hat{N}}} \quad (2)$$

An approximate 95 per cent confidence interval for $\hat{N}$ is $\hat{N} \pm t.S_{\hat{N}}$. An estimator of $\hat{q}$ is $\hat{q} = (T - C_1) / (T - C_k)$ (k=3). The validity of the Zippin method was tested by calculating R and T_1, $R = (C_2 + 2.C_3) / (C_1+C_2+C_3)$, (If $R = 0$ or $R\rangle 1$ then the Zippin method is not applicable) and the goodness of fit statistic ($T_1 < \chi^2 =$ 3.841 with k-2 degrees of freedom) for a multinomial distribution where the population size is not known (Seber 1973). The computation used for T_1 was:

$$T_1 = \sum_{i=1}^{k} [\,(C_i - E_i)^2 / E_i\,] \text{ and } (E_1 = \hat{N}.\hat{p}\,; E_2 = \hat{N}.\hat{p}.\hat{q}\,; E_3 = \hat{N}.\hat{p}.\hat{q}^2) \quad (3)$$

The biomass or standing crop $(\hat{B})$ was estimated by $\hat{B} = B.\,(\hat{N} / N)$. Where; B is the total weight of fish caught and N is the total number of fish caught. Values of density and biomass of fish per unit area where catches were estimated by $\hat{N}/A$ and $\hat{B}/A$, respectively. Where A is area of sampling sites (in ha) (Bohlin et al 1989).

3. Results and Discussion

A total area of 1.5256 ha was sampled and 4167 fishes were caught from the Kirmir Stream between February 2007 and November 2007. A total of 9 fish species representing 2 families Cyprinidae and Cobitidae were recorded. Fish species identified are as follows: Chub (*Leuciscus cephalus*), barbel (*Barbus plebelejus escherichi*), *Capoeta tinca*, spirlin (*Alburnoides bipunctatus*), *Capoeta capoeta sieboldi*, tirgis-nase (*Chondrostoma regium*), bleak (*Alburnus orontis*), spined-loach (*Cobitis taenia*), angora-loach (*Noemacheilus angorae*).

Number of fish species of Kirmir Steam is fewer than the most studies such as Guadina Basin (Portugal, 16 species) (Pires et al 1999), Veleka River (Bulgaria, 16 species) (Dikov & Zıkov 2004), Bečva River (Czech Republic, 23 species) (Namin & Spurny 2004), Úpoř Brook (Czech Republic, 13 species) (Vlach et al 2005); more than Sakarya Basin (Turkey, 4 species) (Ölmez 1992), Sugul Brook (Turkey, 4 species) (Korkmaz & Atay 1997), Hatilla Brook (Turkey, 2 species) (Korkmaz et al 1998) and Kadıncık Brook (Turkey, 2 species) (Korkmaz 2005). In freshwater, comparisons of the difference between the numbers of species are difficult. Because the habitat structure of sampling sites and abiotic-biotic factors may vary. Small streams may be characterized by great changes in environmental conditions along the gradient of stream size and discharge (Vlach et al 2005).

A. orontis was the most dominant species, constituting 1199 fish and 28.77% whilst *C. taenia* was the least species 18 fish and 0.43% (Table 2). Number of fish identified (4167 fish) in Kirmir Stream is fewer than 5548 fish Bečva River by Namin & Spurny (2004); more than 1303 fish Veleka

River by Dikov & Zikov (2004), 1166 fish Sakarya Basin by Ölmez (1992), 2943 fish Sugul Brook by Korkmaz & Atay (1997), 748 fish Hatila Brook by Korkmaz et al (1998) and 79 fish Kadıncık Brook by Korkmaz (2005). These differences can be explained by both species diversity and the higher amount of fish in large rivers where it could be find alternative habitats according to small stream.

Table 2- Population size, density and biomass % of each species in Kirmir Stream

Çizelge 2- Kirmir Çayı'nda türlerin sayısı, yoğunluğu, biyoması ve % değerleri

Species	*N* (fish)	*N%*	$\hat{N}$ (fish ha^{-1})	$\hat{N}$%	$\hat{B}$ (kg ha^{-1})	$\hat{B}$%
L.cephalus	454	10.90	6100	12.94	268.88	9.79
B. p. escherichi	584	14.01	6880	14.59	215.92	7.86
Capoeta tinca	1173	28.15	13036	27.65	656.76	23.91
A. bipunctatus	322	7.73	3856	8.18	59.56	2.17
C. c. sieboldi	65	1.56	856	1.82	82.64	3.01
C. regium	245	5.88	2892	6.14	53.12	1.94
A. orontis	1199	28.77	12304	26.10	1404.28	51.13
C. taenia	18	0.43	161	0.34	1.34	0.05
N. angorae	107	2.57	1056	2.24	3.84	0.14
Total	4167	100.00	47141	100.00	2746.34	100.00

Total fish density in Kirmir Stream varied between 161 fish ha^{-1} and 3036 fish ha^{-1}. *C. tinca* dominated with 27.65% (13036 fish ha^{-1}) of the total density. *A. orontis* was also very abundant (26.10%, 12304 fish ha^{-1}). *B.p.plebejus*, *L.cephalus*, *A.bipunctatus* and *C.regium* accounted for 14.59% (6880 fish ha^{-1}), 12.94 % (6100 fish ha^{-1}), 8.18% (3856 fish ha^{-1}) and 6.14% (2892 fish ha^{-1}), respectively. The density of other species reached the total value of 2073 fish ha^{-1} (<10%). The biomass of the fish assemblage estimated the value of 2746.34 kg ha^{-1}. The dominant species were *A. orontis* (1404.28 kg ha^{-1}) and *C. tinca* (656.76 kg ha^{-1}) which accounted for 51.13% and 23.91% of the total biomass. Other species are as follows: *L. cephalus* created 9.79 % (268.88 kg ha^{-1}), *B. p. plebejus* 7.86% (215.92 kg ha^{-1}), and the remaining species < 5% (2.976.98 kg ha^{-1}) (Table 2). If these results are referred to the components of the ichthyofauna, it can be stated that the highest density of fish and biomass states were estimated from locations in which the *A. orontis* and *C. tinca* were present.

The comparative analyses of fish density and biomass in streams studied by Ölmez (1992), Korkmaz & Atay (1997), Dikov & Zikov (2004), Namin & Spurny (2004), Vlach et al (2005), Korkmaz (2005) have shown that the fish density and biomass in the Kirmir Stream is >5338 fish ha^{-1} and 126.1 kg ha^{-1} for 16 species in Veleka River, 35452.2 fish ha^{-1} and 1728.9 fish ha^{-1} for 23 species in Bečva River, 1166 fish ha^{-1} and 319 kg ha^{-1} for 4 species obtained using mark-recapture in Sakarya Basin, 1009 fish ha^{-1} and 48.47 4.1 kg ha^{-1} for 4 species in Sugul Brook and 32 fish ha^{-1} and 4.1 kg ha^{-1} in Kadıncık Brook. However, values of the fish density and biomass 74074 fish ha^{-1} and 395 kg ha^{-1} for 13 species in Úpoř Brook were higher than our results. These differences can be said to be caused by the fact that selective fishing or catch efficiency. The variable catch efficiency is not only dependent on the characteristics and habits of fish populations but also on factors related to the design and implementation of the sampling and on the physical, chemical and environmental characteristics of the habitat (Bravo et al 1999).

The results of successive electrofishing together with estimates of density and biomass at the four stations and sampling periods are presented in Tables 3-6.

Table 3- Stock density and biomass obtained from sampling sites in the Kirmir River, February 2007. C_1-C_3 are the catch from successive electrofishing; N and B are total numbers and weights, respectively; *, absolute estimate; **, fish number; *, fish weight**

*Çizelge 3- Kirmir Çayı'ndaki örnekleme yerlerinden elde edilen balıkların yoğunluk ve biyomas tahminleri (Şubat 2007). C_1-C_3 ardışık elektrikle avcılıktan elde edilen av; N ve B sırasıyla toplam balık sayısı ve ağırlığı; *, mutlak tahmin; **, balık sayısı; ***, balık ağırlığı*

Sites	*Fish species*	C_1	C_2	C_3	N	B (g)	$\hat{N} \pm t \times S_{\hat{N}}$	$\hat{B}$ (g)	$\hat{p}$	$(1-\hat{q}^3)$	R	T_1	$\hat{N}$ (fish ha^{-1})	$\hat{B}$ (kg ha^{-1})
K1	*L.cephalus*	27** (1365.08)***	11 (615.37)	1 (389.17)	39	2369.62	40±4	2430.38	0.69	0.97	0.33	1.74	388	23.55
	B.p.escherichi	33 (910.25)	11 (327.04)	9 (263.81)	53	1501.10	58±8	1642.71	0.55	0.91	0.55	1.82	562	15.92
	C. tinca	3 (137.73)	2 (92.61)	0 (0)	5	230.34	5±2	230.34	0.61	0.94	0.40	1.02	48	2.23
	A.bipunctatus	7 (57.34)	4 (31.58)	1 (8.14)	12	97.06	13±4	105.15	0.55	0.91	0.50	0.33	126	1.02
	C.c.sieboldi	3 (176.93)	0 (0)	1 (31.17)	4	208.10	4*	208.10	0.67	0.96	0.50	2.64	39	2.02
	C.regium	6 (96.28)	2 (29.17)	1 (17.12)	9	142.57	10±2	158.41	0.63	0.95	0.44	0.08	97	1.53
	A.orontis	42 (515.80)	22 (267.03)	9 (101.65)	73	884.48	82±12	993.53	0.52	0.89	0.55	0.19	795	9.63
	N. angorae	1 (4.7)	0 (0)	0 (0)	1	4.7	1*	4.70	1.00	1.00	0.00	0.00	10	0.05
K2	*L.cephalus*	33 (1295.26)	14 (642.03)	9 (378.13)	56	2315.42	63±10	2604.85	0.51	0.88	0.57	0.43	543	22.46
	B.p.escherichi	15 (469.42)	7 (241.84)	3 (67.56)	25	778.82	28±6	872.28	0.55	0.91	0.52	0.02	241	7.52
	C.tinca	123 (5856.27)	42 (1786.29)	13 (503.46)	178	8146.02	185±8	8466.37	0.66	0.96	0.38	0.10	1595	72.99
	A.bipunctatus	5 (40.96)	3 (25.17)	1 (8.11)	9	74.24	10±4	82.49	0.51	0.88	0.56	0.14	86	0.71
	C.c.sieboldi	3 (246.03)	1 (71.23)	1 (22.30)	5	339.56	6±4	407.47	0.51	0.88	0.60	0.26	52	3.51
	C.regium	8 (134.95)	5 (88.32)	1 (23.17)	14	246.44	16±4	281.65	0.54	0.90	0.50	0.69	138	2.43
	A.orontis	30 (341.59)	11 (134.64)	9 (84.12)	50	560.35	57±10	638.80	0.51	0.88	0.58	1.35	491	5.51
	N. angorae	18 (74.14)	6 (20.17)	3 (12.22)	27	106.53	29±2	114.42	0.63	0.95	0.44	0.19	250	0.99
K3	*L.cephalus*	10 (697.54)	2 (79.19)	1 (26.14)	13	802.87	13±4	802.87	0.73	0.98	0.31	0.29	195	12.06
	B.p.escherichi	17 (482.35)	9 (275.92)	5 (142.03)	31	900.30	37±12	1074.55	0.46	0.84	0.61	0.00	556	16.13
	C.tinca	39 (1654.70)	14 (608.61)	1 (39.88)	54	2303.19	55±2	2345.84	0.73	0.98	0.30	2.22	826	35.22
	A.bipunctatus	14 (104.25)	7 (60.97)	4 (27.92)	25	193.14	29±10	224.04	0.48	0.86	0.60	0.02	435	3.36
	C.c.sieboldi	1 (478.16)	0 (0)	0 (0)	1	478.16	1*	478.16	1.00	1.00	0.00	0.00	15	7.18
	C.regium	12 (203.15)	5 (92.11)	3 (51.89)	20	347.15	22±6	381.87	0.54	0.90	0.55	0.13	330	5.73
	A.orontis	1 (14.56)	1 (10.38)	0 (0)	2	24.94	2*	24.94	0.51	0.88	0.50	0.75	30	0.37
	N. angorae	1 (3.74)	1 (2.11)	0 (0)	2	5.85	2*	5.85	0.51	0.88	0.50	0.75	30	0.09
K4	*L.cephalus*	10 (741.12)	5 (263.27)	2 (114.95)	17	1119.34	19±6	1251.03	0.54	0.90	0.53	0.04	168	11.05
	B.p.escherichi	9 (281.44)	3 (83.49)	2 (52.13)	14	417.06	15±4	446.85	0.59	0.93	0.50	0.29	133	3.95
	C. tinca	81 (3507.71)	33 (1582.03)	12 (534.57)	126	5624.31	134±10	5981.41	0.61	0.94	0.45	0.06	1184	52.84
	A.bipunctatus	12 (90.4)	7 (59.47)	2 (15.1)	21	164.97	23±6	180.68	0.52	0.89	0.52	0.48	203	1.60
	C.c.sieboldi	3 (212.76)	1 (94.60)	0 (0)	4	307.36	4*	307.36	0.73	0.98	0.25	0.27	35	2.72
	C.regium	21 (341.28)	8 (125.44)	3 (44.10)	32	510.82	34±4	542.75	0.63	0.95	0.44	0.01	300	4.79
	A.orontis	106 (1245.87)	35 (364.87)	22 (236.91)	163	1847.65	175±12	1983.67	0.59	0.93	0.48	2.59	1546	17.52
	C. taenia	1 (11.07)	0 (0)	0 (0)	1	11.07	1*	11.07	1.00	1.00	0.00	0.00	9	0.10
Total		695 (21792.83)	272 (8074.95)	119 (3195.75)	1086	33063.53		35284.59					11456	346.78

Table 4- Stock density and biomass obtained from sampling sites in the Kirmir River, May 2007, symbol explanation presented in Table 3

Çizelge 4- Kirmir Çayı'ndaki örnekleme yerlerinden elde edilen balıkların yoğunluk ve biyomas tahminleri (Mayıs2007), simgelerin açıklaması Çizelge 3'de verilmiştir

Sites	*Fish species*	C_1	C_2	C_3	N	B (g)	$\hat{N} \pm t \times S_{\hat{N}}$	$\hat{B}$ (g)	$\hat{p}$	$(1-\hat{q}^3)$	R	T_1	$\hat{N}$ (*fish* ha^{-1})	$\hat{B}$ (*kg ha*$^{-1}$)
K1	*L.cephalus*	12 (701.26)	5 (244.65)	3 (142.03)	20	1087.94	22±6	1196.73	0.54	0.90	0.55	0.13	217	11.78
	B.p.escherichi	18 (513.67)	7 (200.55)	3 (83.91)	28	798.13	30±4	855.14	0.61	0.94	0.46	0.02	295	8.42
	C. tinca	9 (451.23)	2 (85.61)	1 (37.21)	12	574.05	12±2	574.05	0.73	0.98	0.33	0.27	118	5.65
	A.bipunctatus	5 (47.31)	0 (0)	2 (20.46)	7	67.77	7±2	67.77	0.61	0.94	0.57	4.60	69	0.67
	C.regium	4 (104.12)	2 (47.98)	0 (0)	6	152.10	6±2	152.10	0.66	0.96	0.33	0.78	59	1.50
	A.orontis	41 (410.86)	14 (168.45)	9 (112.04)	64	691.35	69±8	745.36	0.59	0.93	0.50	1.12	679	7.34
	C. taenia	1 (10.84)	0 (0)	0 (0)	1	10.84	1*	10.84	1.00	1.00	0.00	0.00	10	0.11
	N. angorae	2 (6.8)	0 (0)	0 (0)	2	6.8	2*	6.80	1.00	1.00	0.00	0.00	20	0.07
K2	*L.cephalus*	22 (1243.02)	11 (627.84)	5 (236.91)	38	2107.77	43±8	2385.11	0.52	0.89	0.55	0.02	377	20.92
	B.p.escherichi	21 (602.62)	8 (324.91)	7 (191.33)	36	1118.86	42±10	1305.34	0.48	0.86	0.61	1.06	368	11.45
	C. tinca	40 (2012.58)	17 (1421.63)	8 (387.16)	65	3821.37	71±8	4174.11	0.57	0.92	0.51	0.05	623	36.62
	A.bipunctatus	2 (16.14)	1 (9.25)	0 (0)	3	25.39	3*	25.39	0.66	0.96	0.33	0.39	26	0.22
	C. c. sieboldi	6 (675.81)	3 (215.92)	1 (240.36)	10	1132.09	11±4	1245.30	0.55	0.91	0.50	0.07	96	10.92
	C.regium	8 (148.70)	2 (41.52)	1 (18.97)	11	209.19	11±2	209.19	0.69	0.97	0.36	0.18	96	1.84
	A.orontis	29 (345.06)	12 (142.89)	7 (91.53)	48	579.48	53±8	639.84	0.54	0.90	0.54	0.26	465	5.61
	C. taenia	10 (87.97)	4 (16.99)	2 (17.27)	16	122.23	17±2	129.87	0.57	0.92	0.50	0.04	140	1.14
	N. angorae	22 (91.27)	11 (35.12)	3 (4.68)	36	131.07	39±2	141.99	0.57	0.92	0.47	0.52	342	1.25
K3	*B.p.escherichi*	18 (486.28)	7 (199.37)	4 (99.56)	29	785.21	32±6	866.44	0.55	0.91	0.52	0.17	506	13.71
	C. tinca	67 (2467.08)	21 (1478.56)	12 (578.93)	100	4524.57	106±8	4796.04	0.63	0.95	0.45	1.45	1677	75.89
	A.bipunctatus	15 (150.22)	6 (50.01)	4 (37.47)	25	237.70	28±6	266.22	0.53	0.90	0.56	0.30	443	4.21
	C. c. sieboldi	2 (335.55)	0 (0)	0 (0)	2	335.55	2*	335.55	1.00	1.00	0.00	0.00	32	5.31
	C.regium	3 (61.39)	0 (0)	0 (0)	3	61.39	3*	61.39	1.00	1.00	0.00	0.00	47	0.97
	A.orontis	15 (175.61)	5 (67.12)	4 (50.12)	24	292.85	26±6	317.25	0.55	0.91	0.54	0.78	411	5.02
K4	*L.cephalus*	17 (1021.22)	9 (472.36)	4 (232.59)	30	1726.17	34±8	1956.33	0.51	0.88	0.57	0.04	304	17.47
	B.p.escherichi	13 (335.71)	6 (161.94)	2 (66.13)	21	563.78	23±4	617.47	0.59	0.93	0.48	0.09	205	5.51
	C. tinca	17 (872.50)	6 (312.54)	4 (224.79)	27	1409.83	29±6	1514.26	0.57	0.92	0.52	0.48	259	13.52
	A.bipunctatus	5 (41.59)	3 (25.28)	1 (10.24)	9	77.11	10±4	85.68	0.51	0.88	0.56	0.14	89	0.76
	C.regium	4 (73.14)	1 (18.72)	1 (13.41)	6	105.27	6±2	105.27	0.61	0.94	0.50	0.51	54	0.94
	A.orontis	68 (785.62)	23 (264.22)	10 (121.56)	101	1171.40	106±6	1229.39	0.63	0.95	0.43	0.22	946	10.98
	N. angorae	1 (2.55)	0 (0)	0 (0)	1	2.55	1*	2.55	1.00	1.00	0.00	0.00	9	0.02
Total		497 (14277.72)	186 (6633.43)	98 (3018.66)	781	23929.81		26018.77					8982	279.82

Table 5- Stock density and biomass obtained from sampling sites in the Kirmir River, August 2007, symbol explanation presented in Table 3

Çizelge 5- Kirmir Çayı'ndaki örnekleme yerlerinden elde edilen balıkların yoğunluk ve biyomas tahminleri (Ağustos2007), simgelerin açıklaması Çizelge 3'de verilmiştir

