http://agriprojournal.com
JOURNAL OF AGRICULTURAL PRODUCTION
ISSN: 2757-6620
PRENSIP
https://prensip.gen.tr

RESEARCH ARTICLE

Prediction of Energy Balance Based on Milk Parameters Across Different Lactation Stages

Vildan Koçbeker✉

Selçuk University, Beyşehir Ali Akkanat School of Applied Sciences, Department of Emergency and Disaster Management, Konya/Türkiye

ARTICLE INFO

Article History
Received: 22.10.2024
Accepted: 12.01.2025
First Published: 26.03.2025

Keywords
Acidosis
Energy balance
Ketosis
Milk fat
Milk protein

ABSTRACT

Following the changes observed in milk parameters throughout the lactation period will offer an easy and practical method for the evaluation of the feeding programs of animals as well as presenting opportunities to improve the quality of milk. For this purpose, the milk samples collected from 1390 Holstein cows Bursa Province in Turkey on the test day of the month (at an interval of 30 days) were examined and their fat, protein, dry matter and lactose contents were measured. The cows with boundary values for the fat/ protein accepted for the metabolic states of the cows in the study are considered to be at risk of acidosis if they are lower than 1.2, to be healthy if they are between 1.2 and 1.4 and to have a ketosis risk if the values are over 1.4. The results of the study have shown that the risk for acidosis among the animals are 39.5%, 32.4% and 33.9% respectively during the lactation periods 1, 2 and 3. The percentage of animals at risk of ketosis was determined to be 30.2%, 37.9%, 36.6% respectively. Energy balance is defined as the difference between energy intake from feed and energy required for animal performance. It is an important concept in cattle management and nutrition because it directly impacts the health, productivity, and reproductive success of cows, particularly during lactation. The percentages of the animals at the positive energy balance are 30.3, 29.7 and 29.6 respectively. Estimates for early, mid and late lactation show that in early lactation 31% of cows have acidosis, 37% have ketosis and 32% have positive energy balance, in mid lactation 31% have acidosis, 28% have ketosis and 32% have positive energy balance, while in late lactation 34% have acidosis, 34% have ketosis and 32% have positive energy balance.

Please cite this paper as follows:

Koçbeker, V. (2025). Prediction of energy balance based on milk parameters across different lactation stages. *Journal of Agricultural Production*, *6*(1), 10-14. https://doi.org/10.56430/japro.1571558

1. Introduction

In a nutritionally balanced dairy cattle ration, approximately seventy percent of the animal's protein requirement should be met by microbial protein produced as a result of the fermentation of nutrients in the feed in the rumen. Achieving this important task largely depends on the supply and adequate consumption of energy and protein in appropriate amounts and proportions in the ration. Reaching the optimum level of milk yield and composition in dairy cattle can only be achieved by ensuring good rumen fermentation. For this, the amount and degradability of energy and protein sources in the diet must be balanced to ensure the optimization of rumen functions (Beever, 1993). Metabolic disorders caused by nutrient deficiency or imbalance in the diet also cause changes in the chemical composition of milk. Therefore, changes in the protein and fat content of individual milk samples during the lactation period of cows are important parameters that directly affect the health, reproduction and productivity of the animals (Mäntysaari & Mäntysaari, 2010).

In the late lactation period, as the productivity of cows decreases, roughage can meet the energy and other nutritional

✉ Correspondence
E-mail address: vildankocbeker@selcuk.edu.tr

needs of cows. In such cases, milk composition reflects forage quality. High-quality forages are rich in both energy and protein content and can provide milk yields of around 30 kg or more per day with little or no added nutrients. Negative energy balance, which occurs due to inadequate feeding of cows despite high milk yield in the early lactation period, is an important problem that reduces milk yield and threatens milk quality in the postpartum period. Monitoring the symptoms of subclinical ketosis is important in terms of milk quality, herd health and reproductive performance, and preventing economic losses in the enterprise (Arnould et al., 2013).

