Effects of Somatic Cell Count, Parity and Lactation Stage on Yield and Components of Milk in Holstein-Friesian Cows

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Geliş Tarihi: 25.02.2016 **Kabul Tarihi: 25.04.2016**

Abstract: In this study, 1200 records from 126 Holstein-Friesian cows (first and second lactation) were used to investigate the effects of somatic cell count (SCC), parity and lactation stage on the milk yield and the protein, fat, lactose and urea nitrogen contents of the milk. In the second lactation, it was found that the milk yield and the protein content of milk was approximately 6% and 1% higher, respectively, while the fat and milk urea nitrogen (MUN) contents were 4% lower and the fat to protein ratio, 6% lower. In the first period of lactation, the milk yield was seen to be about 11% and 54% higher than that of the second and third period, respectively. In the last period of lactation, it was observed that the protein and fat content of milk was 8% and 10% higher than that of the first period and 5% and 8% higher than that of the second period, respectively. Finally, it was determined that milk yield, lactose and the MUN contents were about 12%, 10% and 17% higher, respectively, when the SCC was ≤200,000, compared to when the SCC was ≥1,001,000, and that the protein content of milk was 4% lower.

Keywords: *Milk Urea Nitrogen, Somatic Cell Count, First and Second Lactation, Holstein Cattle*

Siyah-Alaca İneklerde Somatik Hücre Sayısı, Laktasyon Sırası ve Döneminin Süt Verimi ve Süt Bileşimine Etkileri

Özet: Siyah-Alaca sığırlarda somatik hücre sayısı (SHS), laktasyon sırası ve döneminin, süt verimi ve sütün protein, yağ, laktoz, üre azotu içeriğine etkilerinin araştırıldığı çalışmada birinci ve ikinci laktasyondaki 126 ineğe ait 1200 veri kullanılmıştır. İkinci laktasyonda süt verimi ve sütün protein içeriğinin sırasıyla yaklaşık %6 ve %1 oranında daha fazla; yağ ve üre azotunun %4, yağ-protein oranının ise %6 daha az olduğu belirlenmiştir. Laktasyonun ilk döneminde süt verimi ikinci ve üçüncü döneme göre sırasıyla yaklaşık %11 ve %54 oranında yüksek bulunmuştur. Laktasyonun son döneminde sütün protein ve yağ içeriğinin ilk döneme göre sırasıyla % 8 ve %10; ikinci döneme göre sırasıyla %5 ve %8 oranında yüksek olduğu görülmektedir. SHS'nın ≤200.000 olduğu grupta süt verimi, sütün laktoz ve üre azotu içeriği SHS'nın ≥1.001.000 olduğu gruba göre sırasıyla yaklaşık %12, %10 ve %17 oranında fazla; sütün protein içeriğinin %4 oranında az olduğu belirlenmiştir.

Anahtar Kelimeler: *Süt Üre Azotu, Somatik Hücre Sayısı, Birinci ve İkinci Laktasyon, Laktasyon Dönemi*

Introduction

Milk is regarded as a staple food by nutrition physiologists, due to its combination of vital nutritional ingredients. Milk fat, which positively affects the physical properties of dairy products, is responsible for improving the taste of dairy products, while milk protein is of significant importance, in terms of nutritional value, owing to the fact that it is the basic ingredient (e.g. cheese) and the most essential component (e.g. yoghurt, concentrated milk and dried powder milk) of dairy products. For these reasons, protein and fat contents function as the key determinants for pricing milk in some countries, with premium prices being paid for milk that has high protein content. Milk yield and composition change according to the breed of livestock, lactation period, age of livestock, physical condition of the livestock, climatic conditions, nutrition and various other factors (Lindmark-Mansson et al., 2000). Worldwide, approximately 83% (635,575,895 tons) of the 768,640,663 tons of milk produced annually is obtained from cattle, according to the data provided by the Food and Agriculture Organization (FAO) (2013). The most important breed of dairy cattle in Turkey is the Holstein breed, which is responsible for providing approximately 90% of the country's annual cattle milk production. In Germany, the records show that there are 2 million Holstein-Friesian dairy cows, whose milk production is 9097 kg in 305 days, and their fat and protein contents, 4.05% and 3.38% respectively (Anonymous, 2012). Every year new studies are being conducted on how to increase the output obtained per unit in the agriculture and livestock breeding sectors in order to meet the food requirements of the rapidly increasing world population. The choice of milk and dairy products for satisfying the animal protein requirement, so important for human nutrition, has fostered the increasing number of initiatives to introduce new implementations that serve to increase milk production. As a result of these new implementations, however, problems related to the reproductive efficiency of the cattle have frequently been encountered, certain metabolic dysfunctions have emerged, and furthermore, due to the breakout of various diseases, mastitis being at the forefront, some of the animals are forced to be isolated from the cattle herds (Richardt, 2000).