Sites	*Fish species*	C_1	C_2	C_3	N	*B (g)*	$\hat{N} \pm t \times S_{\hat{N}}$	$\hat{B}$ *(g)*	$\hat{p}$	$(1-\hat{q}^3)$	R	T_1	$\hat{N}$ *(fish* ha^{-1}*)*	$\hat{B}$ *(kg ha^{-1})*
K1	*L.cephalus*	14 (754.91)	6 (287.12)	3 (149.63)	23	1191.66	25±6	1295.28	0.55	0.91	0.52	0.03	382	19.81
	B.p.escherichi	18 (766.34)	7 (289.28)	3 (131.89)	28	1187.51	30±4	1272.33	0.61	0.94	0.46	0.02	459	19.45
	Capoeta tinca	9 (471.67)	3 (279.34)	2 (152.09)	14	903.10	15±4	967.61	0.59	0.93	0.50	0.29	229	14.80
	A.bipunctatus	2 (27.43)	1 (9.57)	0 (0)	3	37.00	3*	37.00	0.66	0.96	0.33	0.39	46	0.57
	C.c.sieboldi	4 (273.33)	0 (0)	0 (0)	4	273.33	4*	273.33	1.00	1.00	0.00	0.00	61	4.18
	C.regium	6 (171.34)	1 (38.14)	1 (22.09)	8	231.57	8±2	231.57	0.73	0.98	0.38	0.99	122	3.54
	A.orontis	6 (85.11)	3 (40.63)	1 (13.27)	10	139.01	11±4	152.91	0.55	0.91	0.50	0.07	168	2.34
K2	*L.cephalus*	23 (1242.65)	9 (415.90)	6 (315.27)	38	1973.82	42±8	2181.59	0.54	0.90	0.55	0.50	494	25.67
	B.p.escherichi	10 (416.3)	4 (171.62)	2 (96.45)	16	684.37	17±4	727.14	0.57	0.92	0.50	0.04	200	8.55
	Capoeta tinca	27 (904.91)	7 (534.62)	7 (351.18)	41	1790.71	44±6	1921.74	0.59	0.93	0.51	2.88	518	22.61
	C.c.sieboldi	1 (596.57)	1 (280.31)	0 (0)	2	876.88	2*	876.88	0.51	0.88	0.50	0.75	24	10.32
	C.regium	1 (41.93)	1 (27.16)	0 (0)	2	69.09	2*	69.09	0.51	0.88	0.50	0.75	24	0.81
	A.orontis	22 (297.26)	10 (135.61)	4 (57.12)	36	489.99	39±6	530.82	0.57	0.92	0.50	0.03	459	6.24
	N. angorae	6 (18.7)	2 (5.79)	2 (4.15)	10	28.64	11±2	31.50	0.51	0.88	0.60	0.55	129	0.37
K3	*L.cephalus*	2 (109.14)	0 (0)	0 (0)	2	109.14	2*	109.14	1.00	1.00	0.00	0.00	30	1.66
	B.p.escherichi	10 (408.21)	6 (253.91)	2 (85.13)	18	747.25	21±6	871.79	0.51	0.88	0.56	0.28	320	13.29
	Capoeta tinca	28 (1179.34)	13 (742.37)	5 (312.08)	46	2233.79	50±8	2428.03	0.57	0.92	0.50	0.07	762	37.01
	A.bipunctatus	9 (114.92)	4 (58.31)	2 (26.15)	15	199.38	17±4	225.96	0.54	0.90	0.53	0.02	259	3.44
	C.c.sieboldi	3 (195.48)	1 (28.28)	0 (0)	4	223.76	4*	223.76	0.73	0.98	0.25	0.27	61	3.41
	C.regium	3 (89.19)	2 (62.56)	0 (0)	5	151.75	5±2	151.75	0.61	0.94	0.40	1.02	76	2.31
	A.orontis	15 (233.18)	5 (68.75)	4 (52.76)	24	354.69	26±6	384.25	0.55	0.91	0.54	0.78	396	5.86
K4	*L.cephalus*	7 (327.81)	2 (124.96)	1 (79.36)	10	532.13	10±2	532.13	0.66	0.96	0.40	0.12	92	4.88
	B.p.escherichi	9 (351.17)	3 (113.35)	1 (38.70)	13	503.22	14±2	541.93	0.66	0.96	0.38	0.02	128	4.97
	Capoeta tinca	34 (1563.51)	15 (905.62)	5 (539.47)	54	3008.60	58±6	3231.46	0.59	0.93	0.46	0.17	532	29.65
	A.bipunctatus	3 (49.44)	1 (13.20)	1 (9.79)	5	72.43	6±4	86.92	0.51	0.88	0.60	0.26	55	0.80
	C.regium	5 (111.71)	2 (49.23)	1 (25.73)	8	186.67	9±2	210.00	0.57	0.92	0.50	0.03	83	1.93
	A.orontis	12 (151.91)	8 (135.64)	1 (16.37)	21	303.92	23±6	332.86	0.55	0.91	0.48	1.92	211	3.05
Total		289 (10953.46)	117 (5071.27)	54 (2478.68)	460	18503.41		19898.77					6320	251.52

Table 6- Stock density and biomass obtained from sampling sites in the Kirmir River, November 2007, symbol explanation presented in Table 3

Çizelge 6- Kirmir Çayı'ndaki örnekleme yerlerinden elde edilen balıkların yoğunluk ve biyomas tahminleri (Kasım2007), simgelerin açıklaması Çizelge 3'de verilmiştir

Sites	*Fish species*	C_1	C_2	C_3	N	B (g)	$\hat{N} \pm t \times S_{\hat{N}}$	$\hat{B}$ (g)	$\hat{p}$	$(1-\hat{q}^3)$	R	T_1	$\hat{N}$ (fish ha^{-1})	$\hat{B}$ (kg ha^{-1})
K1	*L.cephalus*	9 (271.36)	3 (112.37)	2 (90.54)	14	474.27	15±4	508.15	0.59	0.93	0.50	0.29	123	4.15
	B.p.escherichi	11 (567.14)	4 (203.61)	2 (101.37)	17	872.12	18±4	923.42	0.61	0.94	0.47	0.08	147	7.54
	Capoeta tinca	3 (101.54)	1 (37.65)	0 (0)	4	139.19	4*	139.19	0.73	0.98	0.25	0.27	33	1.14
	A.bipunctatus	4 (468.84)	2 (251.77)	0 (0)	6	720.61	6±2	720.61	0.66	0.96	0.33	0.78	49	5.89
	C.c.sieboldi	2 (359.44)	1 (60.42)	0 (0)	3	419.86	3*	419.86	0.66	0.96	0.33	0.39	25	4.07
	C.regium	2 (64.53)	1 (33.96)	0 (0)	3	98.49	3*	98.49	0.66	0.96	0.33	0.39	25	0.95
	A.orontis	13 (201.56)	5 (70.69)	2 (34.12)	20	306.37	21±4	321.69	0.61	0.94	0.45	0.00	172	3.12
	N. angorae	2 (6.13)	1 (2.25)	0 (0)	3	8.38	3*	8.38	0.66	0.96	0.33	0.39	29	0.07
K2	*L.cephalus*	6 (287.31)	2 (79.16)	0 (0)	8	366.47	9±2	412.28	0.73	0.98	0.25	0.56	89	4.07
	B.p.escherichi	5 (239.20)	3 (141.83)	1 (42.12)	9	423.15	10±4	470.17	0.51	0.88	0.56	0.14	99	4.65
	Capoeta tinca	8 (802.96)	4 (324.96)	0 (0)	12	1127.92	12±2	1127.92	0.66	0.96	0.33	1.55	119	11.15
	A.bipunctatus	3 (568.14)	3 (229.47)	0 (0)	6	797.61	7±4	930.55	0.51	0.88	0.50	1.84	69	9.20
	C.c.sieboldi	3 (505.22)	0 (0)	0 (0)	3	505.22	3*	505.22	1.00	1.00	0.00	0.00	30	4.36
	C.regium	2 (75.62)	2 (47.81)	0 (0)	4	123.43	5±4	154.29	0.51	0.88	0.50	1.18	49	1.33
	A.orontis	26 (413.58)	9 (141.06)	5 (62.09)	40	616.73	43±6	662.98	0.61	0.94	0.48	0.41	425	5.72
	N. angorae	2 (7.76)	1 (2.58)	0 (0)	3	10.34	3*	10.34	0.66	0.96	0.33	0.39	25	0.04
K3	*L.cephalus*	4 (214.06)	1 (322.12)	0 (0)	5	536.18	5*	536.18	0.79	0.99	0.20	0.21	62	6.62
	B.p.escherichi	6 (288.36)	3 (153.45)	1 (44.96)	10	486.72	11±4	535.39	0.55	0.91	0.50	0.07	136	6.61
	Capoeta tinca	14 (1128.71)	6 (751.67)	4 (494.36)	24	2374.74	27±8	2671.58	0.51	0.88	0.58	0.23	333	32.98
	A.bipunctatus	5 (621.69)	2 (191.23)	1 (34.02)	8	846.94	9±2	952.81	0.57	0.92	0.50	0.03	111	11.76
	C.c.sieboldi	2 (437.83)	1 (105.77)	0 (0)	3	543.60	3*	543.60	0.66	0.96	0.33	0.39	37	8.16
	C.regium	3 (84.57)	2 (50.39)	0 (0)	5	134.96	5±2	134.96	0.61	0.94	0.40	1.02	62	2.03
	A.orontis	4 (66.25)	1 (17.63)	1 (13.57)	6	97.45	6±2	97.45	0.61	0.94	0.50	0.51	74	1.46
K4	*L.cephalus*	1 (429.21)	0 (0)	0 (0)	1	429.21	1*	429.21	1.00	1.00	0.00	0.00	9	4.04
	B.p.escherichi	3 (134.11)	1 (40.60)	1 (36.24)	5	210.95	6±4	253.14	0.51	0.88	0.60	0.26	56	2.38
	Capoeta tinca	13 (925.88)	6 (517.39)	2 (367.51)	21	1810.78	23±4	1983.24	0.59	0.93	0.48	0.09	217	18.67
	A.bipunctatus	1 (124.88)	1 (73.41)	0 (0)	2	198.29	2*	198.29	0.51	0.88	0.50	0.75	19	1.87
	C.regium	4 (128.75)	2 (71.23)	1 (39.18)	7	239.16	8±4	273.33	0.51	0.88	0.57	0.00	75	2.41
	A.orontis	11 (167.12)	5 (52.67)	2 (27.28)	18	247.07	20±4	274.52	0.57	0.92	0.50	0.02	188	2.43
Total		172 (9691.75)	73 (4087.15)	25 (1387.36)	270	15166.21		6297.24					2887	168.87

Since $T_1 < \chi^2 = 3.84$, there were no significant difference (95% certainty) between capture probabilities and equations (1-2) are appropriate. According to sampling period, the lowest density and biomass values were observed during November 2007 with 2887 fish ha^{-1} and 168.87 kg ha^{-1} whilst the highest density and biomass values were observed during February 2007 with 11456 fish ha^{-1} and 346.78 kg ha^{-1}. Water temperature is the most important factor that influences on population parameters ($\hat{N}$ and $\hat{B}$). The reason for the decrease in total fish density and biomass during the sampling period can be explained by seasonal changes occurred in the water temperature.

4. Conclusions

A total of 9 fish species representing 2 families Cyprinidae and Cobitidae were recorded. *A. orontis* was the most dominant species by its density and biomass. The results of this study contribute to knowledge of fish density and biomass in Kirmir Stream. Moreover, this study, being the first quantitative survey on fish communities in the Kirmir Stream, provides a baseline for future evaluation of the changes. Therefore it has been not put forward any recommendation terms of managerial politics in this study. Additionally, long-term sampling is necessary to predict changes in fish communities and to implement successful planning of stream fish monitoring.

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Some Chemical and Physical Properties, Fatty Acid Composition and Bioactive Compounds of Wheat Germ Oils Extracted From Different Wheat Cultivars

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ABSTRACT

Fatty acid composition, antioxidant activity, total phenolics and α-tocopherol contents of wheat germ oils obtained from two bread wheats (*Triticum aestivum* L.) and one durum wheat (*Triticum durum* L.) species commonly cultivated in Turkey were investigated in this study. Fourteen different fatty acids were determined in wheat germ oil samples in which linoleic acid (53.88-57.55%), oleic acid (16.56-20.38%) and palmitic acid (16.66-17.70%) were found as predominant fatty acid types. Among the major fatty acids, linoleic acid was the primary fatty acid in bread wheat germ oils whereas oleic and palmitic acids were the predominant fatty acids in durum wheat samples. The antioxidant activity of the wheat germ oil samples ranged between 0.94-1.01 μmol g^{-1} whereas the total phenolic and the α-tocopherol between 67.79-126.51 mg GAE 100 g^{-1} and 1343 to 2176 mg kg^{-1}, respectively. The lowest antioxidant activity and total phenolic content were detected in bread wheat germ oil while the other bread wheat and the durum wheat exhibited the highest antioxidant activity and total phenolic content, respectively.

Keywords: Wheat; Germ oil; Fatty acids; Antioxidant activity; Total phenolic compound

Farklı Buğday Çeşitlerinden Ekstrakte Edilen Rüşeym Yağlarının Kimi Kimyasal ve Fiziksel Özellikleri, Yağ Asidi Kompozisyonu ve Biyoaktif Bileşikleri

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ÖZET

Bu çalışmada, Türkiye'de yaygın olarak yetiştirilmekte olan iki ekmeklik (*Triticum aestivum* L.) ve bir makarnalık (*Triticum durum* L.) buğday çeşitlerinden elde edilen rüşeym yağlarının; yağ asidi kompozisyonu, antioksidan aktivite,

toplam fenolik madde ve α-tokoferol miktarları araştırılmıştır. Ruşeym yağı örneklerinde toplam 14 farklı yağ asidi tespit edilmiş olup, bütün numunelerde hakim yağ asitleri; linoleik asit (% 53.88-57.55), oleik asit (% 16.56-20.38) ve palmitik asit (% 16.66-17.70) olarak saptanmıştır. Ruşeym yağı örneklerinin antioksidan aktivitelerinin 0.94 μmol g^{-1} ile 1.01 μmol g^{-1}, toplam fenolik madde miktarlarının 67.79 mg GAE 100 g^{-1} ile 126.51 mg GAE 100 g^{-1} ve α-tokoferol içeriklerinin 1343 mg kg^{-1} ile 2176 mg kg^{-1} arasında değiştiği tespit edilmiştir. Antioksidan aktivite ve toplam fenolik madde miktarı bakımından en düşük oranın ekmeklik çeşitte, en yüksek antioksidan aktivitenin ise diğer ekmeklik çeşitte bulunduğu ve en yüksek toplam fenolik maddenin makarnalık çeşitte bulunduğu görülmüştür.

Anahtar Kelimeler: Buğday; Rüşeym yağı; Yağ asidi; Antioksidan aktivite; Toplam fenolik bileşikler

1. Introduction

Cereals and cereal-based foods are the major nutritional sources for human in Turkey as well as in the world. Wheat is placed on the top among the cereal plants consumed (Çifci & Doğan 2013). *Triticum aestivum* (bread type), *Triticum durum* (durum) and *Triticum compactum* (biscuit, Topbaş wheat) are major wheats grown in Turkey and all over the world (Hoseney 1994; Bushuk 1998). Wheats having horny endosperm are generally used for production of leavened foods such as bread, pastry and bagel while the ones having floury endosperm are utilized for bakery products such as biscuit, cracker, waffle and cake, which are produced with chemical leavening agents. Durum wheat is used for production of semolina for pasta and spaghetti, and granular products including bulgur and kuskus. Since production level of Topbaş wheat is very low, bread type wheat which has low protein level and quality is preferred for biscuit production (Hoseney 1994; Elgün & Ertugay 1995; Bushuk 1998; Morris 2004). Indeed, differences in hardness among *Triticum aestivum* L. or between *T. aestivum* L. and *T. turgidum* L. ssp. durum wheat cultivars determine not only their milling properties, but also the properties of flour or semolina endosperm particles, their preferential use in cereal-based applications, and the quality of the latter (Pauly et al 2013).

Wheat germ is one of the by-products of wheat milling. Germ constitutes 2-3% of the wheat grain and contains approximately 8-14% oil in its composition. Several health benefits of wheat germs were attributed to germ oil, such as the plasma and hepatic cholesterol lowering effect and anti-aging properties. These beneficial effects were suggested to be related to the presence of several bioactive compounds at high concentrations in germ oil (Kahlon 1989). Additionally, wheat germ has high vitamin content especially vitamins E and B (Pomeranz 1987) and it is one of the richest natural sources of α-tocopherol (Dunford 2001). Tocopherols constitute approximately 18% of the non-saponifying components of the germ oil (Azzi & Stocker 2000). For these reasons, determination of physicochemical and functional properties of the germ or germ oil is important for the utilization purpose of it since due to its functional porperties many foods could be enriched with addition of this nutritive by-product.

In this study, the fatty acid composition as well as antioxidant activity, total phenolic and α-tocopherol contents were investigated as significant bioactive characteristics, and components of germ oils which were obtained from *Triticum aestivum* L. (bread wheat) and *Triticum durum* L. (durum wheat), commonly cultivated wheat species in Turkey. The origin of the wheat determines the biochemical characteristics of the germ. For this reason, the chemical composition of germ samples obtained from different wheat species, especially fatty acid composition and several nutritional parameters were investigated in order to determine the differences among different wheat varieties.

2. Material and Methods

2.1. Materials

In this study, two cultivars of bread wheat [*Triticum aestivum* L; Bezostaja-1 (B) and Esperia (E)] and

one cultivar of durum wheat [*Triticum durum* L; Ç-1252(C)] were used as representative samples. Wheat germ samples coded as B and C were obtained from Tekbasak Flour Industry Co. (Afyonkarahisar, Turkey), and samples coded as E were obtained from Marmara Flour Industry Co. (Ankara, Turkey). Figure 1 represents the germ production process from wheat samples.

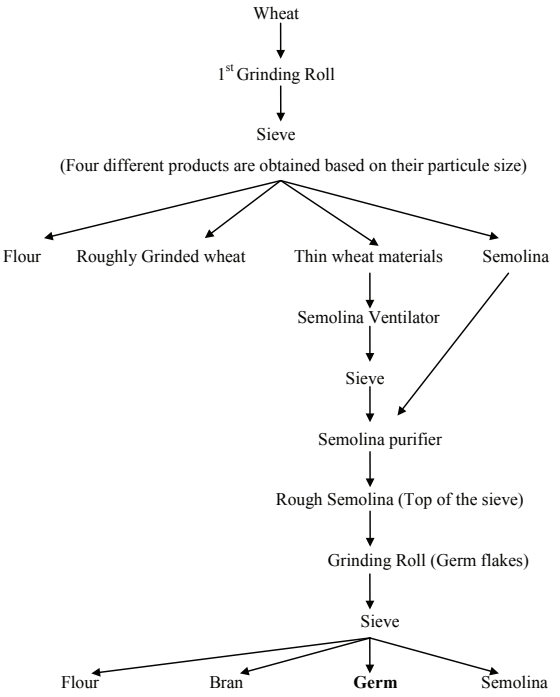

Figure 1- Process flow chart for the production of wheat germ

Şekil 1- Buğday ruşeymi eldesi için proses akım şeması

2.2. Analysis of the germ samples

Soxhlet method was used for the determination of the oil content and, the moisture content was determined according to the standard method of AACC (2000). Kjeldahl method using a semi-automized device (Foss) was used for the determination of the nitrogen content, and protein calculated as N% x 5.7. Total ash content of the samples was determined according to the method reported by Özkaya & Özkaya (1990) and AACC (2000).

2.3. Analysis of the germ oil samples

Germ oil was extracted from the germ samples according to the methodology described by Megahad & El Kinawy (2002) with slight modifications. Briefly, 200 mL of hexane was added to 50 g of ground germ and then the mixtures were blended at 200 rpm for 4 hours at room temperature, the solution was filtered and hexane was then regained using a rotary evaporator at 35 ^{o}C.

The free fatty acids, peroxide, refractive index and iodine values of germ oil samples were determined according to previously described methods of AOCS Official Method Ca 5a-40, AOCS Official Method Cd8a-53 and AOCS Official Method Cc 7-25, respectively (AOCS 1989).

The color of the wheat germ oil samples was determined by measuring *L, a, b* values with a Minolta equipment. In order to achieve this, the *L, a* and *b* values of germ oil samples were measured and the recorded values were averaged.

The fatty acid composition of the germ oil samples and their quantities were determined with gas chromatography (GC, Agilent Technogies 6890 N Network GC System) equipped with a Flame Ionization Detector (FID). The germ oil samples obtained by cold extraction were esterified and injected into the GC according to the method of AOAC (1990). Supelco SP-2380 analytical column was used and oven operating temperature was started up with 165 °C for 30 min and reached to a final temperature of 200 °C for 5 min. The carrier gas was hydrogen and dry air with a mobility of 30 mL min^{-1} and 300 mL min^{-1}, respectively with a split ratio of 70:1. The fatty acids found in germ samples were expressed as % ratio.

The DPPH (1,1-diphenyl-2-picrylhydrazyl) method was used to determine the antioxidant activity of the wheat germ oil samples (Brand-Williams et al 1995; Pokorny et al 2001; Yu et al 2002). The DPPH radical scavenging activity was calculated as percent inhibition of the reaction (Equation 1).

$$\text{DPPH Radical scavenging activity}, \% = \frac{\text{Abs}_{\text{Control}} - \text{Abs}_{\text{Sample}}}{\text{Abs}_{\text{Control}}} \times 100 \quad (1)$$

The extract or standard material concentration that provides 50% inhibition of the DPPH is defined as IC_{50}. This value was calculated by plotting the studied concentrations against the % free radical scavenging activity and the results were given as IC_{50}, μmol g^{-1}.

