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Comparative analysis of raw milk samples in Amasya region

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Abstract
Milk is a complete and incredibly nutritious food supply for humans. Millions of tons of raw milk have been processed by the dairy industry to meet huge public demand. Therefore, there are studies needed related to the classification of raw milks in the supply chain. The aim of this study is to evaluate the quality of raw milk samples in Amasya region. Firstly, raw cow's milk is classified according to its protein and fat values. In the first period, the mean fat value of raw milk collected from three lines was found to be 3.86, 3.89, and 3.87 as (%) the percent value, respectively, while the mean protein value of raw milk collected from three lines was found to be 3.29, 3.28, and 3.25 as (%) the percent value, respectively. In the second period, the mean fat value of raw milk collected from three lines was found to be 3.93, 3.99, and 4.03 as (%) the percent value, respectively, while the mean protein value of raw milk collected from three lines was found to be 3.34, 3.35, and 3.34 as (%) the percent value, respectively. The findings indicated that during both periods, the daily raw milk collected from three lines is class A, where protein value (%) is 3.1 and above while fat value (%) is 3.5 and above. Since the quality of raw milk is important not only for milk consumers but also for the quality of the corresponding dairy products, the quality of raw milk must be controlled correctly. Consumer requirements for high-quality milk and dairy are of importance on dairy products.
Keywords: Milk Classification, Statistical Analysis, ANOVA, Dairy Industry

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INTRODUCTION

The dairy industry is an important component of many economies and is an important industry in most developed and developing economies of the world. The dairy industry is a large-scale industry due to the large number of farms, collection centers, production facilities, and distribution centers. Dairy products are sensitive to environmental conditions and are affected by rapid changes in environmental conditions (Sel and Bilgen, 2015). Dairy industry is an important income source in Türkiye. In Türkiye, raw milk production was 21 million 563 thousand 492 tons in 2022, decreased by 0.4% in 2023, and became 21 million 481 thousand 567 tons (TÜİK, 2023). To improve the quality of dairy products, it is important to use raw milk of appropriate quality. Collecting different types of milk entails significant additional logistics costs in an uncertain environment. Therefore, it is very important to organize a healthy distribution system to control the supply chain for dairy products. In particular, the distribution of milk from farms to consumers can pose high risks in terms of pathogens and nutritional losses. Milk, unlike other products, needs a protection and monitoring system to ensure healthy conditions (Sayin et al., 2011). Demirbaş et al. (2009) examined the role of milk collection centers in supplying quality and safe milk. They determined that milk collection centers, which act as bridges between farmers and the dairy factory, have an important role in food safety and quality assurance in the milk processing industry. Mu et al. (2016) examined the effect of supply chain management on the quality of milk in their study. In order to reduce testing costs in their study, they proposed mixed testing, in which milk from more than one farmer is tested once. Sayin et al. (2011) used an empirical (Logit) model to examine the factors affecting the role of milk collection centers in providing a safe distribution channel in Türkiye. According to the results, milk sales decisions are significantly affected by income and demographic characteristics. Ahmad et al. (2010) used multiple linear regression, artificial neural network, and k-nearest neighbor techniques to predict raw milk quality. Sangatash et al. (2012) used fuzzy logic in their study to classify raw milk according to microbiological and physicochemical qualities. Berhilevych et al. (2019) estimated the number of bacteria from the *Enterobacteriaceae* family in raw milk stored under refrigeration conditions using an artificial neural network. Reguillo et al. (2018) analyzed the effect of milk collection frequency and milking time on the numbers of total mesophilic aerobic bacteria and psychrotrophic bacteria in raw milk samples. Milking in the morning showed a significant decrease in the number of mesophilic aerobic bacteria compared to milking in the evening. Ndahetuye et al. (2020) analyzed the effects of somatic cell count, total bacterial count, *Escherichia coli, Salmonella*, and *Brucella* species on the quality of milk. They determined that contamination of milk with *Escherichia coli* occurred more frequently in milk collection centers. Preka and Bekteshi (2016) presented physicochemical characteristics of cow's milk gathered in the Shkodra region. In their study, Uzun and Allahverdi (2021) developed a fuzzy logic-based decision support system to predict the spoilage of heat-treated raw milk. In Tohidi et al. (2018), they detected the presence of detergent powder in raw milk with an artificial olfactory machine based on eight metal oxide semiconductor sensors. Multivariate analysis of variance was used to optimize the data matrix. Additionally, linear discriminant analysis, support vector machine, and adaptive network-based fuzzy inference system method were used for qualitative classification. Cebeci (2019) determined the microbiological quality of raw cow milk samples sold in public markets and investigated foodborne pathogens in Giresun. In their study, Neware (2023) checked the quality of cow milk with a data set consisting of 1059 milk samples taken from various cows using k-nearest neighbor, logistic regression, support vector machine and artificial neural network.