The protein and fat contents of milk, which are particularly important variables for the dairy industry, serve as significant markers for identifying certain important nutrition and herd management problems, as well as for providing information about the level of success of nutritional regimens introduced to the dairy cattle. For example, the protein and fat content is able to provide information about the fat to protein ratio, the presence of metabolic dysfunctions, such as acidosis and ketosis, the energy level and level of available crude protein in feed, MUN, the level of indigestible protein in the feed and the nitrogen balance in the rumen. MUN, which is an indicator of the relation between feed protein content and energy level, also reveals information about the utilization of crude protein in the feed (Jonker et al., 1999; Godden et al., 2001b; Richardt, 2004). Nitrogen balance in the rumen has a close relation with MUN in the German nutrition system. These different variables help to determine the presence of sub-clinical ketosis in cases where the fat to protein ratio of milk is ≤1.1 and the acidosis is ≥1.5. It should be noted, however, that no changes will be observed in the fat to protein ratio of milk in cases where acidosis and ketosis take place at the same time (for example, in cases where feed rations are rich in sugar and starch and there is low feed consumption at the beginning of lactation period) (Richardt, 2000). It has been reported that under proper nutrition conditions, the optimum amount of MUN, which constitutes 2.5-3% of the total nitrogenous substances in the milk, should be between 15-30 mg/dl (Hamann and Krömker, 1997). In this study, the aim was to determine the effects of SCC, parity and lactation stage in Holstein-Friesian cattle on milk yield and the protein, fat, lactose and MUN contents in the milk, and to define the strategies needed to secure the improvement of these factors, all of which have a direct effect on the quality of dairy products.

Materials and Methods

The data for this study was collected between 2012 and 2013 from 126 Holstein-Friesian cows belonging to two farms located in Stuttgart, Germany, on the days when the milk was checked individually on a monthly basis. Milk protein, fat, lactose and MUN contents were determined using the Near Infrared Spectroscopy (NIR) (MilkoScan FT6000, Foss Electric, Denmark), and the SCC was determined using the Flow Cytometry Fossomatic 5000, Foss Electric, Denmark). The least square method was employed in order to examine the effects of SCC, parity and lactation stage on milk yield and the milk protein, fat, lactose and MUN contents. To compare the means in the subgroups, the Student-t test was used. In this regard, parity was divided into two groups, with the first group comprising cattle giving birth to their first calf, and the second group comprising those calving for the second time; lactation stage was divided into three groups, as 6-105 days, 106-205 days and more than 205 days; SCC was divided into four groups, as those ≤200,000, between 201,000-500,000, between 501,000-1,000,000, and ≥1,001,000 (Mundan et al., 2015). Statistical analyses were performed using SPSS software (Version 17.0).