The total phenolic content of the wheat germ oil samples was determined with a modified Folin-Ciocalteu method using gallic acid as standard (Singleton & Rossi 1965). The total phenolic content was expresedas mg gallic acid 100 g^{-1} sample.

The α-tocopherol content of the wheat germ oil samples was determined according to AOCS (1999) method by using High Performance Liquid Chromatography (Shimadzu LC-10A). The injection volume was 10 μL. The mobile phase was methanol and the elution was performed at a flow-rate of 1.0 mL min^{-1}. The temperature of the analytical column (Nucleodur C_{18}) was kept at 30 °C. To determine α-tocopherol in the samples, α-tocopherol standard solutions were always analyzed together with the samples, and peak-area ratios were used for calculations following the internal standard method. Detection was performed with an UV/Visible-Diode array detector at 290 nm.

2.4. Statistical analysis

The results were presented as mean±standard deviation. The SAS 8.0 package software was used for the statistical analysis. The data obtained at each analysis were analysed by Duncan's new multiple range test with a confidence interval of 95%.

3. Results and Discussion

3.1. Chemical properties of wheat germ samples

The moisture, oil, protein and ash contents of germ samples obtained from different wheat species are given in Table 1.

Table 1- Some chemical properties of the wheat germ samples

Çizelge 1- Buğday ruşeymi örneklerinin bazı kimyasal özellikleri

Sample	*Moisture (%)*	*Oil (%)*	*Protein (%)*	*Ash (%)*
B*	11.59^{b}±0.05	11.67^{a}±0.49	27.70^{a}±0.04	5.03^{a}±0.01
C	11.58^{b}±0.02	10.44^{a}±0.04	23.99^{b}±0.38	4.58^{c}±0.06
E	12.96^{a}±0.50	9.68^{a}±0.71	27.26^{a}±0.61	4.87^{b}±0.03

*, different lowercase superscript letters in the same column show significant differences among the samples ($P<0.05$)

Moisture content of the germ samples was determined in the range of 11.58% (C) and 12.96% (E). As seen from the Table 1, moisture content of the B and C samples was very close to each other. As is known, wheat is conditioned prior to grinding in order to maintain uniform moisture content.

Protein content of the B, C and E germ samples was determined as 27.70, 23.99 and 27.26%, respectively (Table 1). No significant difference was observed between protein contents of B and E samples ($P>0.05$) which were higher than that of C. The differences in the protein content could be attributed to the differences of wheat species, cultivation conditions and environmental factors. Previous studies reported the protein content of wheat germ to be in the range of 26-35% (Posner & Li 1991), 25-30% (Kirk & Sawyer 1991), 26% (Atwell 2001) and 26.5% (Bilgiçli et al 2006). The results obtained in the present study were in accordance with previously reported values. As seen from the findings, wheat germ is a very important protein source. They are rich in the essential amino acids which are not generally found in many cereals (Yiqiang et al 1999). Protein isolate extracted from

wheat germ meal can be utilized for some foods due to their high nutritional values (Hettiarachchy et al 1996; Ge et al 2000).

Ash contents of the wheat germ samples analyzed in the present study ranged between 4.58% (C) and 5.03% (B). The results of the present study were consistent with the previous ones (Oymak 2006; Gelmez 2008; Xie & Dunford 2011). However, lower ash content values were reported for wheat germ in the other studies (Posner & Li 1991; Atwell 2001; Jiang & Niu 2011). Ash content is an indicator of the minerals in wheat and ash is widely present in the scab and the germ parts of the wheat plant. Due to the non-uniform fractionation by sieving, the ash contents of different wheat germs may vary. The wheat germ is also rich in mineral composition. In a study conducted by Arshad et al (2007), it was demonstrated that calcium, iron and potassium levels of the cookies increased with supplementation of the wheat germ.

Oil contents of the germ samples were between 9.68% (E) and 11.67% (B). The results obtained in the present study were in accordance with previously obtained results in the literature (Kirk & Sawyer 1991; Oymak 2006; Xie & Dunford 2011). The slight differences could be resulted from wheat types, processing conditions of wheat and climatic factors directly affecting chemical composition of wheat. When considering the results obtained in the present and previous studies, it can be concluded that the wheat germ might be economically utilized as oil source.

3.2. Physicochemical properties of wheat germ oil samples

Colour values (*L, a* and *b*) of the extracted oil samples were presented in Table 2. *L, a* and *b* values of the samples ranged between 49.39-51.17, 0.75-3.92 and 32.17-35.19, respectively. There was no significant difference in color values of the three samples with the exception of sample B which had significantly lower *a* value than the other two groups. As it is seen from the results, color values of the samples were found to be very close to each other.

Free fatty acids, peroxide, iodine and refractive index values of the wheat germ oil samples extracted from different wheat varieties were given in Table 2. Free fatty acid values of the oil samples were determined to be 1.53, 1.82 and 4.95% oleic acid for B, C and E, respectively. Sample E had the highest free fatty acid value, which might result from its high unsaturated fatty acid content and low antioxidant activity. Jiang and Niu (2011) also studied free fatty acid contents of two different wheat germ oils and they found as 12.8 and 9.1% oleic acid, respectively. In the other study, Eisenmenger & Dunford (2008) studied bioactive properties of the wheat germ oil

Table 2- Some physicochemical properties of the wheat germ oils

Çizelge 2- Buğday ruşeymi yağlarının bazı fizikokimyasal özellikleri

Sample	*FFA*	*PV*	*IV*	*RI*
B*	1.53^{b}±0.10	1.68^{b}±0.11	135.32^{a}±0.01	1.4635^{b}
C	1.82^{b}±0.18	1.45^{b}±0.17	130.20^{b}±0.72	1.4602^{c}
E	4.95^{a}±0.13	2.73^{a}±0.17	135.78^{a}±0.47	1.4672^{a}
Sample	*Colour values*			
	L	*a*	*b*	
B	51.17^{a}±0.23	3.92^{a}±0.01	34.26^{a}±0.82	
C	50.93^{a}±0.88	0.75^{b}±0.04	35.19^{a}±1.12	
E	49.39^{a}±0.61	3.20^{a}±0.45	32.17^{a}±1.05	

*, different lowercase superscript letters in the same column show significant differences among the samples (P<0.05); FFA, free fatty acid (oleic acid, %); PV, peroxide value (meq O_2 kg^{-1}); IV, iodine value; RI, refractive index

extracted with hexane and they found that free fatty acid value of the oil sample was 7.9%. There are also different studies which supported our findings. El-Shami et al (2011) determined the free fatty acid values of wheat germ oils to be in the range of 4.5-5.0%. There are many factors affecting these variations since factors resulting in deterioration of oil also influence free fatty acid formation.

Peroxide values (PV) of B, C and E samples were determined to be 1.68, 1.45 and 2.73 meq O_2 kg^{-1} oil (Table 2). PV of B and E samples were found to be higher than that of the durum wheat (C) germ oil. This outcome was believed to be a consequence of the higher unsaturated fatty acid content of the bread wheat germ oil samples than the durum wheat germ oil sample. The saturation level of the oil sample was previously reported to affect the oxidative stability. Higher unsaturated fatty acid content is considered as an indicator for lower oxidative stability (Nas et al 2001). PV of solvent and SC-CO_2 (supercritical carbondioxide) extracted wheat germ oil samples were reported to be 2.95 and 2.05 meq O_2 kg^{-1} oil (Jiang & Niu 2011) and to be 0.9-1.0 meq O_2 kg^{-1} oil.

El-Shami et al (2011) determined the iodine value to be in the range of 115-120 in the previous study related with the fatty acid composition and nutritional value of the wheat germ oil extracted with chloroform/methanol and hexane solvents. The results obtained in the present study were lower than the values obtained by Jiang & Niu (2011).

Another important parameter analyzed in the present study is iodine value (IV) which provides information about saturation or unsaturation level of the oils. IV of the oil samples ranged between 130.20 and 135.78 (Table 2). The IV of the samples was close to each other; however, IV of sample C was found significantly lower ($P<0.05$) than those of the other two oil samples. Jiang & Niu (2011) and El-Shami et al (2011) determined IV of wheat germ oils extracted with different solvents in the range of 142.8-148.1 and 115-120, respectively.

The refractive index (RI) value of oil increases with the increases in the amount of unsaturated fatty acids and fatty acid chain length. In addition, it is possible to predict the IV based on the refractive index value of oil; therefore, correlation between IV and RI value is generally expected. RI value of the oil samples extracted from wheat germs was found in the range of 1.4602 and 1.4672 (Table 2). Data from Table 2 also indicated that significant difference was observed among RI values of the samples ($P<0.05$). RI values of different wheat germ oils varied between 1.474 and 1.483 at 25 °C (El-Shami et al 2011). The differences in RI values in the present study could be resulted from the fatty acid composition of the oils. Many factors including wheat types, climatic conditions, environmental factors and oil extraction process could affect these variations.

3.3. Fatty acid compositions of the germ oils

The fatty acid compositions of the germ oil samples were shown in Table 3. Fourteen fatty acids were determined in the wheat germ oil samples. In the fatty acids profile, palmitic acid (C16:0), oleic acid (C18:1) and linoleic acid (C18:2) were found as the predominant fatty acids with the varying concentrations of 18.00-18.87%, 17.92-21.54% and 59.59-64.08%, respectively. On the other hand, there was no significant ($P>0.05$) difference between total SFA amounts of B and E samples whereas C sample had the highest ($P<0.05$) SFA and MUFA levels.

Fatty acid composition of wheat germ oil has also been investigated by different researchers. Dunford & Zhang (2003) reported that the wheat germ oil extracted with hexane under high pressure conditions was composed of 56% linoleic acid. It was also reported that 81% of the fatty acid of the wheat germ oil was constituted by unsaturated fatty acids, 64% of which was polyunsaturated ones. The fatty acid composition of wheat germ oil was comprised of palmitic acid (16.72%), oleic acid (15.79%), linoleic acid (60.23%) and linolenic acid (6.2%) (Megahad & El Kinawy 2002). Arshad et al (2008) reported that fatty acid composition of wheat germ oil consisted of linoleic acid (56.99%), palmitic acid (18.09%), oleic acid (14.69%) and linolenic acid (9.51%), 82% and 66% of which were unsaturated fatty acid and PUFA, respectively.

Table 3- Fatty acid composition of the wheat germ oil samples (%)

Çizelge 3- Buğday rüşeymi yağı örneklerinin yağ asidi kompozisyonları (%)

Fatty acids	*Sample*		
	B	*C*	*E*
Myristic (C14:0)*	0.08^{a}±0.002	0.07^{a}±0.006	0.07^{a}±0.020
Palmitic (C16:0)	17.00^{ab}±0.04	17.70^{a}±0.08	16.66^{b}±0.46
Margaric (C17:0)	0.03^{a}±0.001	0.04^{a}±0.001	0.04^{a}±0.016
Stearic (C18:0)	0.69^{a}±0.01	0.74^{a}±0.047	0.59^{b}±0.017
Arachidic (C20:0)	0.16^{a}±0.01	0.15^{a}±0.055	0.18^{a}±0.045
Behenic (C22:0)	0.12^{a}±0.001	0.11^{a}±0.007	0.25^{a}±0.019
Lignoseric (C24:0)	0.09^{b}±0.040	0.07^{b}±0.028	0.21^{a}±0.027
Palmitoleic (C16:1) (C16:1)	0.07^{c}±0.002	0.11^{a}±0.002	0.09^{b}±0.003
Heptadecenoic (C17:1) (C17:1)	0.06^{a}±0.003	0.06^{a}±0.001	0.07^{a}±0.013
Oleic (C18:1)	16.59^{b}±0.10	20.38^{a}±0.048	16.56^{b}±0.22
Gadoleic (C20:1)	1.65^{a}±0.04	0.80^{c}±0.03	0.94^{b}±0.05
Erucic (C22:1)	0.25^{a}±0.01	0.19^{b}±0.02	0.24^{a}±0.01
Linoleic (C18:2)	56.05^{b}±0.02	53.88^{c}±0.36	57.55^{a}±0.21
Linolenic (C18:3)	7.15^{a}±0.03	5.70^{b}±0.50	6.53^{ab}±0.25
SFAs	18.18^{b}±0.09	18.87^{a}±0.12	18.00^{b}±0.24
MUFAs	18.62^{b}±0.15	21.54^{a}±0.01	17.92^{c}±0.20
PUFAs	63.20^{b}±0.05	59.59^{c}±0.13	64.08^{a}±0.04

*, different lowercase superscript letters in the same row show significant differences among the samples (P< 0.05); SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid

3.4. Bioavtive compounds of wheat germ oils

The antioxidant activity, total phenolics and α-tocopherol contents of the wheat germ oil samples were shown in Table 4. Antioxidant activity values of the germ oil samples ranged from 0.94 to 1.01 μmol g^{-1} germ oil.The sample B had the highest antioxidant activity (P<0.05). Total phenolic content of sample E was found as the lowest (P<0.05). The α-tocopherol levels varied from 1343 to 2176 mg kg^{-1} among the samples.

Antioxidant compounds neutralize free radicals in living organisms, thus, protecting the cells or facilitating cell renewal process (Gök & Serteser 2003). Antioxidant compounds react with free radicals to prevent cellular damage and tumor progression in tissues and they provide a healthy and high quality life in which the adverse effects of aging are minimal (Başer 2002).

The antioxidant activity of wheat germ oil has been widely investigated in the literature; however

Table 4- Bioactive properties of the wheat germ oils

Çizelge 4- Buğday rüşeymi yağlarının biyoaktif özellikleri

Sample	*Antioxidant activity (μmol g^{-1} germ oil)*	*Total phenolic content (mg GAE 100 g^{-1} oil)*	*α-tocopherol (mg kg^{-1})*
B*	1.01^{a}±0.01	116.42^{a}±2.79	2176^{a}±1.41
C	0.95^{b}±0.01	126.51^{a}±8.17	1343^{b}±2.83
E	0.94^{b}±0.01	67.79^{b}±6.53	1923^{a}±1.41

*, different lowercase superscript letters in the same column show significant differences among the samples (P<0.05)

germ oils obtained from Turkish wheat varieties have not been studied in terms of their antioxidant activity. Wheat germ oil has been demonstrated to have considerable antioxidant activity in the previous studies. Jiang & Niu (2011) determined the DPPH free radical scavenging activity of wheat germ oil and noted that the sample concentration of 40 mg mL^{-1} was able to inhibit 96.08% of the total DPPH radicals. Megahed et al (2011) reported that 60% free radical inhibition was achieved by the treatment with 400 µg mL^{-1} of wheat germ oil concentration. Pellegrini et al (2006) determined total antioxidant activity of white durum wheat as 13.1 mmol Fe^{2+} kg^{-1}, 2.1 mmol trolox kg^{-1} and 2.7 mmol trolox kg^{-1} by using the fluorescence recovery after photobleaching (FRAP), total radical-trapping antioxidant parameter (TRAP) and trolox-equivalent antioxidant capacity (TEAC) assays, respectively. Gelmez (2008) tested ultrasound assisted supercritical carbon dioxide ($SC\text{-}CO_2$) extraction method for antioxidant extraction from roasted wheat germ. In the results, amount of the total phenolics and tocopherols and total antioxidant activity were found to be 3-7 mg GAE g^{-1} extract, 0.31 mg tocopherol g^{-1} and 40-165 mg DPPH scavenger g^{-1} germ, respectively. As can be seen in the previous studies, different solvents and extraction methods for extraction of bioactive compounds from different food matrixes were investigated (Tsao & Deng 2004; Huang et al 2005). Phenolics were reported to be the most significant compounds with strong antioxidant activity in wheat (Andlauer & Fürst 1998; Anıl 2006; Doğan & Meral 2006; Dykes & Rooney 2007). In this respect, the results of this study were in accordance with those of the previous findings.

Similarly, Jiang & Niu (2011) reported that total phenolic content of the wheat germ oil obtained by $SC\text{-}CO_2$ and solvent extraction methods were found to be 8.64 µg GAE mL^{-1} and 4.02 µg GAE mL^{-1}, respectively. King (1962) reported the phenolic content in wheat germ as 3.49 mg ferrulic acid equivalent g^{-1}. Melikoglu (2005) noted that phenolic content of the ethanolic extracts of roasted and unroasted wheat germs were 1.7 mg GAE g^{-1} and as 2 mg GAE g^{-1}, respectively. In another study, total phenolic content of wheat was reported as 150 mg GAE 100 g^{-1} (Adom & Liu 2002).

Tocopherols constitute approximately 18% of the unsaponifiable fractions of wheat germ oil (Dunford 2008). Several different methods were used for the determination of the α-tocopherol content of wheat germ oil samples. In the previous studies, α-tocopherol contents were reported as 1300-2700 mg kg^{-1} (Wang & Johnson 2001), 1660 mg kg^{-1} (Arshad et al 2008), 1390 mg kg^{-1} (hexane extraction), 2560 mg kg^{-1} ($SC\text{-}CO_2$ extraction; Eisenmenger 2003), 1510 mg kg^{-1} (hexane extraction), 2560 mg kg^{-1} ($SC\text{-}CO_2$ extraction; Eisenmenger & Dunford 2008), 1640 mg kg^{-1} (hexane extraction) and 1665 mg kg^{-1} (chloroform/methanol extraction) (El-Shami et al 2011).

It is clear from the results of the previous studies that oil extraction method had aconsiderable effect on the α-tocopherol content of foods. The α-tocopherol content of the wheat germ oil obtained by $SC\text{-}CO_2$ extraction was reported to be higher than that of the oil obtained by hexane extraction in various studies (Eisenmenger 2003; Eisenmenger & Dunford 2008; El-Shami et al 2011). In the present study, the α-tocopherol contents of the samples B and E were higher than the previously reported values in spite of the employment of hexane extraction, whereas the α-tocopherol content of the sample C was similar to the previously reported values.

4. Conclusions

Several chemical properties of germ and germ oil samples obtained from different species of wheat were investigated in the present study and the results were compared based on the wheat variety. Investigation of the nutritional factors of wheat germ samples including oil, protein and ash indicated that the bread wheat germ (B, E) samples exhibited higher nutritional value than the durum wheat sample (C). Wheat germ is rich in protein content especially in comparison to other vegetable sources and it would be considered as a nutritional supplement owing to its highly nutritious content.

The wheat germ oil samples were shown to be considerably rich in unsaturated fatty acids, specifically polyunsaturated fatty acids. In addition, essential fatty acids such as linoleic acid and linolenic acid, which are not synthesized in the metabolism but rather need to be supplemented, were present in wheat germ oil at high levels. The quantity of some of the most significant functional compounds with favourable effects (apart from its nutritional value) on human health in wheat germ oil such as antioxidants, phenolic compounds and α-tocopherol were also determined. The antioxidant activity of the samples was almost similar. The phenolic contents were shown to vary even though it was the highest in the durum wheat germ oil sample (C). The α-tocopherol contents of the bread wheat germ oil samples (B, E) were considerably higher than that of the durum wheat germ oil sample. Approximately 5 g of wheat germ oil would be sufficient to meet the daily adult requirement which is 7-10 mg α-tocopherol. Wheat germ oil samples exhibited high contents of unsaturated fatty acids, essential fatty acids, antioxidant compounds and α-tocopherol which are eminently important bioactive compounds for human health. With this purpose in mind, wheat germ and wheat germ oil would be suggested as a supplement to enrich food products.

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Comparison of Energy Efficiencies of a Small Centrifugal Pump at Constant and Variable Speed Operations

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ABSTRACT

The objective of this study was to compare the energy efficiencies of flow rate valves used in different lines and variable speed drive (VSD) in a small centrifugal pump irrigation system. The tests were done by using an outlet valve, inlet valve, by-pass valve, and VSD. The study included four replications of constant speed and variable speed experiments, and three replications of constant pressure experiments. In each test, power consumption, inlet pressure, and outlet pressure were measured at different flow rates. During the constant speed tests at about the operating point, by-pass valve saved energy up to 66% and 5% compared to the outlet valve and inlet valve, respectively. Reducing the flow rate by 20% resulted in 7% less energy consumption with the use of both the by-pass valve and the inlet valve, and 19% more energy consumption with the outlet valve. The use of VSD showed profound advantage over the valves used in constant speed tests, with 41%, 44%, and 80% less energy demand compared to the by-pass, inlet, and outlet valve, respectively. Also, VSD and by-pass valves were compared in constant pressure operations. VSD offered 2 to 37% less energy consumption at pressures from 4.0 bar to 2.5 bar. The savings were less at high flow rates and quickly increased as the flow rate need decreased. The low system efficiency found in constant speed tests suggested that the pump was not appropriate for the hydraulic system used in low pressure applications. According to constant pressure tests, the system efficiency for VSD (26-29.1%) was greater than that of the by-pass valve (21.3-25.5%). In conclusion, the VSD was the most energy efficient method and suggested significant energy savings in small powered pump systems.