Figure 1. The map of Amasya province (Anonymous, 2024).

To summarize, since the quality of raw milk is important not only for milk consumers but also for the quality of related dairy products, the quality of raw milk must be accurately controlled. Each milk delivery is inspected to determine certain qualitative characteristics. Microbiological and physicochemical analyses are important in monitoring the quality of raw milk and its products. Consumer requirements for high-quality milk and dairy products have placed a significant responsibility on dairy producers, so dairy factories need a good system to evaluate and classify the quality of the raw milk they receive (Sangatash et al., 2012). Studies in the literature are generally developed for specific problems. Models with problem-specific restrictions and assumptions are not suitable for every type of problem. Therefore, there is a need for researchers to design improved methods that can be used to evaluate the quality of raw milk. The objective of this study is to provide an academic contribution by utilizing statistical analysis to assess the quality of raw milk in Amasya region.

MATERIALS AND METHODS

Proposed Methodology

Dataset is provided from the Cattle Breeders' Association of Amasya. Association was founded in 1998 by dairy cattle breeders operating in the Amasya region (Figure 1). Every day, samples taken from milk cooling tanks, milk collection vehicles, and factory milk purchasing vehicles in the villages are analyzed (AIDSYB, 2024). Kjeldahl analysis method was used to determine protein content of milk samples. Gerber method was employed for fat content determination. Precise weighing method using laboratory style oven was employed for the determination of dry matter value. The dataset was first evaluated according to fat and protein values. Raw cow milk is classified according to its protein and fat values as shown in the table below (Anonymous, 2019).

Table 1. Raw cow milk classification (Anonymous, 2019).

Class	Protein Value (%)		Fat Value (%)	
	October – March (Second period)	April – September (First period)	October – March (Second period)	April – September (First period)
Class A	3.2 and above	3.1 and above	3.6 and above	3.5 and above
Class B	$3 \leq protein\ value\ < 3.2$	$3 \leq protein\ value\ < 3.1$	$3.3 \leq fat\ value\ < 3.6$	$3.2 \leq fat\ value\ < 3.5$
Class C	$2.9 \leq protein\ value\ < 3$	$2.9 \leq protein\ value\ < 3$	$fat\ value\ < 3.3$	$fat\ value\ < 3.2$

In this paper, three different lines (village or individual) that arrived at the milk collection center were examined. The first line (Line 1) includes Balgöze, Ortaova, Gümüştepe, Oymaağaç, Yolüstü, Sarıbuğday, Karşıyaka, Yalnız, Çaybaşı, Mahmutlu, individual 2, individual 5, and individual 6. Second line (Line 2) includes Sarıköy, Alıcık, Karamağara, Elmayolu, Diphacı, Hanköy, Doluca, Akören, Bulak, individual 1, and individual 4. Third line (Line 3) includes Hacıyakup, Yakup, Kıreymir, Yakacık, Sazlıca, and Pekmezci. Descriptive statistics for the first period and second period are given in Table 2 and Table 3 for three lines. According to the results, all lines are Class A.

Table 2. Descriptive statistics for first period.