Results

The means (± standard deviation) related to milk yield, the protein, fat, lactose and MUN contents and the fat to protein ratio are provided in Table 1, together with their maximum and minimum values. Table 2 presents the means (± standard error), obtained using the least square method, for milk yield, the protein, fat, lactose and MUN contents and fat to protein ratio. And finally, in Table 3, the correlation coefficients for the variables have been given. The effects of parity and lactation stage on milk yield, the protein, fat, lactose and MUN contents and the fat to protein ratio were found to be significant ($P<0.01$; $P<0.001$). The SCC was determined to have an important effect on milk yield and the milk protein, lactose and MUN contents, while its effect on fat content and the fat to protein ratio was found to be insignificant ($P≥0.05$). In the second lactation, it was observed that milk fat and MUN were 4% lower and the fat to protein ratio 6% lower, while the milk yield and protein content were, respectively, around 6% and 1% higher (Table 2). The effects of lactation stage on milk yield and the milk protein, fat, lactose and MUN contents were determined to be significant at a level of $P<0.001$; and the fat to protein ratio was determined to be significant at a level of $P<0.01$. Compared to the second and third stage, milk yield in the first stage of lactation was observed to be 11% and 54% higher, respectively. Furthermore, it was found that in the last stage of lactation, the milk protein and fat contents, as compared to the first stage, were 8% and 10% higher, respectively, and compared to the second stage, 5% and 8% higher, respectively (Table 2). Milk yield and the milk lactose and MUN contents of the group with a SCC ≤200,000 were approximately 12%, 10% and 17% higher, respectively, compared to the group with a SCC ≥1,001,000, while the milk protein content was approximately 4% lower (Table 2).

Table 1. The mean, standard deviation, minimum and maximum value of milk yield, the protein, fat, lactose and milk urea nitrogen content and fat to protein quotient (n=1200).

	Milk yield kg/day	Protein %	Fat %	Lactose %	MUN mg/ml	Fat/Protein
Mean	25.36	3.24	3.94	4.61	20.67	1.22
Standard deviation	7.32	0.29	0.61	0.11	5.44	0.17
Minimum	5.30	2.38	2.01	4.09	1.00	0.63
Maximum	53.80	4.61	6.25	4.70	40.00	2.08

Table 2. The least square means (± standard error) of milk yield, the protein, fat, lactose and milk urea nitrogen content of milk and fat to protein quotient[1].

	Milk yield kg/day	Protein %	Fat %	Lactose %	MUN mg/ml	Fat/Protein
Parity[2]						
1	24.41±0.34^{b}	3.27±0.02^{b}	4.06±0.04^{a}	4.47±0.00^{a}	20.12±0.31^{a}	1.24±0.01^{a}
2	25.89±0.33^{a}	3.31±0.01^{a}	3.89±0.03^{b}	4.47±0.00^{b}	19.26±0.30^{b}	1.17±0.01^{b}
P[3]	***	**	***	**	**	***
Lactation Stage[2]						
1	29.56±0.39^{a}	3.17±0.02^{c}	3.82±0.04^{b}	4.47±0.00^{a}	20.38±0.36^{a}	1.21±0.01^{ab}
2	26.69±0.38^{b}	3.27±0.02^{b}	3.89±0.04^{b}	4.47±0.00^{a}	20.60±0.35^{a}	1.19±0.01^{b}
3	19.21±0.36^{c}	3.43±0.02^{a}	4.21±0.04^{a}	4.46±0.00^{b}	18.09±0.33^{b}	1.23±0.01^{a}
P[3]	***	***	***	***	***	**
SCC[2]						
1	25.99±0.20^{a}	3.20±0.01^{b}	3.91±0.02^{a}	4.66±0.00^{a}	20.95±0.18^{a}	1.22±0.01^{a}
2	25.34±0.38^{a}	3.32±0.02^{a}	3.99±0.04^{a}	4.55±0.00^{b}	20.86±0.35^{a}	1.20±0.01^{a}
3	26.16±0.65^{a}	3.29±0.03^{a}	4.02±0.07^{a}	4.41±0.00^{c}	19.02±0.59^{b}	1.22±0.02^{a}
4	23.12±0.87^{b}	3.34±0.04^{a}	3.98±0.09^{a}	4.25±0.00^{d}	17.93±0.79^{b}	1.19±0.03^{a}
P[3]	**	***	n.s.	***	***	n.s.

[1]Means in a column for parity number, lactation stage and SCC with no common superscript differ significantly (P<0.05).
[2]Parity: 1: First lactation 2: Second lactation; Lactation stage: 1: 6-105 days, 2: 106-205 days, 3: ≥ 206 days; SCC 1: ≤ 200,000, 2: 201,000-500,000, 3: 501,000-1,000,000, 4: ≥ 1,001,000.
[3] ***: P<0.001; **: P<0.01; *: P<0.05; n.s. (not significant): P≥0.05.