Both the fat and protein percentage of milk on the control day are significantly associated with the risk of subclinical ketosis, and it has been reported that high milk fat percentage and low milk protein percentage significantly increase the risk of subclinical ketosis. While an increase of 1% in milk fat increased the risk of subclinical ketosis by at least twofold, an increase of 1% in milk protein reduced the risk of subclinical ketosis by more than 50% (Duffield et al., 1997). In ketosis, which is a metabolic disorder frequently seen in early lactation, milk protein content generally decreases while milk fat content increases. However, in subclinical acidosis, milk protein content increases and milk fat content decreases (Pavlata et al., 2008). It has been reported that milk protein and especially casein levels depend on the increase in the level of starch (cereal) consumed in the diet, but this increase raises the risk of rumen acidosis (Beever, 2006; Yang & Beauchemin, 2007). Mackle et al. (2000) reported that increasing energy level in the diet affects milk protein, and this may be related to the increase in microbial protein synthesis in the rumen.

The amount of fat and protein in milk is an effective parameter for monitoring the efficiency of the ration. Changes in the concentrations or mutual ratios of these two milk components in milk can give important clues about changes or problems in health as well as nutritional deficiency or balance in the ration (Lean & Golder, 2024; Nelson & Redlus, 1989; Rathwell, 1990). This study aimed to evaluate the milk fat/milk protein ratio of cows at various stages of lactation as an indicator of metabolic disorders and to use this ratio in estimating energy balance.

2. Materials and Methods

The data of the study were obtained from individual data collected from 1390 Holstein dairy cattle in the commercial dairy cattle farm registered to the cattle breeders association in Bursa province. On the farm where the research was conducted, animals housed in free stall barns are grouped according to their milk yield level, and the number of milking is 3 for those with high milk yield and 2 for animals with low milk yield. 9,920 data consisting of fertility and milk yield records of individual animals were evaluated. This study monitored the lactation periods of cows, which were divided into three stages:

Early lactation: Days in milk (DIM) 0–100

Mid lactation: Days in milk 100–200

Late lactation: Days in milk >200

The research was conducted to determine milk fat, milk protein, milk solids and milk lactose values of milk samples collected on monthly test days during a 10-month period between August and May (30 days apart) with a Bently FTS/FCM COMBI 400 (Bentley Nexgen 400) model device. On the farm where the research was conducted, animals are fed with full rations suitable for milk yield. Dry matter, crude protein, crude fat, neutral detergent fiber (NDF), acid detergent fiber (ADF), crude ash analyses of the ration samples taken during the morning feeding on the first control day and monthly (on test days) throughout the duration of the research were carried out in the Feed Analysis Laboratory of the Department of Animal Science, Faculty of Agriculture, Selçuk University (Table 1). NDF and ADF contents of feed materials and rations were determined with Van Soest (1994), and other nutrients were determined through methods specified by Akyıldız (1984). The average nutrient compositions of the rations used on the farm are shown in Table 1. Statistical analyses in the research were carried out using the SPSS 21 package program. Differences between groups were determined by repeated One-Way-ANOVA.

Table 1. Feed analysis information on the farm.

	Feed analysis information on the farm	
Farm Groups	MY*<35	MY≥35
DM (%)	35.22	40.85
CF (%)	4.68	6.31
CA (%)	6.70	6.39
CP (%)	13.54	14.50
ADF (%)	20.62	18.31
NDF (%)	34.92	32.19
ME (Mcal/kg KM**)	1.73	2.63
NFC***	34.41	34.24
Roughage/Concentrate Feed	56/44	45/55
NFC/CP	2.54	2.36
ME/CP	0.19	0.11
Ration ID	1	2

*MY: milk yield, kg/day.
**ME (Mcal/kg DM): (3227+62.86%CF-31.79%CA-32.50%ADF)/1000.
***NFC (non-fiber carbohydrate):%DM-(CP+CF+NDF+CA).