		N	Mean	Standard Deviation	Standard Error	Minimum	Maximum
Fat value	Line 1	145	3.86	0.14	0.01198	3.54	4.21
	Line 2	145	3.89	0.11	0.00939	3.62	4.21
	Line 3	145	3.87	0.16	0.01295	3.55	4.42
	Total	435	3.87	0.14	0.00666	3.54	4.42
Dry matter value	Line 1	145	8.86	0.14	0.01137	8.52	9.18
	Line 2	145	8.86	0.12	0.01002	8.58	9.19
	Line 3	145	8.80	0.11	0.00895	8.56	9.08
	Total	435	8.84	0.13	0.00600	8.52	9.19
Protein value	Line 1	145	3.29	0.06	0.00509	3.14	3.42
	Line 2	145	3.28	0.05	0.00404	3.16	3.40
	Line 3	145	3.25	0.06	0.00485	3.13	3.38
	Total	435	3.27	0.06	0.00278	3.13	3.42

Table 3. Descriptive statistics for second period.

		N	Mean	Standard Deviation	Standard Error	Minimum	Maximum
Fat value	Line 1	153	3.93	0.10	0.00773	3.72	4.16
	Line 2	153	3.99	0.09	0.00698	3.77	4.20
	Line 3	153	4.03	0.17	0.01347	3.73	4.59
	Total	459	3.98	0.13	0.00602	3.72	4.59
Dry matter value	Line 1	153	8.90	0.14	0.01169	8.64	9.19
	Line 2	153	8.95	0.07	0.00557	8.80	9.14
	Line 3	153	8.91	0.11	0.00862	8.71	9.17
	Total	459	8.92	0.11	0.00528	8.64	9.19
Protein value	Line 1	153	3.34	0.04	0.00311	3.27	3.43
	Line 2	153	3.35	0.04	0.00293	3.27	3.43
	Line 3	153	3.34	0.03	0.00257	3.26	3.43
	Total	459	3.35	0.04	0.00169	3.26	3.43

Analysis of variance (ANOVA) was used to analyze whether there were differences between lines. ANOVA is a method used to test the difference in group means or treatment means of data obtained from k independent or k dependent groups (Özdamar, 2013). The following hypothesis was tested in this study.

H_0: There is no difference between the means.

H_1: At least one mean differs from the others.

In this paper, Welch's ANOVA is used. Welch's ANOVA is a test for multiple comparisons of means. It is a modified One-Way ANOVA that is robust to the assumption of equal variances. Welch's ANOVA is an extension of the 2 sample t-test for means, assuming unequal variance (Sigmaxl, 2024).

RESULTS AND DISCUSSION

Milk is an important source of protein, including casein and essential amino acids, fats, and total solids that define milk's quality from an industrial perspective. Fat content is crucial because yield of butter production or production of dairy products with high fat content matters in industrial processing of milk. Protein and total solid content are important not only in terms of nutritional value but also structural quality of dairy products (Guetouache et al., 2014). Confidence interval plot for samples are given in Figure 2-7.

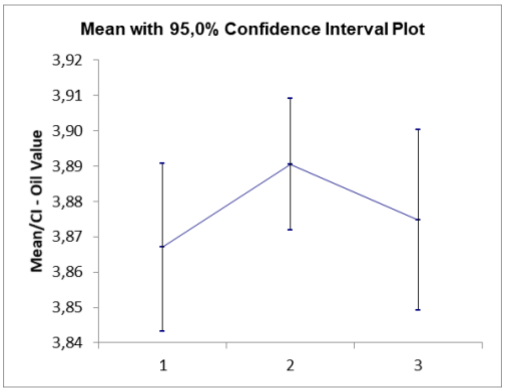

Figure 2. Confidence interval plot for fat value in first period.

For fat value in the first period, the group means are equal because the p-value for Welch's ANOVA is 0.2754, which suggests that we do not reject H_0. Pairwise mean difference and Welch pairwise probabilities are given in Table 4.

Table 4. Pairwise mean difference and Welch pairwise probabilities for fat value in first period.

Pairwise Mean Difference (row - column)	**1**	**2**	**3**
1	0	-0.02	-0.01
2		0	0.016
3			0
Welch Pairwise Probabilities	**1**	**2**	**3**
1		0.12	0.66
2			0.32
3			

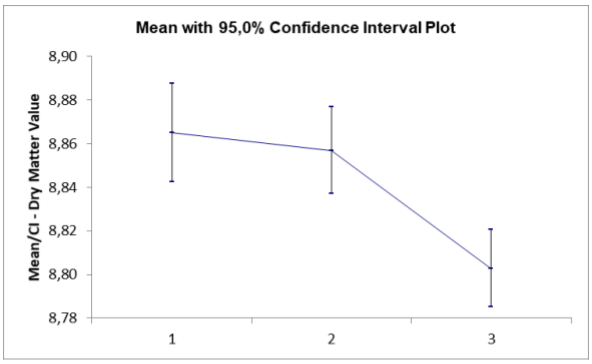

Figure 3. Confidence interval plot for dry matter value in first period.