Table 3. The correlation coefficients of variables[1].

	PN	LS	SCC	MY	P	F	L	MUN
MY	0.070*	-0.580***	-0.187***					
P	0.126***	0.407***	0.216***	-0.472***				
F	-0.107***	0.265***	0.080**	-0.450***	0.437***			
L	-0.155***	-0.156***	-0.951***	0.207***	-0.226***	-0.101***		
MUN	-0.105***	-0.188***	-0.160***	0.353***	-0.233***	-0.369***	0.196***	
F/P	-0.206***	0.027$^{n.s.}$	-0.059*	-0.191***	-0.163***	0.811***	0.043$^{n.s.}$	-0.251***

[1]PN:Parity; LS:Lactation stage; SCC: Somatic cell count; MY: Milk yield (kg/day);
P: Protein content (%); F: Fat content (%); L: Lactose content (%); MUN: Milk urea nitrogen (mg/ml); F/P: Fat to protein ratio
***: P<0.001; **: P<0.01; *: P<0.05; n.s.: P≥0.05.

As seen in Table 3, there was a positive correlation between parity and milk yield and milk protein content and a negative correlation between milk fat, lactose, MUN contents and fat to protein ratio. In terms of the lactation stage and SCC, a negative correlation was found between milk yield and lactose and MUN content and a positive correlation between the protein and fat contents of milk.

Discussion

It was determined that parity, lactation stage and SCC have significant effects on milk yield, and that the milk yield of the cows in their first lactation was lower than the milk yield of those in the second lactation. The reason for this can be attributed to the increase that occurs in the weight of the cows over the years and the completion of the development of the udder tissue. Milk yield increases until the age of maturity (6 years), at which point after it begins to decrease. It was found that the milk yield decreases throughout the period of lactation, and that such a decrease were more apparent for the cattle in the second lactation. The milk yield of the cows in the second lactation of the first lactation stage versus the milk yields in the second and third lactation stages were found to be 26.4% and 77.5% higher, respectively, while for the cattle in the first lactation, as compared to the same, the yields were 7.8% and 38.1% higher, respectively. While a significant positive correlation was determined between MUN and milk yield in the present study, it should be noted that the relationship between these variables have been shown to have mixed results in other studies, with some reporting a positive relationship (Johnson and Young, 2003; Hojman et al., 2004; Hojman et al., 2005), others reporting a negative relationship (Diab and Hillers, 1996) and still others, no relationship (Baker et al., 1995).

Lactation stage and MUN were found to have an effect on milk protein content. Between lactation stage and milk protein content, a positive correlation was determined, while between MUN and milk yield, a negative correlation was determined. It has been reported that milk protein content increases up to the second lactation and then proceeds to decrease 0.02-0.03% on average at every lactation thereafter, and that protein content is high at the beginning and end of the lactation (Fürst, 2005). It has also been confirmed by various researchers that protein content increases as the lactation period progresses (Sharaby, 1988; Richardt, 2004). Richardt (2004) has reported that the difference in milk protein content between the first 100 day period and the last 100 day period of lactation is required to be maximum 0.5-0.6%. Certain studies have shown there to be a negative correlation between MUN and milk protein content (Godden et al., 2001a; Johnson and Joung, 2003; Abdouli et al., 2008), and a significant negative correlation between milk yield and protein content (Chauhan and Haves, 1991; Agabriel et al., 1993; Richardt, 2004).

Parity, lactation stage and MUN were determined to have a significant effect on milk fat content. Fat content was found to be considerably high in the first lactation, and it was detected that fat content increases as the lactation progresses, with the fat content reaching its highest value in the last stage of lactation. Martin et al. (2006) have reported that milk fat content is high in the first lactation and decreases thereafter and that milk fat content increases during the course of lactation. Various other researchers have also confirmed that fat content increases as the lactation period progresses (Sharaby, 1988; Lal and Narayanan, 1991). Milk fat content was found to reach the highest value in cases where the MUN was <15 mg/dl, with the fat content decreasing in proportion to the increase in the MUN content. Some researchers have reported there to be a negative correlation between MUN and milk fat content (Godden et al., 2001a; Johnson and Young, 2003) and a significant negative correlation between milk yield and milk fat content (Chauhan and Haves, 1991; Martin et al., 2006).