3. Results and Discussion

Changes in the biochemical composition of milk can be used as a reflector of the physiological state of the cow (Hamann & Krömker, 1997). Especially in large-scale commercial herds, applying a feeding program appropriate to the lactation periods throughout lactation is very important in terms of monitoring the health status of the animals and milk yield and quality (Stoop et al., 2009). The optimum milk fat/milk protein ratio is between 1.2-1.4, indicating that cows are in positive energy balance, while values higher than 1.4 (or values where the milk protein/milk fat ratio is equal to or lower than 0.75) are a signal of energy deficiency and indicate a high risk of subclinical ketosis (Geishauser et al., 1998; Heuer et al., 1999). A milk fat/milk protein ratio lower than 1.2 is most probably an indicator of subclinical acidosis, and it has been reported that low values may negatively affect the reproductive performance of cows and increase the possibility of disorders in mineral metabolism (Čejna & Chladek, 2005). Insufficient dietary fiber levels in herds can cause health problems, such as a decrease in milk fat level, acidosis and laminitis (Heuer et al., 1999). It has been reported that a milk fat/milk protein ratio below 1.2 indicates ration cellulose deficiency and energy excess, values between 1.2 and 1.4 are the optimum value, and above 1.4 is considered an indicator of ration energy deficiency and fiber excess (Alphonsus et al., 2013; Čejna & Chiladek 2005).

In the study, the percentage of animals at risk of acidosis in the 1st, 2nd and 3rd lactation was 39.5, 32.4 and 38.9%, respectively, and 33.9% for the whole herd. While the percentage of animals in positive energy balance was highest in the 1st lactation (30.3%), it was 29.7% in the 2nd lactation and 22.2% in the 3rd lactation, and was found to be 29.6% in the herd overall (Table 2). The percentage of animals at risk of ketosis in the 1st, 2nd and 3rd lactation was 30.2, 37.9 and 38.9%, respectively, and 36.5% for the herd overall. According to the results of the research, the problems seen in positive energy balance were found to be higher in young animals in the first lactation than in adult animals, especially since young animals in the first lactation, which constitute the majority of the herd, are more sensitive to pregnancy, hormonal changes and diseases.

It is so important to take into account the indicators used to estimate metabolic energy balances, to detect possible errors in feeding early enough and to manage the herd as well as to take the necessary precautions, especially for animals in the first lactation. If the negative effects observed in energy balance cannot be prevented in the 1st lactation, it is highly likely that more significant health and productivity losses will be experienced in the 2nd and 3rd lactation periods.

Table 2. The estimation of energy balance based on the milk fat/milk protein ratio for lactation number (x̄±Sx).

Limit values for milk fat/milk protein ratio		**1st Lactation (1.30±0.30)**		**2nd Lactation (1.37±0.3)**		**3rd Lactation (1.29±0.21)**		**TOTAL**	
		N	%	N	%	N	%	N	%
<1.2	Acidosis	68	39.5	227	32.4	7	38.9	302	33.9
>1.4	Ketosis	52	30.2	266	37.9	7	38.9	325	36.5
=1.2-1.4	Positive energy balance	57	30.3	208	29.7	4	22.2	264	29.6
TOTAL		172	100	701	100	18	100	891	100

The milk fat-to-protein ratio variable reached its highest value in the second lactation and its lowest value in the first lactation (P<0.05). Milk protein variable reached its highest value in the first lactation (3.21±0.39) and its lowest value in the second lactation (2.94±0.31). Milk fat variable reached its highest value in the first lactation (3.99±0.68) and its lowest value in the second lactation (3.34±0.42).

According to the research results, the percentage of ketosis was lowest (28%) in the mid-lactation period, and the highest percentage value (37%) was detected in the early lactation period (Table 3). Hanuš et al. (2013) reported that ketosis is a lack of energy and means an insufficient level of glucose in the blood. In ketosis, milk fat content increases due to the breakdown of body fats, while on the contrary, protein content decreases. Negative energy balance, which occurs due to inadequate feeding of cows despite high milk yield in the early lactation period, may be the possible cause of reproductive disorders such as abomasum displacement, mastitis and retention of end, which reduce milk yield and threaten milk quality in the postpartum period (Hanuš et al., 2013). It has been reported that ketosis cases, which are mostly seen in the first 50 days of lactation, can be diagnosed accurately within the first 10 days of lactation and that the use of milk analysis records in the early lactation period is common in practice, but the use of daily milk records for the first 10 days of lactation, which is a risky period for ketosis, will give more accurate results (Manzenreiter et al., 2013).

Table 3. The estimation of energy balance based on the milk fat/milk protein ratio for lactation stages (x̄±Sx).