For dry matter value in the first period, the group means are not equal because the p-value for Welch's ANOVA is 0, which suggests that we reject H_0. Pairwise mean difference and Welch pairwise probabilities are given in Table 5. It can be concluded that the dry matter value in the first period is different between Line 1 and 3. In addition, the dry matter value in the first period is different between Line 2 and 3.

Table 5. Pairwise mean difference and Welch pairwise probabilities for dry matter value in first period.

Pairwise Mean Difference (row - column)	**1**	**2**	**3**
1	0	0.01	0.06
2		0	0.05
3			0
Welch Pairwise Probabilities	**1**	**2**	**3**
1		0.59	**0.00**
2			**0.00**
3			

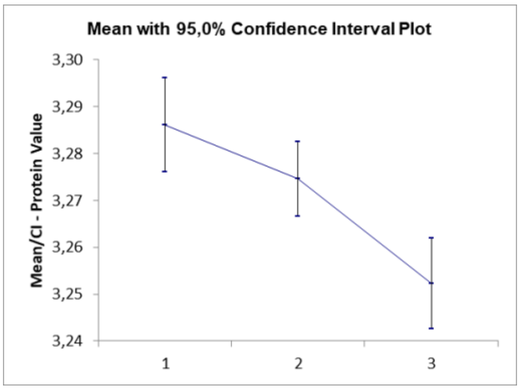

Figure 4. Confidence interval plot for protein value in first period.

For protein value in the first period, the group means are not equal because the p-value for Welch's ANOVA is 0, which suggests that we reject H_0. Pairwise mean difference and Welch pairwise probabilities are given in Table 6. It can be concluded that the protein value in the first period is different between Line 1 and 3. In addition, the protein value in the first period is different between Line 2 and 3.

Table 6. Pairwise mean difference and Welch pairwise probabilities for protein value in first period.

Pairwise Mean Difference (row - column)	**1**	**2**	**3**
1	0	0.01	0.03
2		0	0.02
3			0
Welch Pairwise Probabilities	**1**	**2**	**3**
1		0.08	**0.00**
2			**0.00**
3			

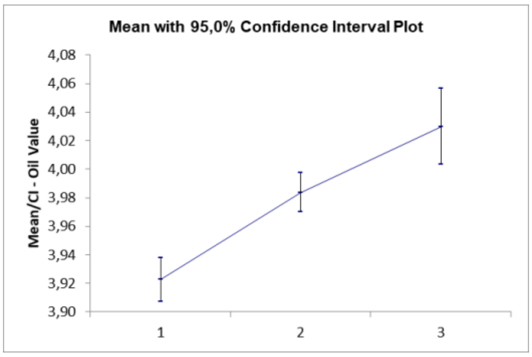

Figure 5. Confidence interval plot for fat value in second period.

For fat value in the second period, the group means are not equal because the p-value for Welch's ANOVA is 0, which suggests that we reject H_0. Pairwise mean difference and Welch pairwise probabilities are given in Table 7. It can be concluded that the fat value in the second period is different between Line 1 and 2. In addition, the fat value in the second period is different between Line 1 and 3. Also, the fat value in the second period is different between Line 2 and 3.

Table 7. Pairwise mean difference and Welch pairwise probabilities for fat value in second period.