Keywords: Centrifugal pump; Irrigation; Power consumption; Energy efficiency; Variable speed drive

Küçük Bir Santrifüj Pompanın Sabit ve Değişken Hızlı Çalışma Koşullarında Enerji Etkinliğinin Karşılaştırılması

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ÖZET

Bu çalışmanın amacı, küçük bir santrifüj pompanın kullanıldığı sulama sisteminde farklı hatlarda kullanılan debi ayar vanalarının ve değişken hızlı sürücü (DHS) kullanımının enerji etkinliğinin karşılaştırılmasıdır. Testler; emme vanası, basma vanası, by-pass vanası ve değişken hız kontrolü kullanılarak gerçekleştirilmiştir. Denemeler; sabit debi ve değişken hız şartlarında dört tekrarlı, sabit basınç çalışma koşullarında üç tekrarlı yapılmıştır. Her bir testte, farklı debilerde güç tüketimi, emme basıncı ve çıkış basınçları ölçülmüştür. İşletme noktasındaki sabit hız testlerinde by-pass vanası, çıkış vanasına ve giriş vanasına göre sırasıyla % 66 ve % 5 daha fazla enerji kazancı sağlamıştır. Debinin % 20 azaltılması, by-pass ve giriş vanası kullanıldığında enerji tüketimini % 7 azaltırken çıkış vanasında % 19 artırmıştır. DHS kullanımı; sabit hız testlerinde kullanılan by-pass, giriş ve çıkış vanalarına göre % 41, % 44 ve % 80 daha az enerji kullanımıyla çok önemli avantaj sağlamıştır. Ayrıca, DHS ile by-pass vanası sabit basınç testleri ile karşılaştırılmıştır. DHS 4.0 bar ile 2.5 bar arasında % 2 ile % 37 arasında enerji kazancı sağlamıştır. Enerji kazancı, yüksek debilerde daha az iken debi gereksinimi düştükçe kazanç hızla artmıştır. Sabit devir testlerinde bulunan düşük sistem verimi, kullanılan pompa ve hidrolik sistemin küçük basınçlı çalışmalar için uygun olmadığını göstermiştir. Sabit basınç testlerine göre, DHS'nün sistem verimi (% 26-29.1), by-pass vanasından (% 21.3-25.5) daha yüksektir. Sonuç olarak, DHS enerji yönüyle en etkin yöntemdir ve küçük debili sistemlerde önemli oranda enerji kazancı sağlayabilmektedir.

Anahtar Kelimeler: Santrifüj pompa; Sulama; Güç tüketimi; Enerji etkinliği; Değişken hız kontrolü

1. Introduction

Different reasons can motivate a farmer to vary the flow rate to irrigate plants in specific fields. The need to vary the flow rate or pressure may arise from irrigating different field or field segment sizes using the same pump station. When the same pump is to be used in different fields, the static head may differ due to variations in topography. In this type of operation the flow rate needs to be maintained while pressure head varies. Warmer days during the irrigation season may require more water than the early growth stages of the plants. And in this type of operation, the pressure should be constant whereas flow rate varies. Since many fields have varying elevations and different sizes with multiple blocks to be treated, irrigation systems do not require constant pressures (ITRC 2011) or flow rates.

In automated systems incorporating moisture sensors to manage irrigation, the flow rate needs to be variable, too. Variable rate irrigation systems are used to apply different amounts of water to different zones in the fields (LaRue 2011) and may be used with various sensors with integrated wireless communication systems as well (Coates & Brown 2005; Han et al 2009). In such systems, the flow rate adjustment needs to be done by varying the pump speed automatically. Using valves is the common method of varying the flow rate in small scale irrigation systems. In most applications, flow rate control is done by using a valve either on the suction line, pressure line, or by-pass line without using the speed control of the pump impeller.

Although the modernization of irrigation techniques improves water use efficiency, the pressurized pipes result in substantial energy use in agriculture, increasing the concern for energy savings and sustainability (Rocamora et al 2013). For instance in drip irrigation water efficiency, evaporation, and runoff are minimized and water efficiency may be up to 80 to 90% (Provenzano 2007). When pumping station efficiency is considered, however, there seems to be opportunities for improving the overall energy efficiency during irrigation. In central California, data from 15000 electric irrigation pumps showed that great number of the pumps operate inefficiently (Urrestarazu & Burt 2012). Thus, official administrations promote initiatives to improve energy efficiency in irrigated agriculture, and researchers are opt to develop different tools to achieve more energy efficient delivery of the irrigation water (Rocamora et al 2013). In some countries, agricultural energy conservation

programs primarily focus on improving the energy efficiency of the pumping plants (ITRC 2011).

Pumping costs can be minimized by focusing on areas such as irrigation scheduling, application efficiency, efficiency of the pumping plant, and the pressure required for the system (Martin et al 2010). The main areas for energy conservation regarding the pumping station include controlling the flow rate by speed variation, eliminating flow control valve, and eliminating by-pass control (UNEP 2006). However, using the flow rate valves has been the most common method of varying the flow rate and the majority of today's farmers use a flow rate valve installed either at the outlet (discharge) line or at the inlet (suction) line to vary the flow rate. In most countries, only a few percentages of the farmers practice the use of by-pass valves in irrigated agriculture and most pumping stations lack adjustable speed drives.

When energy consumption is considered, the best method of reducing energy consumption is the variable speed control of the pumps to meet varying demands since a slight reduction in speed can result in a significant reduction in input power (NRCS 2010). The improvement of pumping system performance depends on VSD (Sobhy et al 2011). Energy savings could be up to 35% by installing VSDs to pumping stations (Barutçu et al 2007; Lamaddalena & Khila 2012). Instead of using a valve to reduce the flow rate, reducing the pump impeller speed by 20% can reduce input power requirements by approximately 50% under certain conditions (Boyadjis 2004). Power demand from water pumps in big pumping stations may also be dropped by 40%. Reduction in the energy consumption in irrigation networks is also possible through functional programming and scheduling (Carrillo Cobo et al 2011).

The general objective of this study was to determine the energy efficiency of a small centrifugal pump under different operating conditions. The specific aim was to conduct constant speed, variable speed, and constant pressure experiments to determine the differences in the energy consumptions among different methods of varying the flow rate, including the use of an outlet flow rate valve, inlet flow rate valve, by-pass valve, and VSD (Sahib 2014).

2. Material and Methods

2.1. Material

The experiments were conducted on a centrifugal pump test bench (Figure 1). The test system includes a water tank, foot valve with suction strainer, vacuum meter, inlet flow rate valve, a centrifugal pump, check valve, flow rate valve, an analog manometer, an outlet pressure sensor, inline flow meter (rotameter), and a control panel consisting of a wattmeter to measure the power consumption. Measurement ranges and the resolutions of the manometer (Aterma En837-1), pressure sensor (Gems 0-6 bars G) , inline flow meter (LZS-32), and the wattmeter were 0-6 bar with 0.1 bar, 0-6 bar with 0.01 bar, 0.6-6 m^3 h^{-1} with 0.2 m^3 h^{-1}, and 0-9999 W with 1 W, respectively. Random measurement error was not more than 0.05 bar and 0.1 m^3 h^{-1} respectively, for the manometer/vacuummeter and the inline flow meter.

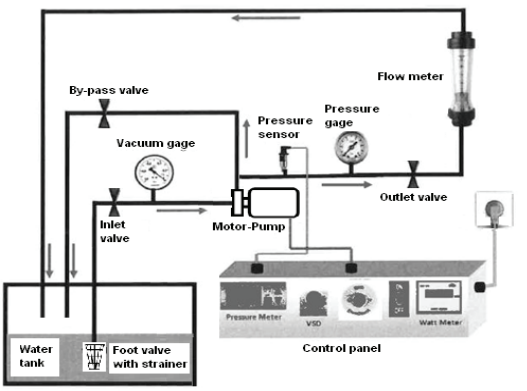

Figure 1- Schematic of the centrifugal pump system used in the study

Şekil 1- Araştırmada kullanılan santrifüj pompa sisteminin şematik görünümü

H_m-Q curve of the pump is given in Figure 2. The rotational speed of the pump is 2900 rpm with a maximum head of 70 m with a flow rate of 50 L min^{-1} (3.0 m^3 h^{-1}).

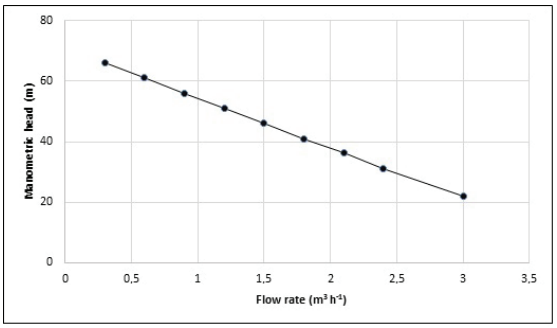

Figure 2- Flowrate-head curve of the pump used in the study (City Pump 2014)

Şekil 2- Araştırmada kullanılan pompanın debi-manometrik yükseklik eğrisi (City Pump 2014)

2.2. Methods

The tests were conducted under three categories:

1) Constant pump speed tests with the outlet valve, inlet valve, and by-pass valve,
2) Variable speed tests with the VSD,
3) Constant pressure tests with the VSD and the pass valve.

In constant pump speed experiments, the tests started at the maximum pump speed and the flow rate was reduced from its maximum value of 3.0 m^3 h^{-1} by 0.2 m^3 h^{-1} decrement with each flow regulating valve. During variable speed tests, the VSD was used to change the pump impeller speed from 2900 to 0 rpm, resulting in variable flow rates. Although the speed of the electrical motor can be estimated, it was not measured in this study, rather predetermined flow rates were supplied by fine tuning the potentiometer on the control panel to collect the relevant data. In some pumping applications, the pressure needs to be constant even if the flow rate needs to vary during the operation. For instance, in agricultural irrigation systems the pressure demand may be from 1.0 bar to 3.0 bar for drippers and from 2.0 bar to 4.0 bar or higher for sprinklers. Therefore, the tests in the third set of experiments relate to constant pressure operations with varying flow rates.

Constant and variable speed tests were replicated four times and constant pressure tests were repeated three times. Among the measured quantities, i.e. flow rate, inlet pressure, outlet pressure, and power consumption, only the flow rate and power consumption data were used in this paper. The averages of measured values were used for comparison purposes. The most energy efficient method was determined by comparing the power consumptions of different methods used for varying the flow rate. To do so, the hydraulic power delivered by the pump was calculated based on the data given in Figure 2. The efficiency curve was unknown, thus the hydraulic power curve was used to determine the flow rate at the operating point. The hydraulic power was calculated using the flow rate and head values of the pump provided by the manufacturer (Figure 3). The greatest power delivered by the pump was considered the best operating point, corresponding to about 2.2 m^3 h^{-1}. The test results were used to compare the energy efficiencies for the operating point and also for about ±20% change in the flow rate, i.e. between 1.8 and 2.6 m^3 h^{-1}.

The system efficiencies were calculated and compared based on calculated hydraulic power and the measured total power needed for the constant speed, variable speed, and constant pressure operations.

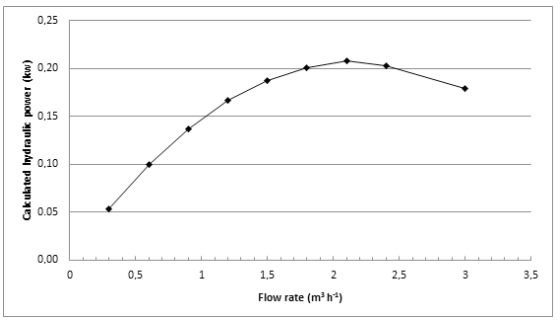

Figure 3- Calculated hydraulic power based on flowrate-head curve of the pump used in the study

Şekil 3- Araştırmada kullanılan pompanın debi-manometrik yükseklik eğrisine bağlı hesaplanan hidrolik güç değerleri

3. Results and Discussion

Systematic tests were conducted on a small powered irrigation pump to determine the energy efficient means of meeting the flow rate and pressure demands. The system had a small static lift (suction head of 0.6 m and discharge head of 0.85 m) along with a number of valves and elbows. Therefore, the measurements do not refer solely to the pump but to a small pumping station, consisting of some total static lift and losses due to the components used in the hydraulic system.

3.1. Constant pump speed tests

The power consumptions resulting from using an outlet valve, inlet valve, and by-pass valve to vary the flow rate were different. When the flow rate was reduced using the outlet valve, the discharge pressure of the pump increased remarkably, resulting in higher power consumptions at lower flow rates (Figure 4). The corresponding outlet and inlet pressures are shown in Table 1. The slope of the power consumption curve in Figure 4 suggested undesirable impact due to very rapid increase in the outlet pressure with decreasing flow rate.

With the use of the inlet valve to reduce the flow rate, the power consumption reduced gradually. However, the inlet vacuum pressure was somewhat high (-0.61 bar) even at the operating point and worsened (-0.70 bar) with a 20% decrease in the flow rate, posing hazards regarding cavitations. Thus, in terms of suction line design, the inlet valve can be used to vary the flow rate, but only in a very limited range below the operating point. When energy consumption was considered, the inlet valve was advantageous compared to the outlet valve. The power consumptions were 1140 W and 409 W at the operating point, and 1354 W and 387 W for a 20% reduction in the flow rate, respectively for the outlet valve and the inlet valve. The inlet valve could be used safely at flow rates higher than the operating point since the vacuum demand kept decreasing accordingly (Table 1).

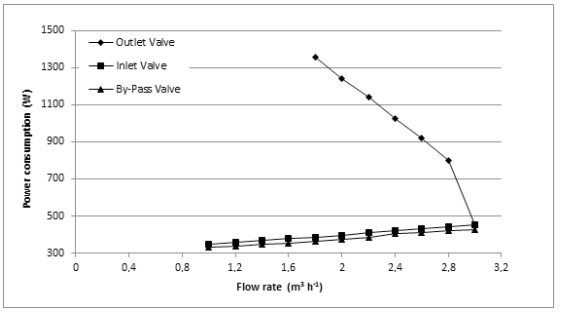

Figure 4- The effect of outlet, inlet, and by-pass valves on the relationship between flow rate and power consumption in constant speed tests

Şekil 4- Sabit pompa hızında basma hattı, emme hattı ve by-pass vanalarının debi-güç tüketimi ilişkisine etkisi

Table 1- Measured inlet and outlet pressures at different flow rates using flow regulating valves in different lines in the hydraulic system

Çizelge 1- Hidrolik sistemin farklı noktalarında debi ayar vanaları kullanılarak değişik debilerde ölçülen giriş ve çıkış basınçları

Flow rate ($m^3 h^{-1}$)	*Outlet valve*		*Inlet valve*		*By-pass valve*	
	Inlet pressure (bar)	*Outlet pressure (bar)*	*Inlet pressure (bar)*	*Outlet pressure (bar)*	*Inlet pressure (bar)*	*Outlet pressure (bar)*
3.0	-0.30	0.70	-0.30	0.70	-0.3	0.69
2.6	-0.23	3.46	-0.44	0.50	-0.3	0.55
2.2	-0.19	4.37	-0.61	0.33	-0.3	0.47
1.8	-0.12	4.96	-0.70	0.20	-0.3	0.25
1.4			-0.77	0.11	-0.3	0.13
1.0			-0.84	0.02	-0.3	0.05

Efficiency of a centrifugal pump usually decreases at a fast rate as the flow rate decreases. Additionally, electrical motor efficiency could reduce with increasing load on the motor. The back pressure on the pump due to the use of outlet valve could cause high loads on the electrical motor, drawing high current values resulting in a combined effect of low system efficiency. Therefore, the combined effect of low pump efficiency with low electrical motor efficiency should have resulted in excess power consumption during outlet valve adjustments, as shown in Figure 4.

The least amount of power was consumed in the case of by-pass valve, compared to the outlet and inlet valves. The energy savings (%) were tabulated in Table 2 to compare the effect of the three valves. Compared to the outlet valve, the energy consumption at the operation point was 64% and 66% less in the inlet and by-pass valve tests, respectively. The energy efficiency increased further for 20% decrease in the flow rate.

Table 2- Per cent energy saving comparisons of flow rate valves in different lines at constant pump speed

Çizelge 2- Sabit pompa hızında debi ayar vanalarının farklı noktalardaki yerleşiminin oransal enerji kazancı karşılaştırması

	Energy saving (%)		
Flow rate (m^3 h^{-1})	*Inlet valve versus outlet valve*	*By-pass valve versus outlet valve*	*By-pass valve versus inlet valve*
3	0	6	6
2.8	45	47	5
2.6	53	55	5
2.4	59	61	4
2.2	64	66	5
2	68	70	6
1.8	71	73	6
1.6			6
1.4			6
1.2			6
1			4

Table 2 demonstrates that compared to the operating point, the energy saving increased about 7% more, i.e.from 64% to 71% for 20% decrease in the flow rate using the inlet valve versus outlet valve. The additional saving in the case of by-pass valve was the same compared to the outlet valve.

The energy use for the inlet and by-pass valves seems to be similar in Figure 3, however by-pass valve was more energy efficient, about 4% to 6%, over the dynamic range of the flow rates tested (Table 2). Also, it was impracticable to reduce the flow rate using the inlet valve due to the rise in the suction pressure, from -0.6 to -0.7 bar. Therefore, even if the comparison is made only in terms of power consumption, the use of by-pass valve proves some advantage over the inlet valve. Since the by-pass valve did not increase the vacuum pressure (-0.3 bar) during the tests, it suggested a major advantage over the inlet valve.

Consequently, the location of a flow rate valve had a defining effect on energy efficiency. It was concluded that using an outlet valve was not an energy efficient method, which required the greatest power for operation. For a constant speed operation, i.e. when a VSD was not available on the pumping system, the best way of varying the flow rate was to use the by-pass valve. For a targeted flow rate, the outlet pressure need was a little lower with the inlet valve; however, the inlet pressure requirement was much higher. The overall effect of these two valves showed that the by-pass valve did not increase the vacuum pressure, minimized the potential suction line problems, decreased the outlet pressure, and needed the smallest energy requirement to vary the flow rate.

3.2. Variable pump speed tests

When all flow rate valves were open, decreasing the pump impeller speed from 2900 to 0 rpm reduced the power consumption due to the reduced major and minor losses in the hydraulic system (Figure 5). A gradual change was observed in power consumption in the VSD tests. The system had a small static lift, various valves, and elbows resulting in losses that affected the system behavior.

With no pressure demanding elements at the exit of the pipe system, the power consumption was about 100 W to 150 W at low flow rates. The power consumptions were 298 W, 230 W, and 177 W at flow rates of 2.6, 2.2, and 1.8 $m^3 h^{-1}$, respectively. Reducing the flow rate by 20% provided 23.2% less energy compared to the operating point. The savings in energy were 5.5% and 6.1% for the inlet and the by-pass valve.

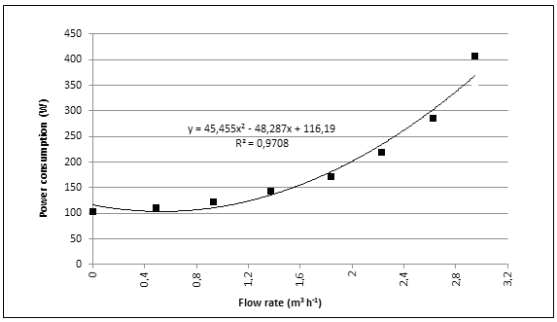

Figure 5- The effect of VSD on the relationship between flow rate and power consumption

Şekil 5- Değişken hız sürücüsünün debi-güç tüketimi ilişkisine etkisi

The energy use of VSD tests was compared to the constant speed tests (Table 3). Energy savings of VSD were 80%, 44%, and 41% compared to the outlet valve, inlet valve, and by-pass valve at 2.2 $m^3 h^{-1}$. Additional 7, 10, and 10% energy savings were calculated in favor of VSD with 20% reduction in the flow rate. Clearly, the VSD increased the dynamic range of the flow rates that can be adjusted without increasing the power consumption. As exclaimed in the previous sub-section, the most favorable method was to use the by-pass valve in the absence of VSD. Integrating the VSD system into the pumping station reduced the energy use further compared to the by-pass valve.

It was concluded that among the use of VSD, outlet, inlet, and by-pass valves, the most energy efficient method to vary the flow rate was the use of VSD since the desired flow rate could be obtained with the smallest energy consumption.

