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INFLUENCE OF ENERGY BALANCE OF RATIONS ON MILK PRODUCTION IN COWS IN A PASTURE-BASED FEEDING SYSTEM

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Abstract

This study aimed to achieve the optimal energy balance of Holstein-Friesian cows, fed to produce 5,000-6,000 l of milk/cow per lactation (restricted production- Pr) on a pasture ration or 8,000-9,000 l of milk/cow per lactation (high production- Pm), on a more intensive feeding regimen using a partial mixed ration (pasture + concentrate). The mean of 4% fat-corrected milk (FCM) and standard deviation was 8,646 ± 1,162 l/cow per lactation for the Pm herd and 6,847 ± 787 l/cow per lactation for the Pr herd. In the first period of lactation, the balance degree estimated negative energy was lower in Pm cows than in Pr cows (-16.1 vs. -29.1 MJ/cow per day, respectively). As such, mobilization of body reserves was also lower in Pm cows, and this was reflected in lower concentrations of nonesterified fatty acids (0.7 vs. 0.8 mmol/l) and β-hydroxybutyrate (0.5 vs .0.7 mmol/l) and higher concentrations of glucose (3.5 vs. 3.3 mmol/l) and insulin for Pm and cows respectively, Pr.

***Key words**: body reserve, fatt corrected milk, lactation, pasture, ration.*

INTRODUCTION

In cow milk production systems, based on pasture feeding, a system often practiced in Romania, it is necessary to choose a calving model, either compact in one season (seasonal calving) or in several seasons (fractional calving), in order to maintain a high level of pasture use and therefore to minimize feed costs (Mark et al., 2021). The ideal would be for farmers to aim to obtain a calf/year/female for reproduction.

However, a calving interval of 12 months is difficult to achieve due to the low fertility of the modern dairy cow Holstein-Friesian (HF), with productive potential for milk above average (Fulkerson et al., 2008).

As such, the fertility of the modern dairy cow has decreased as milk production has increased, particularly in the last 3 decades (Lucy, 2001) because the feeding potential has not kept pace with the potential increase in milk production. So, an increasing proportion of energy must come from the mobilization of body reserves, and this produces metabolic and endocrine changes that can affect fertility (Veerkamp et al., 2003). Mobilisation of body energy reserves is even greater, especially in grassland-based farming systems (Kolver & Muller, 1998). Various experiments were carried out for feeding dairy cows with high genetic potential for milk (producing 44 l/cow per day) with rations made up of unique feed mixtures, in short-term experiments - 4 weeks. Cows fed with these rations obtained 40 l milk/cow/day, and cows that had the ration provided only by high quality pasture, reached 30 l/cow/day (Garcia et al., 2007). The lower milk production of pasture-only cows was largely related to the lower net energy intake from ingested dry matter in that study and indicates, as also shown by Fulkerson et al., 2008, that cows with high genetic potential for milk production, cannot achieve this genetic potential of milk, only on pasture. The reasons for this are the higher energy expenditure in a pasture system, the lower intake capacity of cows when fully fed with a voluminous feed, and that cows are not able to maximize the use of pastures (Clark et al., 2005). Milk and meat animals fed with full-fat soy causes a high quality of milk, meat and fat (Bonea, 2021). Also, corn is considered an important source of protein for animal feed, the content varying between 8-12% (Bonea, 2020; Knight et al., 2004).

Transgenic crops have been widely adopted by growers and are a significant source of feed for livestock. Worldwide, a large part of the

forages used in animal feeds is transgenic (Bonciu, 2023a).
Animal feeds are frequent subject to contamination from diverse sources, including environmental pollution; therefore, the application of sustainable depollution strategies is needed (Bonciu, 2023b; Popa et al., 2016; Popa et al., 2022). A particularly negative impact on animal health is the contamination of feed with various chemicals. There are many methods of monitoring chemical contamination, but one very often used is the biological one, through the Allium test (Bonciu, 2023c).
Therefore, cows grazing at pasture must be supplemented with energy-dense concentrates in order to reach their genetic potential of milk and reduce the need to mobilize excessive amounts of body reserves at the beginning of lactation (Ferris et al., 2002; Dillon et al., 2003; Kennedy et al., 2003., Hennessy et al., 2020; Reist et al., 2003).
The decrease in dry matter intake near calving is only temporary (Bossaert et al., 2008). The cow's appetite will increase within a few weeks after calving, partly due to a decrease in insulin concentration. However, increasing the intake of dry matter does not correspond to the requirement of increasing energy. The peak of lactation occurs between the 4th and 8th week after calving, while the intake of dry matter only increases between the 8th and 22nd week after calving (Bossaert et al., 2008).
Cows with a significant negative energy balance (NEB) show a decrease in the immune system (Widmann et al., 2013; Le Blanc, 2008; Marin et al., 2020). Insufficient dry matter intake of DMI from meadows and calcium concentration around labour combined with negative NEB energy balance and loss of minerals or vitamins early in lactation result in a decreased immune system. This aspect can lead to serious health problems (Logue et al., 1999).
The most important thing is to be able to intervene on the energy level in time, so the cow will be helped to achieve optimal performance. When a cow has a good level of energy, it will contribute positively to milk production, fertility, immunity and calving (Cola & Cola, 2023). However, the ability of a more adequate diet to reduce the mobilization of the body reserves of dairy cows at the beginning of lactation and its subsequent effect on reproductive performance and health is equivocal.
Sutter & Beever (2000) accurately measured energy changes (by using calorimetric chambers and energy losses in feces and urine) during the first 7 weeks of lactation and found that approximately 95 kg of tissue was mobilized, while body weight (BW) loss was about 43 kg. Thus, although BW and BCS are practical indicators of energy status and should be measured, they do not accurately reflect the degree of mobilization of body reserves in early lactation (Buckley et al., 2000).
Interestingly, despite the fact that Rp cows had a greater degree and duration of estimated NEB and therefore a greater level of mobilization of body reserves, the times to onset of ovarian activity and overall reproductive performance were similar to of Hp cows.
In addition, high milk production itself has been associated with health problems, especially mastitis (Ingvartsen et al., 2003).
Therefore, the present study aimed to follow the feeding of Holstein Friesian (HF) dairy cows with average genetic potential for milk, on a system based on pasture rations, in order to obtain either a low milk production (about 6,000 l/cow per lactation) or a high milk production (about 9,000 l/cow/lactation), evaluating the effects on energy balance and metabolite changes.