Limit values for milk fat/milk protein ratio		**Early lactation (1.31±0.34)**		**Mid lactation (1.42±0.38)**		**Late lactation (1.35±0.36)**		**TOTAL**	
		N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
<1.2	Acidosis	54	31	44	30	228	35	326	34
>1.4	Ketosis	65	37	41	28	226	35	332	34
=1.2-1.4	Positive energy balance	56	32	63	42	191	30	310	32
TOTAL		175	100	148	100	645	100	968	100

The milk fat-to-protein ratio variable reached its highest value in the early lactation and its lowest value in the late lactation ($P<0.05$). Milk protein variable reached its highest value in the late lactation (3.04±0.37) and its lowest value in the early lactation (2.84±0.30). Milk fat variable reached its highest value in the late lactation (4.06±0.97) and its lowest value in the early lactation (3.71±0.92).

In a study conducted by Čejna and Chladek (2005), the milk fat/milk protein ratio of individual milk samples taken from Holstein cows on days 25, 45, 73, 101, 133, 166, 199, 224, 253 and 280 of lactation was found to be 1.91, 1.45, 1.38, 1.28, 1.22, 1.14, 1.26, 1.21, 1.09 and 1.18 respectively. The high milk fat/milk protein ratio seen in the first phase of lactation has been attributed to energy deficiency. The sediment quality of milk obtained from these animals was also found to be low. Researchers have reported that the milk fat/milk protein ratio changes throughout the lactation period, and that a high ratio at the beginning of lactation indicates that the cows are undernourished in terms of energy and have a negative energy balance.

In the current study, the percentage of animals at risk of acidosis showed the highest value (35%) in the late lactation period, while the lowest value (30%) was observed in the mid-lactation period (Table 3). The rate of animals at risk of acidosis in the herd overall is 34%, and the rate of animals at risk of ketosis is 34%. While the percentage of animals in positive energy balance was highest in the mid-lactation period (42%), it was lower in the early and late lactation periods (32% and 30%, respectively).

4. Conclusion

The variations observed in the components of milk may reflect metabolic disorders and changes in energy balance. Preliminary symptoms of low milk fat percentage problems, as well as important yield and health problems in the 2nd and 3rd lactate periods, which are commonly encountered on large farms in Türkiye, can be obtained by using individual milk analyses. Thus, they will be able to prevent economic losses by protecting herd health by means of making changes in their feeding programs. In the research, the suitability and effectiveness of the feeding program applied in the evaluation of metabolic disorders were evaluated by using individual milk analyses on the farm.

Compliance with Ethical Standards

The milk samples used in the study originated from the milked cows in a commercial dairy cattle farm. Milks were obtained as a result of the routine milking processes at the farm. Cows were not subjected to any extraordinary applications nor given any agents. Moreover, according to the "Regulation on Working Procedures and Principles of Animal Trials Ethical Committees" (published in Turkish Republic Official Gazette, Number: 28914), milking procedure is not subjected to ethical approval.

Conflict of Interest

The author has no conflict of interest to declare.

References

Akyıldız, R. (1984). *Yemler bilgisi laboratuvar kılavuzu*. Ankara Üniversitesi Ziraat Fakültesi Yayınları. (In Turkish)

Alphonsus, C., Akpa, G. N., Nwagu, B. I., Barje, P. P., Orunmuyi, M., Yashim, S. M., Zanna, M., Ayigun A. E., & Opoola, E. (2013). Evaluation of nutritional status of Friesian x Bunaji dairy herd based on milk composition analysis. *Journal of Animal Science Advances*, *3*(5), 219-225. https://doi.org/10.5455/jasa.20130517033450

Arnould, V. M.-R., Reding, R., Bormann, J., Gengler, N., Soyeurt, H. (2013). Review: milk composition as management tool of sustainability. *Biotechnology, Agronomy, Society and Environment*, *17*(4), 613-621.

Beever, D. E. (1993). *Ruminant animal production from forages: Present position and future opportunities*. Proceedings of the XVIIl International Grassland Congress. New Zealand.