Table 3- Energy savings of VSD compared to the flow rate valves used in different lines of the system

Çizelge 3- Değişken hız kontrolünün sistemin farklı noktalarına yerleştirilen debi ayar vanalarına göre enerji kazancı

		Energy saving (%)		
Flow rate ($m^3 h^{-1}$)	*Power consumption (W)*	*VSD versus outlet valve*	*VSD versus inlet valve*	*VSD versus by-pass valve*
3	451	0	0	-1
2.8	377	53	15	11
2.6	298	68	31	27
2.4	262	74	38	35
2.2	230	80	44	41
2	201	84	49	46
1.8	177	87	54	51
1.6	155		59	56
1.4	138		63	60
1.2	124		65	63
1	113		68	66

3.3. Constant pressure tests

In some pumping operations, the flow rate may need to be varied while the pressure needs to be constant. To simulate such operation conditions two tests were conducted in this part of the study. The first test was conducted by using the VSD to obtain certain pressure values (4.0, 3.5, 3.0, and 2.5 bar) at varying flow rates. The flow rate was adjusted by using the VSD to achieve desired pressure head at the outlet.

The power consumption decreased as the flow rate was reduced at given outlet pressure settings (Figure 6). The power consumption changed at a slow rate at a given pressure setting as a result of varying the flow rate. The power consumption behaved accordingly as the pressure was reduced step by step from 4.0 bar to 2.5 bar at a given flow rate setting. For instance, at 4.0 bar the power consumption decreased from 1000 W to 760 W with

the flow rate reduction. Similarly, at a flow rate of 2.2 $m^3 h^{-1}$, the power consumption reduced from 940 W to 550 W as the pressure demand reduced from 4.0 bar to 2.5 bar.

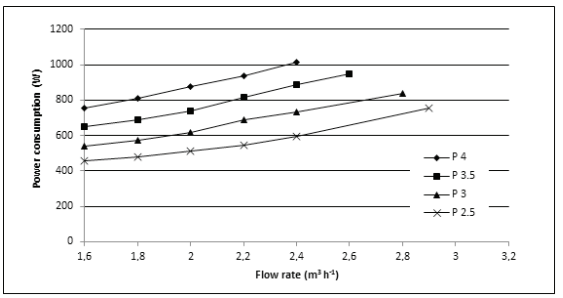

Figure 6- The effect of VSD on the relationship between flow rate and power consumption in constant pressure tests

Şekil 6- Sabit basınç testlerinde değişken hız sürücüsünün debi-güç tüketimi ilişkisine etkisi

The second set of constant pressure experiments were conducted by adjusting the flow rate with the by-pass valve, instead of the VSD. The power consumption fluctuated and did not vary proportionally with the flow rate (Figure 7). It was interesting to note that the power consumption was almost the same at a given pressure setting. For instance, the average power consumption at 4.0 bar was 1039 W with the measured results ranging from 1033 W to 1045 W. This may be explained by the fact that the pump always operated at the maximum speed during the by-pass valve tests whereas the pump impeller speed was reduced step by step during the VSD tests.

The differences in the energy consumption between the VSD and by-pass valve corresponded to 2-27%, 5-30%, 3-35%, and 0-37%, respectively for 4.0, 3.5, 3.0, and 2.5 bar operations (Table 4). The energy consumption difference was low at high flow rates showing more opportunities to save energy as the flow rate needs to be lowered. Thus, the VSD was more advantageous compared to the by-pass valve for varying the flow rate at constant pressure applications as well.

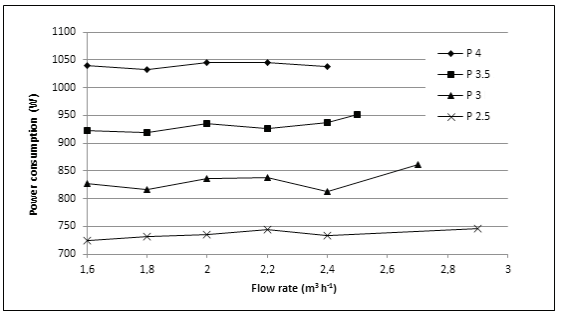

Figure 7- The effect of by-pass valve on the relationship between flow rate and power consumption in constant pressures tests

Şekil 7- Sabit basınç testlerinde by-pass vanasının debi-güç tüketimi ilişkisine etkisi

According to literature, field experiments under different conditions resulted in 33% energy saving by using variable pump speed (Barutçu et al 2007) and power demand from the irrigation system dropped from 291 kW down to 175 kW, corresponding to 40% reduction in electric consumption for one pumping unit in a big pumping station (ABB 2013). In another study, installing VSDs to pumping stations resulted in 27% and 35% less energy consumptions in two different districts in an attempt to optimize energy consumption (Lamaddalena & Khila 2012). The energy savings were similar in the case of a small centrifugal pump, as shown in the current study. When there was a VSD in the system, energy savings at the operating point (2.2 $m^3 h^{-1}$) were 44% and 41% compared to the inlet valve and the by-pass valve, respectively. Using the variable speed drive, 20% decrease in the flow rate further reduced the energy consumption by 10% compared to the operating point, making the VSD a very efficient means of flow rate regulation.

When the irrigation pump is not equipped with a VSD, an inlet valve could be used within a limited flow rate range, and a by-pass valve within a wider flow rate range compared to the use of an outlet valve. More than 60% of the energy could be saved at the operating point if a by-pass or inlet valve was used instead of an outlet valve. Furthermore, the energy saving of a by-pass valve was better (5%) than the inlet valve.

Table 4- Energy saving comparisons between VSD and by-pass valve for constant pressure tests

Çizelge 4- Sabit basınç testlerinde değişken hız kontrolü ile by-pass vanası arasında enerji kazancı karşılaştırması

Outlet pressure (bar)	*Flow rate ($m^3 h^{-1}$)*	*Power consumption (W)*		*Energy saving (%)*
		VSD	*By-pass valve*	*VSD versus by-pass*
4	2.4	1014	1038	2
	2.2	936	1045	10
	2	875	1045	16
	1.8	812	1033	21
	1.6	757	1040	27
3.5	2.6	950	952	0
	2.4	887	937	5
	2.2	818	926	12
	2	738	936	21
	1.8	689	920	25
	1.6	651	924	30
3	2.8	838	861	3
	2.4	734	814	10
	2.2	688	838	18
	2	616	836	26
	1.8	575	817	30
	1.6	540	828	35
2.5	3	758	746	-2
	2.4	596	734	19
	2.2	546	745	27
	2	510	736	31
	1.8	479	732	35
	1.6	457	724	37

In the above discussion, the interpretation of the experimental power consumption values for the given operating conditions allowed to determine the least energy consuming flow rate control method. In a pumping system, the system efficiency is affected by both the input (total power consumed) and the output (hydraulic power). The use of outlet valve caused back pressures exerted on the pump impeller, which was the reason for observing high pressure values in the discharge line during constant pump speed tests. Accordingly, the hydraulic power of the pump was the highest for the outlet valve tests compared to the other options. It seems misleading to note that the bigger hydraulic power obtained in outlet valve adjustments provided better system efficiencies (Table 5). The aim in these tests was to simulate unpressurized fluid flow and to supply the flow rate values with the minimum operational costs. For practical purposes, high pressure head was not needed but the ultimate effect of the outlet valve adjustment was to increase the power consumption profoundly compared to the other means of controlling the flow rate (Figure 4). When the inlet and outlet valves in constant speed tests were compared, the inlet valve was more efficient. This could be due to the fact that more energy is dissipated in order to pass the water through the pump and the by-pass line compared to the reduced mass flow through the pump in the case of inlet valve operation. When the inlet and by-pass valves were compared with the VSD, the system efficiency of VSD was higher and rapidly decreased with the reduction in the flow rate in all cases. Generally the system efficiency was low at constant and variable speed operations and were 14.1%, 11.2%, and 15.1% for the inlet valve, by-pass valve, and the VSD at 2.2 $m^3 h^{-1}$. These findings prove that the pump and the hydraulic system do not match well for low pressure operations unless equipped with VSD.

Table 5- System efficiencies in constant and variable speed tests

Çizelge 5- Sabit ve değişken hız testlerinde sistem verimleri

Flow rate ($m^3 h^{-1}$)	*System efficiency (%)*			
	Outlet valve	*Inlet valve*	*By-pass valve*	*VSD*
3	18.7	18.7	18.7	18.7
2.8	30.7	17.7	17.5	20.9
2.6	29.3	15.9	15.1	23.8
2.4	27.1	15.2	12.8	19.0
2.2	24.7	14.2	11.2	15.1
2	21.7	12.9	9.3	10.3
1.8	19.0	11.8	7.7	8.6
1.6		10.7	6.1	6.4
1.4		9.4	4.9	3.4
1.2		9.0	3.8	1.6
1		6.9	2.9	0.2

Constant pressure tests demonstrated better system efficiencies compared to the constant speed tests both for the by-pass valve and the VSD (Table 6). The calculated system efficiencies were roughly 20-27% and 25-30%, respectively for the by-pass valve and the VSD. More specifically, the system efficiency of the five different flow rates in Table 6 at 4.0, 3.5, 3.0, and 2.5 bar were 26.0-29.1% and 21.3-25.5%, respectively for the VSD and the by-pass valve. Eventually, the results were more favorable for the VSD operations and the degree of benefit in system efficiency depends on the pressure and flow rate demand. As expected, the system efficiency decreased with decreasing flow rate at a set value of outlet pressure. Based on the results and discussions, it may be argued that a constant speed pump cannot be operated over a wide flow rate ranges due to low efficiencies encountered as a result of changes in the flow rate. Therefore, in systems requiring wide dynamic flow rate ranges, it is best to install a VSD in the system.

Table 6- System efficiencies in use of the VSD and the by-pass valve in constant pressure tests

Çizelge 6- Sabit basınç testlerinde değişken hız sürücüsü ve by-pass vanası kullanımında sistem verimleri

Pressure (bar)	*Flow rate ($m^3 h^{-1}$)*	*System efficiency (%)*		
		VSD	*By-pass valve*	*Difference*
	2.4	28.0	27.3	0.6
	2.2	27.7	24.8	2.9
4.0	2	26.6	22.6	3.9
	1.8	25.7	20.6	5.0
	1.6	24.5	18.2	6.2
	2.4	28.3	26.9	1.4
	2.2	28.2	25.0	3.2
3.5	2	28.3	22.3	6.0
	1.8	26.9	20.5	6.4
	1.6	18.1	18.1	0.0
	2.4	29.8	31.1	-1.3
	2.2	28.9	27.7	1.2
3	2	28.7	25.2	3.4
	1.8	27.5	22.9	4.6
	1.6	26.0	20.4	5.6
	2.4	31.3	25.6	5.7
	2.2	31.4	23.1	8.3
2.5	2	29.5	21.4	8.2
	1.8	27.8	19.3	8.4
	1.6	25.8	17.4	8.4

It was concluded that, the use of VSD should be the first preference followed by the use of a by-pass valve for varying the flow rate of a centrifugal pump. The use of a suction valve may be allowed for flow rates above the operating point but could be used very cautiously just below the operating point due mainly to rapidly increasing vacuum pressure in the suction line.

4. Conclusions

The followings could be summarized and concluded as result of this study. A small centrifugal pumping station was used to investigate the energy efficiencies of using flow rate valves in different lines and the VSD. When there was no VSD, the most energy efficient way to deliver different flow rates was to use the by-pass valve with 66% more energy saving than the outlet valve and 5% more than the inlet valve. The use of the inlet valve, albeit energy efficient compared to the outlet valve, could create suction line hazards. VSD provided the most energy efficient operations with 41% less energy consumption compared to the by-pass valve. As the flow rate demand of the irrigation system decreased, the VSD became even more efficient compared to the by-pass valve for regulating the flow rate. In constant pressure experiments, VSD provided 2% to 37% reductions in the energy consumption compared to the by-pass valve, depending on the pressure and flow rate demand. VSD technology should be favored because of its significant impact on increasing the energy efficiency in meeting different flow rate and pressure demands. If a VSD is not available, by-pass technique should be preferred over the inlet valve and outlet valve. The VSD provided better system efficiency compared to the by-pass valve during constant pressure operations, respectively with 26-29.1% and 21.3-25.5%.

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A Variable Extractant Providing Method for On-The-Go Soil Nitrate Analysis Systems

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ABSTRACT

The objective of this study was to develop and test an automated extractant providing method utilizing pressurized air in a laboratory setting. Pressurized air was applied to extractant holder filled with extractant. An electro-pneumatic regulator valve was used to regulate the air pressure at 344.75, 551.6, and 758.45 kPa using an analog electrical signal. A two-position solenoid valve that was controlled via Labview software according to pre-specified time interval was used to provide a high pressure pulse at known durations to the extractant column inside the holder. The mass of extractant transported to the mixing unit during a single air pulse was measured and recorded for all treatments in the experimental design. Analysis of variance was performed to determine significance of each variable, namely pulse duration and air pressure. Step wise linear regression analysis was used to develop calibration models for the prediction of extractant mass. The only significant factor was pulse duration while pressure was insignificant (α= 0.05) on extractant mass for all treatments. Pulse duration was used to find a model to predict extractant mass, and provided a very good prediction (R^2= 0.99) at fixed pressure setting. Laboratory test results proved that pressurized air was effective in obtaining known quantity of extractant. The electro-pneumatic method was capable of obtaining and transporting a precise amount of extractant needed for on-the-go soil nitrate analysis within a short time (less than 100 ms) with a coefficient of variation of less than 3%. It was concluded that the electro-pneumatic method was a viable candidate to be a precise variable extractant supply method for on-the-go soil analysis system.

Keywords: Real-time soil analysis; Extractant provider; Electro-pneumatic method; Agricultural automation

Gerçek Zamanlı Nitrat Analiz Sistemleri İçin Değişken Düzeyli Ekstraktant Sağlama Yöntemi

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ÖZET

Bu çalışmanın amacı, basınçlı hava ile çalışan bir otomatik ektstraktan sağlama yöntemi geliştirmek ve laboratuvar koşullarında test etmektir. Hazne içindeki ekstraktant yüzeyine basınçlı hava uygulanarak hazne basınçlandırılmıştır.

Hava basıncını, bir elektriksel analog sinyal aracılığı ile 344.75, 555.1 ve 758.45 kPa basınçlarında düzenleme amacıyla elektro-pnömatik bir valf kullanılmıştır. Puls süresini kontrol etmek için Labview yazılım programı aracılığı ile denetlenebilen iki-pozisyonlu bir selenoid valf kullanılmıştır. Deneme desenindeki her bir uygulama için puls süresinde elde edilen ekstraktant kütlesi ölçülerek kaydedilmiştir. Her bir değişkenin (puls süresi ve hava basıncı) önemlilik derecesini belirlemek amacıyla varyans analizi ve ekstraktant miktarının tahmini için ise model geliştirmede doğrusal regresyon yapılmıştır. İstatistiksel analizler sonucunda, bütün uygulamalarda extraktan miktarı üzerine sistem hava basıncının etkili olmadığı, sadece puls süresinin etkili olduğu belirlenmiştir (α= 0.05). Ekstraktant miktarı tahmini için modelde sadece puls süresi kullanılmış ve tahmin sonuçları sabit sistem basınç ayarlarında oldukça iyi çıkmıştır (R^2= 0.99). Laboratuvar deneme sonuçları, istenilen miktarda ekstraktan sağlamada, basınçlı havanın oldukça etkili olduğunu ortaya koymuştur. Elektro-pnömatik ekstraktant sağlama yönteminin gerçek zamanlı nitrat analiz sistemleri için gerekli kısa sürelerde (100 ms'den daha az) ve gerekli hassasiyette (% 3'ten daha düşük değişkenliklerde) ekstraktan sağlama ve iletme kabiliyetine sahip olduğu belirlenmiştir. Elektro-pnömatik metodun, değişken-düzeyli hassas ekstraktan sağlama yöntemi olarak uygulamada kullanılmaya aday bir yöntem olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Gerçek-zamanlı toprak algılama; Ekstraktant sağlama; Elektro-pnömatik metot; Tarımsal otomasyon

1. Introduction

The goal of precision agriculture is to optimize agricultural production by applying production input such as fertilizers and pesticides on a point-by-point basis within a field. Therefore, spatial variation across the field has to be accurately measured by collecting data on a finer resolution for success of precision agriculture. Soil nitrate measurement is an important concept to optimize agricultural production and to decrease environmental impact due to excessive fertilization. For this task several different methods have been studied by scientists during the last decades. Dalal & Henry (1986) measured total nitrogen (N) in soils with some success (R^2>0.92) by using Near Infrared Reflectance (NIR) reflectance method in the range of 1100 to 2500 nm; however, the prediction was very poor for lower nitrate concentrations and total N prediction was not possible for a wide range of soil colors. Upadhyaya et al (1994) investigated the feasibility of determining soil mineral-N using NIR absorbance data in the 1000 to 2400 nm range. They used both partial least squares regression (PLS) and Fast Fourier (FFT) techniques to analysis data. They reported that NIR absorbance data could be used to predict the amount of soil mineral-N in the soil samples if the correlation was blocked by moisture content (air dry, 10%, 15%). The standard prediction error was also reported high. McGrath & Skotnikov (1996) developed an integrated system for determining optimum site-specific fertilizer application. Their system consisted of a soil sampler, a sample preparation unit, a laboratory workstation for soil analysis, and an expert software system to convert the soil analysis and supporting data into a fertilizer application program. The sampler collected samples automatically across the field and packaged them in plastic bags that were connected to form a long band. The automated laboratory workstation set up near the field analyzed the banded samples. The initial preparation of automated workstation required 90 minutes and then samples could be analyzed at a rate of 1 sample per minute. The analysis results were then input into an expert system to determine fertilizer recommendations. However, this system seems complicated and time consuming since soil sampling and analysis are done independently.

Adsett & Zoerb (1991) developed a real time nitrate sensing system. Their system consists of soil sampler, a device to collect soil samples, a mixing system to mix and extract a soil solution, and a data and control system to evaluate the nitrates in solution. Ion selective electrode was used for nitrate measurement. In the field test, the sampling component, which used a slot cutter to collect soil from the ground was capable of delivering a soil sample within three seconds; however, the system

did not produce repeatable results, only 40% of the nitrate readings were correct, and mixing and filtration system required improvement. Extraction system performance was affected by the soil consistency, which varied with soil type, relative speed, compaction, and soil moisture content. They concluded that ion-selective electrode technology is adaptable to automated field monitoring of soil nitrate levels. Adsett et al (1999) built and tested an automated, on-the-go; soil nitrate monitoring system (NMS) consisted of a soil sampler, a soil metering and conveying unit, a nitrate extraction and measurement, and a control unit. The soil sampler employs a woodsaw blade powered by a hydraulic motor. Nitrate ion selective electrode (ISE) was used to sense nitrate concentration. A field calibration process predicted soil nitrate levels within 10 s after soil sampling. Based on laboratory tests, nitrate level could be predicted with 95% accuracy after 6 s of measurement for a silty clay loam soil. They concluded that overall laboratory performance of NMS was very satisfactory; however, more work need to be done before using the system in the field.

Ion-selective field-effect transistors (ISFET) technology is a newer development that consists of a membrane, which responds to nitrate ions. It is based on the same chemical principles as ISE. Birrell & Hummel (2001) investigated the use of ion-selective field-effect transistors (ISFET) in conjunction with flow injection analysis (FIA) for use as a system for real-time soil nitrate sensing. They reported that the multi-ISFET/FIA system was successful to measure soil nitrate within 1.25 s in manually extracted soil extracts (R^2>0.9) using washout time of 0.5 s an injection time of 0.75 s. Nitrate ion selective field effect transistors (ISFETs) technology promises a convenient and fast method for on-the-go soil nitrate measurement. The nitrate measurement system requires a very small sample volume to minimize extractant use. They concluded that the rapid response and low sample volume requirement by the multi-sensor ISFET/FIA system makes it a strong candidate for use in real time soil nitrate sensing. However, automated soil extractant system requires considerable improvement.

Continuous soil sampling must become faster with increasing precision and accuracy in order to automate overall nitrate measurement process in the field. The collection of a known mass of soil, to maintain a constant repeatable soil/extractant ratio, is critical to the success of the complete nitrate analysis system. Yıldırım et al (2006) developed an automated electro-pneumatic soil sampling method for providing fast, reliable and accurate soil samples for real-time soil analysis. Laboratory results indicated that it was possible to obtain consistent soil samples within a short time period (less than 36 milliseconds) across a range of soil texture and moisture levels.

After collecting a soil sample the next step is to mix a known mass of soil sample with known amount of extracting solution, filter the slurry and then present the soil filtrate to the sensor to determine the nitrate concentration of the filtrate. It is important that the soil/extractant ratio is fixed and repeatable, or that this ratio can be accurately determined, to calculate the in-situ soil nitrate concentration. Therefore accurate extractant amount has to be supplied according to known soil mass collected by an automated soil sampler.