Pairwise Mean Difference (row - column)	**1**	**2**	**3**
1	0	-0.06	-0.11
2		0	-0.05
3			0
Welch Pairwise Probabilities	**1**	**2**	**3**
1		**0.00**	**0.00**
2			**0.00**
3			

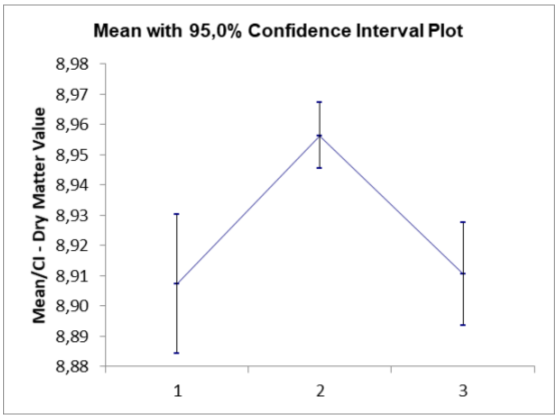

Figure 6. Confidence interval plot for dry matter value in second period.

For dry matter value in the second period, the group means are not equal because the p-value for Welch's ANOVA is 0, which suggests that we reject H_0. Pairwise mean difference and Welch pairwise probabilities are given in Table 8. It can be concluded that the dry matter value in the second period is different between Line 1 and 2. Also, the dry matter value in the second period is different between Line 2 and 3.

Table 8. Pairwise mean difference and Welch pairwise probabilities for dry matter value in second period.

Pairwise Mean Difference (row - column)	**1**	**2**	**3**
1	0	-0.05	-0.00
2		0	0.05
3			0
Welch Pairwise Probabilities	**1**	**2**	**3**
1		**0.00**	0.82
2			**0.00**
3			

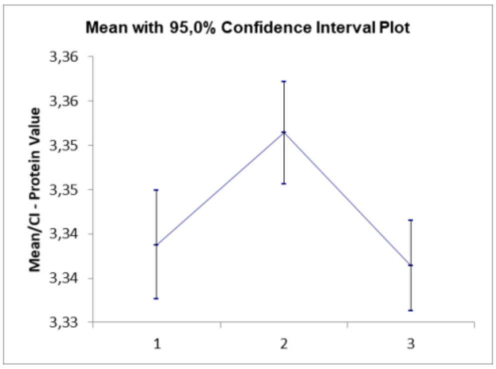

Figure 7. Confidence interval plot for protein value in second period.

For protein value in the second period, the group means are not equal because the p-value for Welch's ANOVA is 0.0004, which suggests that we reject H_0. Pairwise mean difference and Welch pairwise probabilities are given in Table 9. It can be concluded that protein value in the second period is different between Line 1 and 2. Also, protein value in second period is different between Line 2 and 3.

Table 9. Pairwise mean difference and Welch pairwise probabilities for protein value in second period.

Pairwise Mean Difference (row - column)	**1**	**2**	**3**
1	0	-0.01	0.00
2		0	0.01
3			0
Welch Pairwise Probabilities	**1**	**2**	**3**
1		**0.00**	0.55
2			**0.00**
3			

CONCLUSION

In conclusion, the mean fat value of raw milk collected from three lines was found to be 3.86, 3.89, and 3.87 as (%) the percent value, respectively, while the mean protein value of raw milk collected from three lines was found to be 3.29, 3.28, and 3.25 as (%) the percent value, respectively in the first period. In the second period, the mean fat value of raw milk collected from three lines was found to be 3.93, 3.99, and 4.03 as (%) the percent value, respectively, while the mean protein value of raw milk collected from three lines was found to be 3.34, 3.35, and 3.34 as (%) the percent value, respectively. The results showed daily raw milk collected from three lines is class A for both periods. Second, daily raw milk collected from three lines was compared considering fat, dry matter, and protein values. ANOVA was used for statistical analysis. Differences were found in group means for daily raw milk collected from three lines. This study shows that ANOVA analysis can be successfully implemented in classifying raw milk during the collection stage, and it may help accelerate milk selection in industrial applications in dairy processing. Classification is of importance in terms of hastening the processing of raw milk in the production of high quality dairy products. Therefore, this study sheds a light on using ANOVA to classify raw milk at the beginning of milk processing. In the future, more studies should be implemented on a wide range of areas to implement ANOVA to classify raw milk for huge dairy industries.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Declaration of Interests

The author has no conflict of interest to declare.

Author contribution

SLİ designed, analyzed the data, and wrote the paper. The author read and approved the final manuscript.

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