Beever, D. E. (2006). The impact of controlled nutrition during the dry period on dairy cow health, fertility and performance. *Animal Reproduction Science*, *96*(3-4), 212-226. https://doi.org/10.1016/j.anireprosci.2006.08.002

Čejna, V., & Chládek, G. (2005). The importance of monitoring changes in milk fat to milk protein ratio in Holstein cows during lactation. *Journal of Central European Agriculture*, *6*(4), 539-546.

Duffield, T. F., Kelton, D. F., Leslie, K. E., Lissemore, K. D., & Lumsden, J. H. (1997). Use of test day milk fat and protein to predict subclinical ketosis in Ontario dairy herds. *Canadian Veterinary Journal*, *38*, 713-718.

Geishauser, T., Leslie, K., Duffield, T., & Edge, V. (1998). An evaluation of protein/fat ratio in first DHI test milk for prediction of subsequent displaced abomasum in dairy cows. *Canadian Journal of Veterinary Research*, *62*(2), 144-147.

Hamann, J., & Krömker, V. (1997). Potential of specific milk composition variables for cow health management. *Livestock Production Science*, *48*(3), 201-208. https://doi.org/10.1016/S0301-6226(97)00027-4

Hanuš, O., Klımešová, V. M., Gustav, C., Petr, R., & Seydlová, R. (2013). Metaanalysis of ketosis milk indicators in terms of their threshold estimation. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, *61*(6), 1681-1692. https://doi.org/10.11118/actaun201361061681

Heuer, C., Schukken, Y. H., & Dobbelaar, P. (1999). Postpartum body condition score and results from the first test day milk as predictors of disease, fertility, yield, and culling in commercial dairy herds. *Journal of Dairy Science*, *82*(2), 295-304. https://doi.org/10.3168/jds.s0022-0302(99)75236-7

Lean, I. J., & Golder, H. M. (2024). Milk as an indicator of dietary imbalance. *Australian Veterinary Journal*, *102*(1-2), 19-25. https://doi.org/10.1111/avj.13294

Mackle, T. R., Dwyer, D. A., Ingvartsen, K. L., Chouinard, P. Y., Ross, D. A., & Bauman, D. E. (2000). Effects of insulin and postruminal supply of protein on use of amino acids by the mammary gland for milk protein synthesis. *Journal of Dairy Science*, *83*(1), 93-105. https://doi.org/10.3168/jds.s0022-0302(00)74860-0

Mäntysaari, P., & Mäntysaari, E. A. (2010). Predicting early lactation energy balance in primiparous Red Dairy Cattle using milk and body traits. *Acta Agriculturae Scandinavica, Section A — Animal Science*, *60*(2), 79-87. https://doi.org/10.1080/09064702.2010.496002

Manzenreiter, H., Fürst–Waltl, B., Egger– Danner, C., & Zollitsch, W. (2013). Zur Eignung des Gehalts an Milchinhaltsstoff en als Ketoseindikator. *40. Viehwirtschaftliche Fachtagung*, 9-19. (In German)

Nelson, A. J., & Redlus, H. W. (1989). Dairy practice management: The key role of records in a production medicine practice. *Veterinary Clinics of North America: Food Animal Practice*, *5*(3), 517-552. https://doi.org/10.1016/S0749-0720(15)30947-6

Pavlata, L., Pechova, A., & Dvorak, R. (2008). Differential diagnosis of cows lying down syndrome. *Veterinarstvi*, *58*, 43-51.

Rathwell, A. C. (1990). *Dairy production medicine: Effective nutrition, dry cow management and body condition on reproduction*. Proceedings Society Ontario Veterinary Conference Hamilton, Ontario.

Stoop, W. M., Bovenhuis, H., Heck, J. M. L., & Van Arendonk, J. A. M. (2009). Effect of lactation stage and energy status on milk fat composition of Holstein-Friesian cows. *Journal of Dairy Science*, *92*(4), 1469-1478. https://doi.org/10.3168/jds.2008-1468

Van Soest, P. J. (1994). *Nutritional ecology of the ruminant*. Cornell University Press.

Yang, W. Z., & Beauchemin, K. A. (2007). Altering physically effective fiber intake through forage proportion and particle length: Chewing and ruminal pH. *Journal of Dairy Science*, *90*(6), 2826-2838. https://doi.org/10.3168/jds.2007-0032