The objective of this study was to develop and test an extractant providing method based on pressurized air for soil analysis systems. Overall objective was to develop a real time soil macro nutrient measurement system based on soil sampling using ISE/ISFET sensor technology. This paper reports a variable extractant providing method which can be integrated into a nitrate analysis system. The effects of applied air pressure and pulse duration on extractant mass were also investigated.

2. Material and Methods

2.1. Equipment

A desktop computer was used to coordinate the operation of laboratory test set up of the electro-pneumatic extractant providing method (Figure 1). A labview program for control was developed and used to run the system automatically. The Electro-

Pneumatic Regulator (EPR) valve (ITV3000 series, SMC, Inc.,) was used to regulate the air pressure. The valve was capable of regulating the pressure from 5 to 900 kPa in proportion to an analog electrical signal. A two-position, direct operated, normally closed solenoid valve (SMC, VX22 series) controlled by Labview programming software according to pre-specified time interval provided a known high-pressure pulse duration to the extractant column inside a holder. When the valve initiated, a quantity of extractant was conveyed into the mixing unit along a delivery pipe. The mass of extractant transported to the mixing unit during a single air pulse was measured and recorded for all treatments in the experimental design.

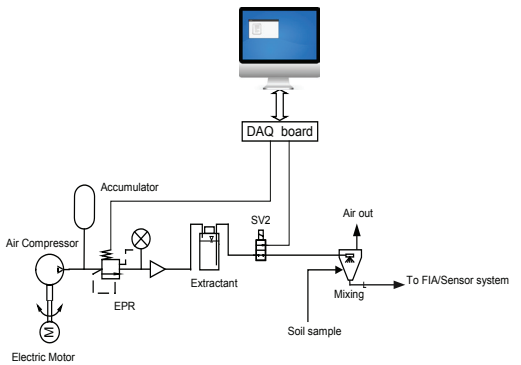

Figure 1- Schematic diagram of the electro-pneumatic extractant supply method for real-time nitrate sensing systems

Şekil 1- Gerçek-zamanlı nitrat ölçme sistemleri için otomatik ekstraktant sağlama yöntem şematiği

2.2. Experimental design and analysis

The randomized, complete block experimental design included three levels of pulse duration (30, 50, and 70 ms) and three levels of air pressure (low: 344.75; medium: 551.60; and high: 758.45 kPa), resulting in 9 different treatments, with five replicates of each treatment. Three levels of pulse were used to determine the effect of pulse duration on the mass of extractant obtained while the levels of air pressure were used to determine the effect of air pressure on the mass of extractant obtained. To determine the significance of each variable (pulse and air pressure) on the measured extractant mass, analysis of variance was performed using Matlab Statistics Toolbox for each extractant mass individually. Air pressure and pulse duration were the independent variables, with extractant mass as the response (dependent) variable. Stepwise Linear Regression was performed at each pressure level and pooled data using Matlab Statistics Toolbox to model the relationship between the extractant mass and the independent variables (air pressure and pulse duration). The statistically significant (α= 0.05) main variables and their interactions were included in the final regression model. Water was used as an extractant during the tests.

3. Results and Discussion

The laboratory tests were conducted to investigate the effect and significance of air pressure and pulse duration on the quantity of extractant mass obtained. The mass of extractant transported to the container during a single air pulse was measured and recorded for all treatments in the experimental design. The mean extractant mass and standard deviations for all treatments studied in this experiment are given in Table 1. Mean extractant mass varied from 0.52 to 5.73 g depending on levels of pulse duration and applied air pressure. The standard deviation varied from 0.01 to 0.06 g, and the coefficient of variation (CV) varied from 0.54% to 2.89% depending on the pulse duration and applied air pressure levels.

Table 1- Mean extractant mass (g) and standard deviation for all laboratory test treatments

Çizelge 1- Deneme desenindeki tüm uygulamalar için ortalama ekstraktant ağırlığı (g) ve standart sapma değerleri

	Pressure		
Pulse	*344.75 kPa*	*551.6 kPa*	*758.45 kPa*
30 ms	1.05 (0.03)	1.02 (0.01)	0.52 (0.01)
50 ms	2.77 (0.06)	3.24 (0.02)	2.97 (0.06)
70 ms	4.72 (0.06)	5.69 (0.03)	5.73 (0.06)

3.1. Effect of pulse duration on extractant mass

The results of statistics analysis showed that pulse duration had a significant effect (α= 0.05) on the extractant mass for all pressure levels. The mean mass values at different pulse durations for each air pressure level are shown in Figure 2. Mean extractant mass varied from 0.52 to 5.73 g, depending on pulse duration and air pressure levels. An increase in pulse duration level yielded a corresponding increase in the extractant mass for all pressure levels. The standard deviations (shown by the error bars) represent the overall standard deviation. This included the variance due to the difference in treatment means (pulse duration and air pressure) and random error. The standard deviations were less than 0.06 for all pressure levels.

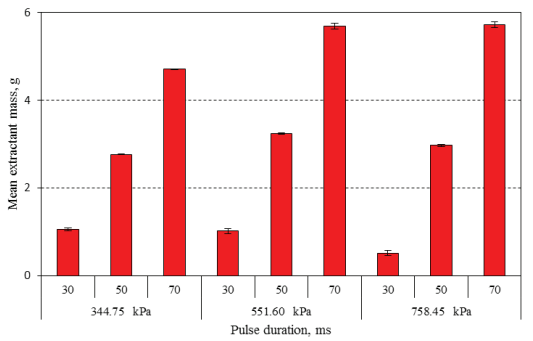

Figure 2- Pulse duration effect on extractant mass for different pressure levels (n= 45), error bars represent standard deviations

Şekil 2- Farklı sistem basınçlarında puls süresinin ekstraktant kütlesi üzerine etkisi

3.2. Effect of air pressure on extractant mass

The statistics analysis suggested that air pressure had no significant effect (α= 0.05) on the extractant mass for all pulse duration levels. The mean mass values at different pulse duration for each air pressure level are shown in Figure 3. An increase in pressure level did not resulted in a corresponding increase in the extractant mass for all pulse durations. The standard deviations (shown by the error bars) represent the overall standard deviation. Mean extractant mass varied from 0.52 to 5.73 g, depending on pulse duration and air pressure levels. The standard deviations were less than 0.06 g for all pulse duration levels.

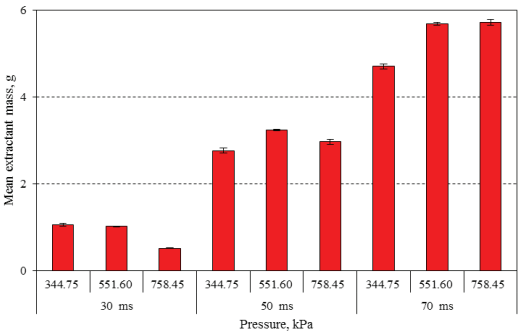

Figure 3- Pressure effect on extractant mass for different pulse durations (n= 45) error bars represent standard deviations

Şekil 3- Farklı puls sürelerinde sistem basıncının ekstraktant kütlesi üzerine etkisi

3.3. Linear models for extractant prediction

Stepwise linear regression analysis was used to develop the calibration models for prediction of extractant mass for each pulse duration level and pooled data. In regression analysis, all parameters were tested including their interactions. The final models only included parameters that were significant at the 5% level. In all cases, pulse duration was the only prediction variable of extractant mass and modeled to predict amount of extractant. The prediction model results for low, medium, high pressure levels, and pooled data are shown in Table 2. Pulse duration provided a very good prediction of extractant mass for all pressure levels, and pooled data. In the prediction model for the low level of pressure, the root mean square error (RMSE) was 0.076 g (mean extractant mass= 2.84 g), and the correlation of determination (R^2) was 0.99. High predictive capability of regression was obtained for medium level of pressure (RMSE= 0.062, R^2= 0.99). Similarly, the good predictive capability of regression was obtained for high level of pressure (the mean extractant mass= 3.07 g, RMSE= 0.093,

and R^2= 0.99). In the case of pooled data, the RMSE was 0.342 g (R^2= 0.97 and the mean extractant mass= 3.08 g). Figure 4 shows the correlation between the estimated extractant mass and the actual measured sample mass at low, medium, high pressure levels, and for pooled data. Pulse duration provided a very good prediction of mass of extractant for all applied pressure levels, and pooled data.

Table 2- The regression model results for prediction of extractant mass for different pressure levels, and pooled data

Çizelge 2- Farklı sistem basınçlarında ekstraktant ağırlığı tahmini için regresyon model sonuçları

Pressure (kPa)	R^2	*RMSE (g)*	*Mean mass (g)*	*Model parameters (a)*
344.75	0.99	0.076	2.84	Pulse
551.6	0.99	0.062	3.32	Pulse
758.45	0.99	0.093	3.07	Pulse
Pooled data	0.97	0.342	3.08	Pulse

a, the final models only included parameters significant at the 5% level

The linear model for the pooled data is shown as Equation 1.

$$E_{mass} = -2.566 + 0.11287 P_L \quad (1)$$

Where; E_{mass}, extractant mass (g) and P_L, pulse duration (ms)

The model indicated that the amount of extractant was only depended on pulse duration. This information withdrawn from the model offered several advantages; such as simplicity, fast response, digital controllability, accuracy and precision to allow automated extractant supply for complete real-time soil analysis system.

4. Conclusions

An electro-pneumatics method that utilizes pressurized air to provide precise amounts of extractant for on-the-go soil analysis was developed and tested under laboratory conditions. The results showed that electro-pneumatics method was capable of obtaining precise extractant mass within

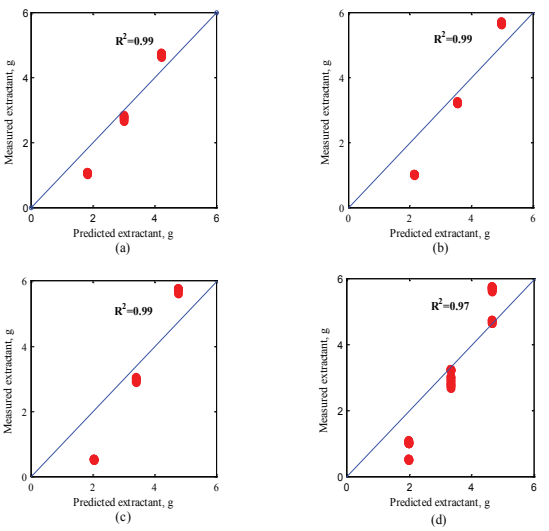

Figure 4- The correlation between measured and predicted extractant mass: a, at low pressure (344.75 kPa); b, at medium pressure (551.60 kPa); c, at high pressure (758.45 kPa); and d, for pooled data (344.75, 551.60, 758.45 kPa; n= 45)

Şekil 4- Tahmin edilen ve ölçülen ekstraktant ağırlığı arasındaki korelasyon: a, düşük basınçta (344.75 kPa); b, orta basınçta (551.60 kPa); c, yüksek basınçta (758.45 kPa); d, tüm basınç değerlerinde (344.75, 551.60, 758.45 kPa; n= 45)

30 to 70 ms with a CV ≤ 3% for all treatments in the experimental design regardless of pressure level. The mass of extractant was only affected by one variable, namely pulse duration. This dependency on one variable provided the flexibility to maintain a consistent soil/extractant ratio by changing pulse duration as soil sample mass varies and allowed easy automation of overall soil sensing system. The electro-pneumatics extractant providing method has the potential to be used in a real-time soil nutrient analysis system based on soil sampling.

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Türk Saanen Keçilerinde Elle Sağım ile Makineli Sağımın Süt Verimi, Süt Bileşenleri ve Kalıntı Süt Bakımından Karşılaştırılması

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ÖZET

Süt sığırlarına benzer şekilde uzun laktasyon süresine sahip olan süt tipi keçilerin makineli sağımı hakkında ülkemizde önemli ölçüde bilgi üretimine gereksinim bulunmaktadır. Bu çalışmada, Türk Saanen keçilerinde makineli sağım ve elle sağım, süt verimi ve süt bileşenleri bakımından karşılaştırılırken, ayrıca makineli sağımda memede kalan "kalıntı süt" miktarı ve bileşenleri incelenmiştir. Çalışma, laktasyonlarının 5. ayında bulunan 3-4 yaşlı 24 baş keçi üzerinde yürütülmüştür. On altı baş keçi elle ve makine ile sağımın yapıldığı sekizer başlı iki gruba ayrılırken, diğer sekiz baş keçiden makine ile sağımdan sonra memede kalan süt elle sağılarak alınmıştır. Süt bileşenleri Milk-Lab Minor süt analiz cihazıyla tespit edilirken, yağ analizi ayrıca Gerber yağ analiz cihazı ile de yapılmıştır. Keçilerde sağım denetimlerinde periyot başına belirlenen süt verimleri elle (1.073 L) ve makineli sağımda (1.095 L) birbirine benzer bulunmuştur (P= 0.8807). Sabah sağımında akşam sağımına göre 140 mL daha fazla süt alınırken, akşam sağımında elde edilen süt, daha yüksek oranda süt bileşenlerine sahip olmuştur (P<0.0001). Elle sağımda elde edilen süt, makineli sağımda elde edilen süte göre daha yüksek oranda süt bileşenlerine sahip olurken, Milk-Lab Minor ile yapılan yağ analizi önemli ölçüde farklılaşmıştır (P= 0.0317). Makineli sağımdan sonra 224-262 mL ve ortalama % 22.6 kalıntı süt elde edilmiştir. Kalıntı sütteki süt yağı, makineli sağımdaki süte göre akşam sağımında % 43-46, sabah sağımında ise % 75 daha fazla orana sahip olurken, yağsız kuru madde (YKM), protein ve laktoz oranları kalıntı sütte % 3-4 daha düşük olmuştur. Bu anlamda özellikle makineli sağımdan sonra kalıntı sütün elle sağımla memeden alınması veya makineli sağımda memede bu ölçüde sütün kalmaması adına sağım ünitesinde düzenlenmelere ihtiyaç olduğu belirlenmiştir. Süt yağı Gerber analizinde ortalama % 3.63 olurken, Milk-Lab Minor cihazı ile ortalama % 3.80 olarak belirlenmiştir (P<0.0001). Ayrıca Gerber ile Milk-Lab Minor yağ analiz değerleri arasında pozitif bir korelasyon katsayısı olduğu görülmüştür (r= 0.91; P<0.0001).

Anahtar Kelimeler: Türk Saanen; Akşam sağımı; Sabah sağımı; Kalıntı süt; Süt yağı

Comparison of Milk Yield, Milk Composition and Residual Milk of Machine and Hand-Milked in Turkish Saanen Goats

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ABSTRACT

Dairy goats have quite long lactation periods like dairy cows, but there is significant lack of knowledge and information about machinery milking of goats. The present study was conducted to compare milk yields and milk components in manual and machinery milking of Turkish Saanen goats and to investigate the amount of "residual milk" and milk components of machinery milking. Experiments were carried out on 24 goats aged 3-4 years and on the 5th month of their lactation period. Of these goats, sixteen were separated in groups of eight goats. The first group was hand-milked and the other group was milked with a milking machine. The remaining eight were also milked with a milking machine and then the residual milk in udders was hand-milked. Milk components were analyzed with Milk-Lab Minor milk analysis device and fat analysis was carried out with Gerber fat analysis device. Milk yields of milking periods were similar in hand milking (1.105 L) and machinery milking (1.095 L) (P= 0.8807). While morning milking had 140 mL more milk than evening milking, evening milk had higher component values than morning milk (P<0.0001). Hand milk also had higher component values than machinery milk and significant differences were observed in fat values determined with Milk-Lab Minor (P= 0.0317). Residual milk after machinery milking was found to be 224-262 mL and 22.6%. Milk fat ratio of residual milk was 43-46% higher than evening machinery milk, 75% higher than morning machinery milk and residual milk had 3-4% higher non-fat dry matter (NFDM), protein and lactose contents. Thus, residual milk after machinery milking should manually be milked up and arrangements should be made on milking units to reduce such high amounts of residual milk. While milk fat ratio was 3.63% in Gerber analysis, the value was observed as 3.80% in Milk-Lab Minor device (P<0.0001). A positive correlation coefficient was observed between Gerber and Milk-Lab Minor fat values (r= 0.91; P<0.0001).

Keywords: Turkish Saanen; Evening milking; Morning milking; Residual milk; Milk fat

1. Giriş

Önceki yıllarda Akdeniz ülkelerinde genellikle ekstansif koşullarda süt üretimi amaçlı keçi yetiştiriciliği yapılırken (Morand-Fehr et al 1983), son yıllarda dünyada ve ülkemizde entansif süt keçiciliği yaygınlaşmaktadır. Bu üretimde sütün tamamının hijyenik koşullarda ve hayvanın meme dokusuna zarar vermeden sağılması öncelikli amaçtır. Süt keçiciliğinde süt kalitesi, zaman ve iş gücü tasarrufu gibi sebeplerden dolayı makineli sağımın elle sağıma göre avantajlı olduğu bilinmektedir (Boyazoglu & Morand-Fehr 2001; Caroprese et al 2007; Tölü & Savaş 2008). Ancak makineli sağımda da makinenin basınç ve pulsasyonu, hijyen koşulları, memeden sütün tamamen alınması gibi konularda sıkıntılar oluşabilmektedir. İtalya'da keçi işletmelerinde yapılan bir çalışmada, makineli sağımın daha hijyenik olduğu, ancak az sayıdaki hayvanın elle sağıldığı işletmelerde de somatik hücre sayısının daha az olduğu belirlenmiştir (Delgado-Pertinez et al 2003).

Çiftlik hayvanlarında süt verim denetimlerindeki günlük süt verimleri sabah ve akşam süt ölçümlerinin toplamından oluşmaktadır. Süt verim kontrolü ölçümlerinde genellikle sabah sağımındaki süt miktarının akşam sağımındaki süt miktarından daha yüksek olduğu belirlenmiştir (Fuertes et al 1998; Katanos et al 2005; Pala & Savaş 2006). Ayrıca akşam sağımı ile sabah sağımı arasındaki fark, süt verimi yanında süt içerikleri bakımından da farka neden olabilmektedir (Fuertes et al 1998; Salama et al 2003).

Makineli sağım ile elle sağım karşılaştırmasında işletme ekonomisini ilgilendiren en önemli noktalar, süt verimi ve süt bileşenlerinin farklılık gösterebilmesidir. Bu konudaki çalışmalar daha ziyade koyunlarda yapılmıştır. Örneğin, Portekiz menşeli Beira Baixa koyunlarında ve Yunaninstan menşeli Boutsiko koyunlarında elle sağıma göre makineli sağım lehine süt verimi istatistiksel olarak önemli seviyede daha yüksek rapor edilmiştir (Carreiro et al 1989; Sinapis 2007). İspanyol Manchega ırkı koyunlarda yapılan diğer bir çalışmada ise, iki sağım tipinde süt verimleri birbirlerine yakın seviyede belirlenirken (Linares et al 1984), yine İspanyol Churra ırkı koyunlarda

yapılan çalışmada ise, önemsiz olmakla beraber elle sağımda biraz daha fazla süt elde edilmiştir (de la Fuente et al 1997).

Süt bileşenleri bakımından makineli sağım ile elle sağım arasındaki değişebilen en önemli farklılık süt yağında gözlenmektedir (Labussiere 1988; Millogo et al 2009). Bu anlamda öncelikle sağlıklı bir sağım süreciyle memedeki sütün tamamının alınması gerekmektedir (Rushen et al 1999; Tölü & Savaş 2008). Memede kalan süt miktarı artıkça süt yağ oranı da artmaktadır. Makineli sağımda memede kalan ve elle sağılarak alınan süt "kalıntı süt" olarak tanımlanmaktadır. Normal bir sağımda sütün % 68'ini bulabilen kalıntı sütün (Anderson et al 1968) yağ içeriğinin, memeden tamamen alınan süte göre % 19-46 oranında daha yüksek olduğu belirlenmiştir (Labussiere 1988; Millogo et al 2009). Atlarda makineli sağımda elle sağıma göre önemli ölçüde daha yüksek oranda süt yağı tespit edilmiştir (Caroprese et al 2007). Dolayısıyla istenilen düzeyde süt yağı oranı ve laktasyon sonunda istenilen süt yağ veriminin elde edilmesi için memede kalan sütün tamamının uygun sağım yöntemi ile alınması gerekmektedir.

Süt yağının belirlenmesinde tüm bileşenlerin analiz edildiği cihazlar kullanıldığı gibi, sadece süt ve peynir yağı analizinde kullanılan ve dünyada en güvenilir yöntemlerden biri olan Gerber cihazı ile süt yağı analiz edilebilmektedir. Saanen ve Alpine keçilerinin süt yağı analizlerinde Gerber ve Foss ile yapılan analiz sonuçlarının birbirlerine yakın seviyelerde seyrettiği görülmüştür (Zan et al 2006). Ülkemizde birçok işletmede yaygın olarak kullanılan ve pratik olarak çok sayıda makro süt bileşenini aynı anda analiz edebilen süt analiz cihazlarının süt yağı analiz sonuçları ile Gerber süt yağı analiz cihazının süt yağı sonuçları arasındaki farklılık veya benzerlikler merak konusudur.