Hamann and Krömker (1997) have reported that changes in the milk composition and the metabolic state of a cow are related to energy instability, and that there is an important correlation between the milk fat to protein ratio and energy. The milk fat to protein ratio of the cows in the first lactation was found to be significantly higher than that of the cows in the second lactation. In a similar manner, it was determined that the fat to protein ratio in the first and last lactation periods was higher than the ratio determined in the middle of lactation. The fat to protein ratio was found to reach the highest level in cases where the MUN was <15 mg/dl, and a significant negative correlation was observed between milk yield and the fat to protein ratio. It has been reported that the fat to protein ratio in milk is required to be between >1.1 and <1.5, and that the optimal value is 1.2 (Richardt, 2004). Moreover, it has been shown that the protein content of cows having a milk yield of 27 kg, 27-35 kg and more than 35 kg are less than 3.2%, 3.0% and 2.8%, respectively, in cases where there is a lack of energy content in the nutrition of the cattle, and that the protein content can be increased to more than 3.8% (max. 4.1%) if the energy content of the feed is increased (Richardt, 2004). The present study found that in the cows who were in their first lactation of the first stage of lactation, the fat to protein ratio varied between 0.63 and 2.08. It is possible to maintain the fat to protein ratio of milk at the desired level with the readjustment of energy content in the nutrition of dairy cattle.

It was concluded that parity and lactation stage, together with MUN content, have a significant effect on the milk's SCC. The SCC was observed to increase as the parity and lactation stage progressed, and a significant correlation was found between MUN and SCC. While Depatie (2000) has suggested that there is no relation between MUN and SCC, Ng-Kwai-Hang et al. (1985) argue a positive correlation and Richardt (2004), a negative correlation. The present study identified a negative correlation between milk yield and SCC and a positive correlation between milk protein and fat contents and SCC. Studies have shown that milk fat content decreases in cases of udder diseases (Martin et al., 2006), and that there is a positive relationship between SCC in the tank bulk milk and milk protein content (Najafi et al., 2009).

It has been reported that a 100 g increase in the feed protein content causes a 3-4 mg/l increase in the MUN content, which normally is required to be 150-300 mg per liter of milk (Richardt, 2004). It is suggested in some studies that the MUN value varies between 10 mg/dl and 16 mg/dl, although this depends on many factors (Johnson and Joung, 2003; Rajala-Schultz and Saville, 2003). While Aboulia et al. (2008) have reported that the MUN is 30.39 mg/dl for cows raised under Mediterranean conditions; this value was determined to be 20.43-32.49 mg/dl by Frank and Swensson (2002), 11.15 mg/dl by Arunvipas et al. (2008) and 12.7-13.9 mg/dl by Meeske et al. (2009). MUN may differ from one herd to the next, as well as between cows within the same herd. It is important that herd managers determine the MUN value on a monthly basis, as excessive consumption of nitrogen decreases the reproductive efficiency in cattle, and the excess amount of nitrogen emission adversely affects the environment (Rajala-Schultz and Saville, 2003). In order to ensure an accurate interpretation of MUN content, it is important to keep in mind that the MUN content is closely correlated with the parity, lactation stage, milk yield, udder health, as well as nutrition of the cattle (Richardt, 2004). Furthermore, it should be noted that 13.3% of the change in the MUN content can be explained by milk yield (Arunpivas et al., 2003), while 37% can be explained by environmental factors (Hojman et al., 2004).

Considering the results from the data, it can be concluded that herd management plays a crucial role in ensuring the health of the livestock and the effectiveness of their nutritional regimen, whereby increases in milk yield and the milk protein and fat content, both of which significantly affect the quality of the dairy products, can be realized.

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