Çiftlik hayvanları içerisinde sığırdan sonra en fazla ve en uzun süre süt üreten keçi türünde, özellikle ülkemiz için makineli sağım ile ilgili daha fazla bilgi üretimine ihtiyaç duyulmaktadır. Bu çalışmada, verim seviyesi yüksek olan ve ülkemiz için önemli bir süt tipi genotipi olan Türk Saanen keçilerinde, makineli sağım ile elle sağımın süt verimi ve süt bileşenleri karşılaştırılarak muhtemel farklılıklar ve farklılıklara etkili faktörler belirlenmiştir. Ayrıca makineli sağımda memede kalan olası "kalıntı süt" miktarı ve içeriği de saptanmıştır.

2. Materyal ve Yöntem

2.1. Hayvanlar ve sağım

Çalışma, Çanakkale Onsekiz Mart Üniversitesi Teknolojik ve Tarımsal Araştırmalar Merkezi (TETAM) Sarıcaeli Yerleşkesi Küçükbaş Hayvan Yetiştirme Birimi'nde, yarı entansif sistemde yetiştirilen Türk Saanen keçileriyle yapılmıştır. Yaklaşık 250 da alana sahip olan merada, 30 da alan çalılık formdadır. Sabah ve akşam saatlerindeki sağımlarda pelet formdaki süt yemi (% 88.14 KM; % 15.84 HP; 2600 kcal ME) bireysel olarak toplam 1 kg baş$^{-1}$ sunulurken, sabah sağımından sonra mısır silajı (% 27.69 KM; % 9.15 HP; 2500 kcal ME) günlük 2 kg baş$^{-1}$ grup koşullarında verilmiştir. Deneme süresince keçiler 7-8 saat merada otlamışlardır. Çalışma, 3-4 yaşlı ve laktasyonlarının 5. ayında bulunan yirmi dört baş keçi üzerinde yürütülmüştür. Çalışmada öncelikle on altı baş keçi elle ve makine ile sağımın yapıldığı sekizer başlı iki gruba ayrılmıştır. Diğer sekiz baş keçi ise öncelikle makine ile sağılmış ve hemen sonrasında memede kalan süt elle sağılmıştır. Çalışma ardışık toplam on altı günde tamamlanmıştır. Yirmi dört baş keçinin gruplara dağılımında yaş, doğum sırası, canlı ağırlık, vücut kondisyonu ve deneme öncesi yapılan aylık süt verimleri dikkate alınmıştır. Gruplarda laktasyonun ilk aylarında periyotlara göre ölçülen hayvan başına ortalama süt verimleri ise, makineli sağım grubunda 1.35±0.41 L, elle sağım grubunda 1.33±0.36 L ve kalıntı süt grubunda ise 1.32±0.45 L olarak belirlenmiştir. Çalışmada kullanılan keçiler 20 yıldır yoğun bir genetik ıslaha konu edilmektedirler. Genetik ıslah parametresi olarak verim ve verim unsurları yanı sıra meme formuna özellikle önem verilmektedir. Bu nedenle bu süre zarfında meme formunda belirgin bir üniformite sağlanmıştır. Türk Saanen keçilerinde laktasyon süreleri 275.4 ile 288.4 gün ve laktasyon süt verimi 408.6 kg ile

521.6 kg arasında değişmektedir (Tölü et al 2010). Çalışmada sağımlar 2 x 12 paralel tipteki küçükbaş süt sağım ünitesinde, sabah 07:00-08:00 ve akşam 18:00-19:00 saatleri arasında gerçekleştirilmiştir. Elektronik pulsatörlü sağım ünitesi, 2000 L dak.$^{-1}$ kapasiteli vakum pompasına sahip, 40 kPa vakum seviyesinde 60:40 nabız oranında dakikada 90 nabız sayısı ile çalışmaktadır (Gürhan & Çetin 2003). Sağım yapılırken süt akışı sürekli takip edilmiş ve süt akışı bittikten sonra sağım başlıkları meme başlarından manüel olarak çıkartılmıştır. Aynı kişi tarafından yapılan elle sağımda avuç içi sağım yöntemi kullanılmıştır. Makine ile sağımda süt ölçümü, sistemin ICAR onaylı mekanik sütölçeri ile yapılırken, elle sağımda bir kovaya alınan süt 2 g'a duyarlı terazide ölçülmüştür. Tartılan sütün özgül ağırlığı 1.030 g mL^{-1} olarak alınmış ve litreye dönüştürülmüştür (da Costa et al 2014). Yapılan süt ölçümlerinden hemen sonra 25 mL kapla her bir keçiye ait süt örneği alınarak laboratuar ortamında analiz edilmiştir. Öncelikle Milk-Lab Minor süt analiz cihazında (Milk-Lab Minor®) yağ, protein, laktoz, yağsız kuru madde (YKM) oranları belirlenmiş (Tölü et al 2012), akabinde Gerber süt yağı analiz cihazı ile süt yağı oranı tespit edilmiştir (Metin 2006; Anonim 2014). Süt verimi ve içeriği ile ilgili tüm ölçüm ve analizler aynı şekilde kalıntı süt belirlenmesinde de uygulanmıştır.

2.2. Süt analizleri

Gerber süt yağ analizi yöntemi, bütirometre adı verilen ölçekli özel cam tüpte, belirli hacimdeki sütün protein ve zor çözünen tuzlarının derişik sülfürik asit ve amil alkol kullanılarak çözündürülmesi ve yağın parçalanması prensibine dayanır. Serbest hale geçen yağın santrifüj yardımıyla ayrılması sağlanır. Santrifüj işlemi sonrası bütirometrenin ölçekli kısmında okuma yapılarak, örnekteki yağ miktarı % olarak ifade edilir (Metin 2006; Anonim 2014). Milk-Lab Minor süt analiz cihazı, hızlı sonuç vermesi ve diğer manüel yöntemlerle kıyaslandığında pratik, masrafsız ve iş gücünden tasarruf sağlaması gibi konularda avantaja sahiptir. Cihaz birçok parametreyi aynı anda okuyabilmektedir. Cihazla YKM, yağ, protein, laktoz, yoğunluk parametrelerine bakılabilmektedir. Söz konusu cihaz ultrasonik ölçüm prensibi ile çalışmaktadır. Süt örneği içerisine ultrasonik ses dalgaları gönderilmekte ve cihaz, ses dalgalarının süt içerisindeki geçiş hızına göre okuma yapmaktadır. Okumada süt sıcaklığının 10-25 ^{o}C arasında olması önerilmektedir. Sonuç % olarak verilmektedir (Anonim 2010).

2.3. İstatistiksel analizler

Süt verimi ve bileşenlerinin istatistiksel analizinde tekrarlamalı ölçümler varyans analizinden yararlanılmıştır. Analizlerde Eşitlik 1 kullanılmıştır. Yapılan ön analizlerde tüm interaksiyonlar istatistiksel olarak önemsiz (P>0.05) olduğu için son analizlerde interaksiyonlar modelden çıkartılmıştır. Çoklu karşılaştırmalarda TUKEY testinden yararlanılan analizler SAS (1999) istatistik paket programı ile gerçekleştirilmiştir.

$$y_{ijklm} = \mu + T_i + G_j + P_k + k_{jl} + e_{ijklm} \quad (1)$$

Burada; y_{ijklm}, i'inci ölçüm gününde, j'inci gruptaki, k'ıncı periyotta l'inci keçiye ait m'inci süt miktarı veya süt bileşenleri oranını; T_i, i'inci ölçüm gününün sabit etkisini (i= 1, …, 16); G_j, j'inci grubun etkisini (j= elle sağım, makineyle sağım); P_k, k'ıncı periyodunun sabit etkisini (k= sabah, akşam); k_{jl}, j'inci gruptaki l'inci keçinin şansa bağlı etkisini (l= 1, …, 16); e_{ijklm} , şansa bağlı hatayı ifade etmektedir.

Süt yağ analizi yöntemlerinin karşılaştırıldığı istatistiksel analizlerde ise Eşitlik (2) kullanılmıştır.

$$y_{ijklmn} = \mu + T_i + G_j + P_k + Y_l + b(\bar{x} - x_{ijklmn}) + k_{jm} + e_{ijklmn} \quad (2)$$

Burada; farklı olarak Y_l, l'inci süt yağı yönteminin etkisini (l= Milk-Lab Minor, Gerber); b, süt miktarının süt yağ oranı üzerine regresyon katsayısını; $\bar{x}$, süt miktarı ortalamasını ve x_{ijklmn}, i'inci ölçüm günündeki, j'inci grubtaki, k'ıncı periyottaki, l'inci süt yağı analiz yöntemindeki, m'inci keçinin, n'inci süt miktarı değerini ifade etmektedir.

3. Bulgular ve Tartışma

Türk Saanen keçilerinde sağım başına süt veriminin sağım tiplerine göre benzer seviyede olduğu belirlenmiştir (Çizelge 1; P= 0.8807). Bu çalışmadaki bulgulara benzer şekilde koyunlarda yapılan çalışmalarda makineli ve elle sağımdaki

süt miktarlarının birbirlerine yakın olduğu rapor edilmiştir (Linares et al 1984; de la Fuente et al 1997). Bazı diğer çalışmalarda ise makineli sağımda, elle sağıma göre süt veriminin daha yüksek olduğu, koyunlarda (Carreiro et al 1989; Sinapis 2007) ve atlarda (Caroprese et al 2007) tespit edilmiştir. Keçilerde süt veriminin elle ve makineli sağıma göre doğrudan karşılaştırıldığı bir çalışmaya ulaşılamamıştır.

Keçilerde sabah sağımında akşam sağımına göre daha yüksek süt elde edildiği bildirilmektedir (Katanos et al 2005; Pala & Savaş 2006). Bu çalışmada da sabah sağımında akşam sağımından 140 mL daha fazla süt sağılmıştır (P<0.0001). Ancak bu çalışmada sabah sağımı ile akşam sağımı arasında geçen sürenin akşam sağımı ile sabah sağımı arasındaki süreden yaklaşık bir saat daha fazla olduğu unutulmamalıdır. Sabah ve akşam sağımları arasındaki süt verimi farkı söz konusu süre farklarından kaynaklanabileceği gibi, iki sağım arasında süreler eşit dahi olsa sabah ve akşam sağımları arasında fark oluşabilmektedir. Bunun muhtemel nedeninin, hayvanların gece daha fazla dinlenme ve gündüz tükettiği besinin sindirimine daha fazla vakit ayırması olabileceği düşünülmüştür.

Süt bileşenlerinden sadece Milk-Lab Minor ile yapılan yağ analizi sağım tiplerine göre önemli ölçüde farklılık gösterirken (P= 0.0317), periyotlara göre süt bileşenlerinin tamamında önemli farklılık bulunmuştur (Çizelge 1; P<0.0001). Sinapis (2007), elle sağıma göre makineli sağımda önemli düzeyde daha fazla süt miktarı belirlemiş, ancak önemli bulunmamakla beraber elle sağımda daha yüksek oranda yağ, protein ve laktoz bulunduğunu bildirmiştir. Bu durumun, süt miktarı artıkça süt bileşenleri oranının düşmesinden kaynaklandığı bildirilmiştir (Katanos et al 2005; Tölü et al 2010). Ancak atlarda makineli sağımda daha yüksek süt miktarı elde edilmesine karşın, daha kısa sağım süresinden kaynaklanarak, önemli ölçüde daha yüksek yağ oranı bulunmuştur (Caroprese et al 2007). Dolayısıyla özellikle yağ içeriği oranı süt miktarından etkilendiği ölçüde, süt sağım hızı ve sütün memeden tamamen alınması ile de ilişkilidir. Mevcut çalışmada da memede kalan süt miktarı daha az olan elle sağımda süt yağı (P= 0.0317) ve diğer bileşenler makineli sağıma göre daha yüksek oranlarda belirlenmişlerdir (Çizelge 1). Benzer durum periyotlar bakımından akşam sağımı lehine gerçekleşmiştir (P<0.0001). Sağım süresi birbirine yakın gerçekleşen elle (102 sn) ve makineyle (114 sn) sağım arasında ve yine periyotlar arasında süt bileşenleri farklarının süt miktarından kaynaklandığı söylenebilir. Nitekim elle ve makine ile sağım benzer süt verimine sahipken, makineli sağımda memede kalan % 22.6 oranındaki süt miktarı (Çizelge 2) nedeniyle süt bileşenleri oranı daha düşük düzeylerde gerçekleşmiş olabilir. Farklı keçi ırklarında yapılan ve bu çalışmadakine benzer

Çizelge 1- Grup ve periyotlara göre süt verimi ve süt bileşenlerine ait en küçük kareler ortalamaları (EKKO), standart hataları (SH) ve P değerleri

Table 1- The least square means (EKKO), standard errors (SH) and P values of milk yield and milk components according to groups and periods

Özellikler	*Elle sağım*		*Makineyle sağım*			*Akşam*		*Sabah*			*Ölçüm günleri*
	EKKO	*SH*	*EKKO*	*SH*	*P*	*EKKO*	*SH*	*EKKO*	*SH*	*P*	*P*
Süt verimi (L)	1.07	0.10	1.09	0.10	0.8807	1.01	0.07	1.15	0.07	<0.0001	0.7713
Süt yağı[1] (%)	3.91	0.21	3.57	0.23	0.2884	3.98	0.16	3.50	0.16	<0.0001	0.1783
Süt yağı[2] (%)	4.05	0.15	3.57	0.15	0.0317	4.07	0.11	3.55	0.11	<0.0001	0.0052
YKM (%)	7.72	0.08	7.59	0.08	0.2939	7.75	0.06	7.56	0.06	<0.0001	<0.0001
Süt proteini (%)	2.82	0.03	2.77	0.03	0.3209	2.83	0.02	2.76	0.02	<0.0001	<0.0001
Laktoz (%)	4.25	0.04	4.17	0.04	0.2698	4.26	0.03	4.15	0.03	<0.0001	<0.0001

1, Gerber; 2, Milk-Lab Minor; YKM, yağsız kuru madde

biçimde sabah sağımında daha fazla süt miktarı belirlenen bir çalışmada, akşam sağımında süt yağı, süt proteini ve laktoz (bir ırk dışında) içerikleri, sabah sağımından çok daha yüksek seviyede belirlenmiştir (Katanos et al 2005).

Çalışmada makine ile yapılan sağımdan hemen sonra yapılan elle sağımda periyotlara göre değişmekle beraber 224-262 mL arasında kalıntı süt tespit edilmiştir (Çizelge 2). Bu miktar sağılabilen toplam sütün % 22.6'sıdır. Makineli sağımda süt ile kalıntı süt arasında pozitif korelasyon (r= 0.27) tespit edilmiştir (P= 0.0018). Katanos et al (2005) farklı keçi ırkları üzerinde yürüttükleri çalışmada, makineli sağımdaki günlük toplam kalıntı süt miktarını 228-298 mL ve oranını ise % 19.8-29.9 arasında belirlemişlerdir. Ayrıca günde iki öğün sağım ile bir öğün sağımın Tinerfena süt tipi keçilerinde karşılaştırıldığı çalışmada, iki öğün sağımda kalıntı süt miktarının haftalara göre değişerek ortalama 150-320 mL (% 5.1-10.9) arasında olduğunu bildirilmiştir (Capote et al 2008). Aynı çalışmada ayrıca süt miktarının daha fazla olduğu günlük tek sağımda, kalıntı süt miktarı da daha yüksek olmuştur. Kalıntı süt oranı farklı keçi ırklarında % 11.61-14.49 arasında değişmiştir (Torres et al 2013). Anderson et al (1968) ineklerde kalıntı süt oranının ortalama olarak % 0.72-37.6 arasında değiştiğini ve kalıntı süt ile makineli sağımda elde edilen süt arasındaki korelasyon katsayısını, önemsiz bulmakla beraber r= 0.41 olarak tespit etmişlerdir. Bu çalışmada, süt verimi sağım yöntemlerine göre birbirine yakın seviyede gerçekleşmiş olsa da (Çizelge 1), kalıntı süt oranının sağılan süt miktarının % 22.6'sı olması, makineli sağımda uygun vakum, nabız sayısı ve nabız oranları ile memeden uygun zamanda sütün alındığını, ancak belli bir seviyenin altında mutlaka memede sütün kalabileceğini göstermektedir. Nitekim çalışmada kullanılan sağım ünitesinde sağım esnasında süt akışının görülmemesine rağmen, sağım başlıklarının memeden çıkartılmasından hemen sonrasında yapılan elle sağımda önemli miktarda süt tespit edilmiştir (Çizelge 2). Muhtemelen elle sağıma göre daha kuvvetli bir vakum ile sütün alındığı makineli sağımda, sağım esnasında daha fazla süt üretiliyor da olabilir. Memenin anatomik farkından kaynaklansa gerek, kalıntı süt, keçilere göre sığırlarda çok daha fazla sorun oluşturmaktadır. Bu anlamda sığırlarda, sağılan sütün % 68'ine ulaşabilen kalıntı süt miktarını azaltmak amacıyla sağım öncesi oksitosin hormonu yaygın biçimde kullanılmaktadır (Anderson et al 1968). Keçilerde ise sığırlardan farklı olarak, meme sarnıcı boşluğunun (cisternal), alveol meme boşluğuna göre daha fazla paya sahip olması nedeniyle (Salama et al 2004) oksitosin enjeksiyonu tam anlamıyla sonuç vermeyebilmektedir (Bruckmaier et al 1994; Torres et al 2014).

Makineli sağımda elde edilen süt ile kalıntı sütteki besin madde bileşenlerinin önemli ölçüde birbirinden farklılık gösterdiği belirlenmiştir (Çizelge 2; $P \leq 0.05$). Kalıntı sütteki süt yağının, periyotlara göre değişmekle beraber % 43-75 oranında makineli sağımdaki sütten daha yüksek seviyede olduğu görülürken, yağsız kuru madde (YKM), protein ve laktoz içeriklerinin % 3-4 oranında daha düşük olduğu tespit edilmiştir ($P \leq 0.05$). Farklı hayvan türlerinde yapılan çalışmalarda kalıntı sütün, sağımdan elde edilen süte göre % 19-46 oranında daha fazla yağ içeriğine sahip olduğu belirlenmiştir (Labussiere 1988; Millogo et al 2009). Bu çalışmada akşam sağımındaki kalıntı süt yağ oranları farkı (% 43-46) diğer çalışmalarla benzer iken, özellikle sabah sağımında kalıntı sütlerdeki % 75'lik oran farkı bir hayli dikkat çekicidir. Bu sebeple özellikle sabah sağımındaki kalıntı sütlerin memeden tamamen alınması çok daha fazla önem arz etmektedir. Süt sığırlarında yapılan çalışmada kalıntı sütteki yağ oranı makineli sağımdaki süte göre 2-2.5 kat daha fazla yağ içeriğine sahip olurken, YKM oranları benzer bulunmuştur (Anderson et al 1968). Farklı keçi ırklarında alveol meme boşluğundan alınan sütteki yağ oranının meme sarnıcı (cisternal) boşluğundan elde edilen süte göre çok daha yüksek olduğu ve bu çalışmadaki bulgulara benzer şekilde YKM, protein ve laktoz bileşenlerinin birilerine yakın düzeylerde olduğu tespit edilmiştir (Torres et al 2012).

Çizelge 2- Periyotlara göre kalıntı sütün miktar ve bileşenlerine ait ortalamaları $(\bar{x})$, standart hataları (SH) ve kalıntı sütün makineli süte oranları (%)

Table 2- The means $(\bar{x})$, standard errors (SH) and the ratios of residual milk to machine milking of residual milk amount and milk components according to periods

Özellikler	*Akşam*		*Makineli sağımdaki süte oranı*	*Sabah*		*Makineli sağımdaki süte oranı*
	$\bar{x}$	*SH*	*%*	$\bar{x}$	*SH*	*%*
Süt verimi (L)	0.22	0.02	22.51	0.26	0.02	22.67
Süt yağı[1] (%)	5.20	0.14	146.06	5.44	0.14	175.48
Süt yağı[2] (%)	5.46	0.16	143.68	5.72	0.16	175.46
YKM (%)	7.50	0.05	94.22	7.32	0.05	96.31
Süt proteini (%)	2.83	0.01	97.25	2.67	0.01	96.04
Laktoz (%)	4.26	0.02	97.48	4.03	0.02	96.41

1, Gerber; 2, Milk-Lab Minor; YKM, yağsız kuru madde

Süt verimi ile süt bileşenleri arasında, YKM dışında negatif yönde bir ilişkinin olduğu belirlenmiştir (Çizelge 3). Özellikle süt yağı oranının süt verimi artıkça önemli ölçüde düştüğü görülmüştür (r= -0.47; r= -0.48; P<0.0001). Gerber yöntemi ile süt yağı tüm gruplarda ortalama % 3.63±0.11 olurken, Milk-Lab Minor cihazı ile % 3.80±0.10 olarak belirlenmesine karşın (P<0.0001), iki yöntem arasında pozitif yönde bir ilişki (r= 0.91) tespit edilmiştir (P<0.0001). Burada her ne kadar ortalamalar arasındaki fark istatistiksel açıdan önemli olsa da, veri sayısının yüksekliği ve varyasyonun düşüklüğü nedeniyle çok küçük farklar dahi istatistiksel açıdan önemli farka işaret edebilir. Öte yandan iki yöntem arasındaki korelasyon katsayısının büyüklüğü, pratik olarak birçok farklı parametrenin belirlenebildiği Milk-Lab Minor cihazının keçi sütünde yağ analizi için kullanılabileceğini göstermektedir. Benzer şekilde Gerber ve Foss cihazlarında Saanen ve Alpine keçilerinin süt yağı oranı birbirine yakın değerlerde bulunmuştur (Zan et al 2006). Gerber ile yapılan yağ analizi oranı diğer süt bileşenleri ile önemli ölçüde negatif korelasyona sahip olurken (P<0.0001), Milk-Lab Minor cihazından elde edilen süt yağ oranının diğer bileşenlerle korelasyonu önemsiz

Çizelge 3- Süt verimi ve süt bileşenleri arasındaki pearson korelasyon katsayısı (diagonalin üstü) ve P (diagonalin altı) değerleri

Table 3- Pearson correlation coefficient (above the diagonal) and P values (under the diagonal) between milk yield and milk components

Özellikler	*Süt verimi (L)*	*Süt yağı[1] (%)*	*Süt yağı[2] (%)*	*YKM (%)*	*Süt proteini (%)*	*Laktoz (%)*
Süt verimi (L)		-0.47	-0.48	-0.01	-0.09	-0.10
Süt yağı[1] (%)	<0.0001		0.91	-0.20	-0.20	-0.16
Süt yağı[2] (%)	<0.0001	<0.0001		-0.03	-0.01	0.02
YKM (%)	0.8651	<0.0001	0.2488		0.85	0.84
Süt proteini (%)	0.0037	<0.0001	0.7215	<0.0001		0.98
Laktoz (%)	0.0014	<0.0001	0.4833	<0.0001	<0.0001	

[1], Gerber; [2], Milk-Lab Minor; YKM, yağsız kuru madde

bulunmuştur. Süt proteini ile laktoz arasında pozitif yönde ve önemli doğrusal korelasyon (r= 0.98; P<0.0001) tespit edilmiş ve YKM'nin de kendisini oluşturan protein ve laktoz oranları ile korelasyon katsayıları sırasıyla r= 0.85 ve r= 0.84 pozitif yönde önemli bulunmuştur (P<0.0001).

4. Sonuçlar

Süt tipi bir keçi genotipi olan ve ülkemizin birçok bölgesine yayılmış Türk Saanen keçilerinde elle sağım ile makineli sağım arasında önemli bir farklılık tespit edilmemiştir. Akşam sağımı ile sabah sağımı arasında önemli ölçüde değişiklik gösteren süt verimi, sabah sağımında daha yüksek olarak belirlenmiştir. Sağım tiplerinin önemli ölçüde farklılaşmadığı keçilerde, makineli sağımdan hemen sonra yapılan elle sağımla % 22.6 oranında kalıntı süt olduğu ve sağılan süt miktarı artıkça kalıntı süt miktarının da arttığı görülmüştür. Bu anlamda aile işletmelerinde makineli sağım sonrasında memelerin kontrol edilerek memede kalan sütlerin elle sağılması yoluna gidilebilir. Diğer yandan makineli sağımda bu düzeyde süt kalmaması için meme dokusuna zarar vermeyecek biçimde sağım ünitesinde düzenleme ve kontroller yapılmalıdır. Zira kalıntı sütte özellikle süt yağı, makineli sağımdaki süte göre % 43-75 daha yüksek orandadır. Gerber cihazı ve Milk-Lab Minor cihazında yapılan süt yağı analizi arasında yalnızca % 0.17'lik bir farkın bulunması ve iki yöntem arasındaki korelasyonun yüksekliği, Milk-Lab Minorın süt yağı analizinde rahatlıkla kullanılabileceğini göstermektedir.

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TARIM BİLİMLERİ DERGİSİ-JOURNAL OF AGRICULTURAL SCIENCES

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Makale; Türkçe Başlık, Türkçe Özet, Anahtar Kelimeler, İngilizce Başlık, İngilizce Özet, Keywords, 1.Giriş, 2.Materyal ve Yöntem, 3.Bulgular ve Tartışma, 4.Sonuçlar, Teşekkür (varsa), Kısaltmalar ve/veya Semboller (varsa), Kaynaklar bölümleri ile Şekil ve Çizelgelerden oluşmalıdır. Bölüm adları koyu yazılmalıdır.

Makale, "Kaynaklar" bölümü dâhil 16 sayfayı geçmemelidir. Yazar(lar), bu kısımların oluşturulmasında derginin web sayfasındaki **Makale Hazırlama Şablonunu** kullanmalıdır.

Başlık: Kısa ve açıklayıcı olmalı, 14 punto ve koyu, kelimelerin ilk harfi büyük olmalı, ortalanarak yazılmalı ve 15 kelimeyi geçmemelidir. İngilizce başlık Türkçe başlığı tam olarak karşılamalı, 13 punto ve koyu yazılmalıdır.

Özet ve Anahtar Kelimeler: Türkçe ve İngilizce özetlerin her biri 300 kelimeyi geçmemelidir. Türkçe ve İngilizce özetlerde sırasıyla "Özet" ve "Abstract" kelimeleri kullanılmalıdır. Özet, çalışmanın amacını, nasıl yapıldığını, sonuçları ve sonuçlar üzerine yazar(lar)ın yaptığı değerlendirmeleri içermelidir. Özetlerin 1 satır altına, her anahtar kelimenin ilk harfi büyük diğerleri küçük harflerle, mümkünse başlıkta kullanılmayan, çalışmayı en iyi biçimde tanımlayacak ve aralarında noktalı virgül (;) olacak şekilde en fazla 6 anahtar kelime yazılmalıdır.

1. Giriş: Bu bölümde; çalışma konusu, gerekçesi, konu ile doğrudan ilgili önceki çalışmalar ve çalışmanın amacı verilir.

2. Materyal ve Yöntem: Kullanılan materyal ve yöntem aynı başlıkta verilmelidir. Alt başlık verilecekse bölüm numarası ile birlikte numaralandırılmalı (2.1. gibi) ve italik yazılmalıdır. Yeni veya değiştirilmiş yöntemler, aynı konuda çalışanlara araştırmayı tekrarlama olanağı verecek nitelikte açıklanmalıdır.

3. Bulgular ve Tartışma: Elde edilen bulgular verilmeli, gerekirse çizelge, şekil ve grafiklerle desteklenerek bulgular açıklanmalıdır. Elde edilen bulgular tekrardan kaçınılması amacıyla ya çizelge ya da grafik olarak verilmelidir. İstatistikî olarak önemli bulunan faktörler, uygulanan istatistik analiz tekniğine uygun karşılaştırma yöntemi ile yorumlanarak ilgili istatistikler üzerinde harflendirme yapılmalıdır. İstatistiki analiz yönteminin doğru seçilmediği ve/ya analizin gereği gibi yapılmadığı durumlarda editörler kurulu makaleyi değerlendirme dışında tutabilir. Bulgular tartışılmalı ancak gereksiz tekrarlardan kaçınılmalıdır. Bulguların başka araştırmalarla benzerlik ve farklılıkları verilmeli, nedenleri açıklanmalıdır.

4. Sonuçlar: Elde edilen sonuçlar, bilime ve uygulamaya katkısıyla birlikte kısa ve öz olarak verilmelidir. Giriş ile Bulgular ve Tartışma bölümünde verilen ifadeler bu kısımda aynı şekilde tekrar edilmemelidir.

Teşekkür: Gerekli ise mümkün olduğunca kısa olmalı ve yapılan katkı ifade edilerek verilmelidir.

Kısaltmalar ve/veya Semboller: Makalede kısaltmalardan mümkün olduğunca kaçınılmalıdır. Semboller Makale Hazırlama Şablonunda belirtildiği gibi verilmelidir. Kısaltma ve semboller metin içinde ilk kez kullanıldığı yerde açıklanmalıdır. Uluslararası geçerliliği olan ve yerleşik kısaltmalar tercih edilmelidir. Kısaltmalar makalenin başlığında kullanılmamalıdır. Semboller SI sistemine göre verilmelidir.

Kaynaklar: Eserde yararlanılan kaynaklara ilişkin atıf metin içinde "(Yazarın soyadı yıl)" yöntemine göre yapılmalıdır. Örnek: (Doymaz 2003), (Basunia & Abe 2001). Yazara atıf yapılırsa sadece yayının yılı parantez içine alınmalıdır. Örnek: Doymaz (2003)'e göre ya da Basunia & Abe (2001). Üç ya da daha fazla yazar için makale içindeki atıfta "et al" kullanılmalıdır. Örnek: (Lawrence et al 2001) veya Lawrence et al (2001)'e göre. Aynı yazarın aynı yıl içinde 1'den fazla yayını varsa, yıldan sonra küçük harfler verilmelidir. Örnek: (Akpınar et al 2003a). Aynı yazarın birden fazla yayınına atıf yapılacaksa yıldan sonra noktalı virgül (;) işareti ile ayırt edilmelidir. Örnek: (Akpınar 2007; 2009; 2013). Birden fazla atıf yapılırsa atıflar arasında noktalı virgül (;) kullanılmalı ve eskiden yeniye doğru yıl sırasına göre verilmelidir. Örnek: (Perl et al 1987; Bailly et al 1996; Copeland & McDonald 2001; Goel & Sheoran 2003). Eğer bilginin, kaynağın belirli bir sayfasından ya da sayfalarından alındığı belirtilmek istenirse (Hardeman & Jochemsen 2012, s 657-674; Naess 1991, s 34) biçiminde gösterilmelidir. Kaynaklarda Anonim ya da Anonymous şeklinde gösterim yapılmamalıdır.

Kaynaklar bölümünde metin içinde atıfı yapılan tüm kaynaklar alfabetik olarak (yazarların soyadlarına göre) ve orijinal dilinde verilir. Aynı yazara birden çok atıf yapılıyorsa önce tek isim, sonra iki isim ve sonra da üç ve daha fazla yazarlı kaynak sırasına göre hepsi kendi içinde eskiden yeniye yıl sırasına göre verilmelidir. İki veya daha fazla yazarlı eserlerin bildiriminde son yazardan önce "&" kullanılmalıdır. Örnek: Lawrence K C, Funk D B & Windham W R (2001). Dergi isimleri kısaltma yapılmadan tam adı ile ve italik yazılmalıdır. Kongre kitaplarında Türkçe ya da yabancı dilde özeti yayınlanmış çalışmalara atıf yapılamaz. Makaledeki yanlış atıf ve kaynak gösterimlerine ait sorumluluk yazar(lar)a aittir. Kaynaklar bölümündeki her bir kaynağın sonuna nokta (.) konmamalıdır.

Dergi:

Doymaz I (2003). Drying kinetics of white mulberry. *Journal of Food Engineering* **61**(3): 341-346

Basunia M A & Abe T (2001). Thin-layer solar drying characteristics of rough rice under natural convection. *Journal of Food Engineering* **47**(4): 295-301

Lawrence K C, Funk D B & Windham W R (2001). Dielectric moisture sensor for cereal grains and soybeans. *Transactions of the ASAE* **44**(6): 1691-1696

Akpinar E, Midilli A & Bicer Y (2003a). Single layer drying behaviour of potato slices in a convective cyclone dryer and mathematical modelling. *Energy Conversion and Management* **44**(10): 1689-1705

Kitap:

Yıldırım O (1996). Bahçe Bitkileri Sulama Tekniği. Ankara Üniversitesi Ziraat Fakültesi Yayınları: 1438, Ders Kitabı: 420, Ankara

Mohsenin N N (1970). Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York

Kitapta Bölüm:

Fıratlı Ç (1993). Arı yetiştirme. (Ed: M Ertuğrul), *Hayvan Yetiştirme*, Baran Ofset, Ankara, s. 30-34

Rizvi S S H (1986). Thermodynamic properties of foods in dehydration. In: M A Rao & S S H Rizvi (Eds), *Engineering Properties of Foods*, Marcel Dekker, New York, pp. 190-193

Yazarı Belirtilmeyen Kurum Yayınları:

TUİK (2012). Tarım İstatistikleri Özeti. Türkiye İstatistik Kurumu, Yayın No: 3877, Ankara

ASAE (2002). Standards S352.2, 2002, Moisture measurement-unground grain and seeds. ASAE, St. Joseph, MI

İnternetten Alınan Bilgi:

FAO (2013). Classifications and standards. http://www.fao.org/economic/ess/ess-standards/en/ (Erişim tarihi:10.02.2013)

Tez:

Koyuncu T (1992). Tarım arabalarında kullanılan çarpma etkili frenlerin araştırılması. Yüksek lisans tezi, Ankara Üniversitesi Fen Bilimleri Enstitüsü (Basılmamış), Ankara

Berbert P A (1995). On-line density-independent moisture content measurement of hard winter wheat using the capacitance method. PhD Thesis, Crandfield University (Unpublished), UK

Tam Metin Kongre/Sempozyum Kitabı:

Yağcıoğlu A, Değirmencioğlu A & Cağatay F (1999). Drying characteristics of laurel leaves under different drying conditions. In: *Proceedings of the 7th International Congress on Agricultural Mechanization and Energy*, 26–27 May, Adana, Turkey, pp. 565–569

Kara Z & Beyoğlu N (1995). Konya ili Beyşehir yöresinde yetiştirilen üzüm çeşitlerinin göz verimliliklerinin belirlenmesi üzerine bir araştırma. *Türkiye II. Ulusal Bahçe Bitkileri Kongresi. Bildiriler (II)*: 3-6 Ekim, Adana, s. 524-528

Şekiller ve Çizelgeler: Şekil, grafik, fotoğraf ve benzerleri "Şekil", sayısal değerler ise "Çizelge" olarak belirtilmelidir. Tüm şekil ve çizelgeler makalenin sonuna yerleştirilmelidir. Şekil ve çizelgelerin boyu tek sayfa düzeninde en fazla 16x20 cm ve çift sütun düzeninde ise genişliği en fazla 8 cm olmalıdır. Şekil ve çizelgelerin boyutu baskıda çıkabilecek çözünürlükte olmalıdır. Araştırma sonuçlarını destekleyici nitelikteki resimler 600 dpi çözünürlüğünde "jpg" formatında olmalıdır. Renkli resimler yerine gri ya da siyah tonlu resimler tercih edilmelidir. Çizelgelerde düşey çizgi kullanılmamalı ve makale hazırlama şablonunda belirtildiği gibi hazırlanmalıdır. Her çizelge ve şekle metin içerisinde atıf yapılmalıdır. Tüm çizelge ve şekiller makale boyunca sırayla numaralandırılmalıdır (Çizelge 1 ve Şekil 1). Çizelge ve şekil başlıkları ve açıklamaları kısa ve öz olmalıdır. Çizelge ve şekillerin İngilizce başlıkları, Türkçe başlığın hemen altına italik olarak yazılmalı, ilk yazılan Türkçe başlık yazısı koyu olmalıdır. Şekil ve çizelge başlık yazıları 9.5 punto, şekil ve çizelgelerin içindeki yazılar 9 punto, çizelge altı yazılar 8 punto Times New Roman yazı karakterinde olmalıdır. Şekillerde yatay ve düşey kılavuz çizgiler ve rakamlar bulunmamalıdır. Ancak istatistiksel karşılaştırmalar yapılıyorsa küçük harfler bulunabilir. Çizelge ve şekillerde kısaltmalar kullanılmış ise hemen altına bu kısaltmalar açıklanmalıdır. Şekil ve çizelge başlıkları ile çizelge altı yazılarının sonuna nokta (.) konmamalıdır.

Birimler: Tüm makalelerde SI (Systeme International d'Units) ölçüm birimleri kullanılmalıdır. Ondalık kesir olarak nokta kullanılmalıdır (1,25 yerine 1.25 gibi). Birimlerde "/" kullanılmamalı ve birimler arasında bir boşluk verilmelidir (m/s yerine m s^{-1}, J/s yerine J s^{-1}, kg m/s^2 yerine kg m s^{-2} gibi). Sayı ile sembol arasında bir boşluk bırakılmalıdır (4 kg N ha^{-1}, 3 kg m^{-1} s^{-2}, 20 N m, , 1000 s^{-1}, 100 kPa, 22 °C ve % 29 gibi). Bu kuralın istisnaları düzlemsel açılar için kullanılan derece, dakika ve saniye sembolleridir (°, ′ ve ″). Bunlar sayıdan hemen sonra konmalıdır (10°, 45', 60" gibi). Litrenin kısaltması "l" değil "L" olarak belirtilmelidir. Cümle sonunda değillerse sembollerin sonuna nokta konulmamalıdır (kg. değil kg).

Formüller ve Eşitlikler: Formüller numaralandırılmalı ve formül numarası formülün yanına sağa dayalı olarak parantez içinde gösterilmelidir. Formüllerin yazılmasında Word programı matematik işlemcisi kullanılmalı, ana karakterler 12 punto, değişkenler italik, rakamlar ve matematiksel ifadeler düz olarak verilmelidir. Metin içerisinde atıf yapılacaksa "Eşitlik 1" biçiminde verilmelidir (…ilişkin model, Eşitlik 1' de verilmiştir).

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References

Cite references in the text as author's family name should be followed by the year of the publication in parentheses (Peter 2010; Basunia & Abe 2001). Use et al after the first author's family name for citations with three or more authors (Lawrence et al 2001). For citations of the same authors published on the same year, use letters after the year (Dawson 2009a).

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Journal Articles

Doymaz I (2003). Drying kinetics of white mulberry. *Journal of Food Engineering* **61**(3): 341-346

Basunia M A & Abe T (2001). Thin-layer solar drying characteristics of rough rice under natural convection. *Journal of Food Engineering* **47**(4): 295-301

Lawrence K C, Funk D B & Windham W R (2001). Dielectric moisture sensor for cereal grains and soybeans. *Transactions of the ASAE* **44**(6): 1691-1696

Akpinar E, Midilli A & Biçer Y (2003a). Single layer drying behavior of potato slices in a convective cyclone dryer and mathematical modeling. *Energy Conversion and Management* **44**(10): 1689-1705

Books

Mohsenin N N (1970). Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York

Book Chapter

Rizvi S S H (1986). Thermodynamic properties of foods in dehydration. In: M A Rao & S S H Rizvi (Eds.), *Engineering Properties of Foods*, Marcel Dekker, New York, pp. 190-193

Publications of Institutions / Standard Books

ASAE (2002). Standards S352.2, 2002, Moisture measurement - unground grain and seeds. ASAE, St. Joseph, MI

Internet Sources

FAO (2013). Classifications and standards. Retrieved in April, 12, 2011 from http://www.fao.org/economic/ess/ess-standards/en/

Thesis and Dissertations

Berbert P A (1995). On-line density-independent moisture content measurement of hard winter wheat using the capacitance method. PhD Thesis, Crandfield University (Unpublished), UK

Conference Proceedings (Full papers)

Yağcıoğlu A, Değirmencioğlu A & Cağatay F (1999). Drying characteristics of laurel leaves under different drying conditions. In: *Proceedings of the 7th International Congress on Agricultural Mechanization and Energy*, 26–27 May, Adana, pp. 565–569

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Units of measurement should all be in SI units. Use a period in decimal fractions (1.24 rather than 1,24). Avoid using "/". Include a space between the units (m s^{-1} rather than m/s,J s^{-1} rather than J/s, kg m s^{-2} rather thankg m/s^2). Units should have a single space between the number and the unit (4 kg N ha^{-1}, 3 kg m^{-1} s^{-2}, 20 N m, 1000 s^{-1}, 100 kPa, 22 °C). The only exceptions are for angular definitions, minutes, seconds and percentage; do not include a space (10°, 45›, 60», 29%). The abbreviation of liter is "L".

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Number each formula with the reference number placed in parentheses at the end. Use Word mathematical processor for formulas with 12pt., variances in Italics, numbers and mathematical definitions in plain text. If needed, refer as "Equation 1" in the text (….the model, as given in Equation 1).

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