MATERIALS AND METHODS

The experiment was conducted at SC Fenov SRL Dolj, during the years 2019-2020. The herd of cows of 180 heads was predominantly made up of Holstein-Friesian breed. From this herd, were formed 2 groups of milk cows, of 40 heads each, with approximately equal milk yields (5,600 l milk/previous lactation), of the same age, cows being at the 4^{th} lactation. Within each group, 40 cows were selected, depending on the date of calving (early autumn and winter), to be strictly monitored regarding the feed ration received.
Cows were fed on pasture and feed rations were supplemented with corn silage (*Zea mays*) up to 3 weeks before calving and with alfalfa hay (*Medicago sativa* L.), corn silage and

mixed concentrated feed per transition cow, in the last 3 weeks until calving, to meet their nutritional requirements. After calving, the cows were assigned to a restricted production group (Pr), in which the cows were fed sufficient rations that provided metabolizable energy (ME) and crude protein (CP) to produce approximately 6,000 l milk/lactation, and to another group, high production (Pm), in which the cows were fed to produce approximately 9,000 l/lactation (Table 1).

Table 1. The average composition of the ration and the analysis of the nutrients of cows according to the level of milk production

Ration composition (kg DM/day)	Nutrition system	
	Pr	Pm
Total dry matter (DM)	20.4 ± 3.4	24.9 ± 2.6
Pasture	8.2 ± 6.2	5.2 ± 4.3
Corn silage	3.7 ± 3.6	6.1 ± 1.8
Silage (alfalfa or sorghum)	1.5 ± 3.2	0.03 ± 0.3
Hay (alfalfa or oats)	2.7 ± 2.9	3.7 ± 1.4
Concentrate	3.7 ± 1.6	9.8 ± 1.7
Wheat	—	0.3 ± 0.7
Urea (g/day)	0.02 ± 0.03	0.02 ± 0.02
Calcium (g/day)	0.01 ± 0.01	0.02 ± 0.05
Nutrient analysis		
Digestibility DM (%)	69.3 ± 0.1	72.7 ± 7.2
CP (% of SU)	16.5 ± 0.1	17.5 ± 0.1
NDF (% of SU)	46.0 ± 0.1	37.4 ± 0.1
ADF (% of SU)	25.4 ± 0.1	20.5 ± 0.2
ME (MJ/kg LS)	9.8 ± 0.6	10.3 ± 0.3

(Pm) high production; (Pr) restricted production; (DM) dry matter; (CP) crude protein; (NDF) neutral detergent fibres; (ADF) acid detergent fibres; (ME) metabolisable energy; (LS) STAS (State Standard milk).

The animals of the Pr group received the entire amount of concentrate twice a day during milking, while the Pm cows received less than 4 kg/cow per day during milking, and the rest was mixed with the feed supplement as a partial mixed ration (RMP). The total ration offered was formulated to provide approximately 250 and 200 MJ of ME/cow/ day and a minimum of 17.5 and 16.5% CP, for Pm and Pr herds respectively.

The offered pastures were sown down with a complex mixture of grasses, *Dactylis glomerata*, over which was sown aristate ryegrass (*Lolium multiflorum* Lam.) in autumn and perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.). Pasture production available to both herds was limited due to drought during the experimental period; therefore, in some months (mainly from mid-May to July), stored fodder such as corn silage, alfalfa hay and oat hay (*Avena sativa* L.), were used for feeding, instead of pasture. Herds of cows started grazing according to the best practices of pasture use, according to the degree of leaf development, used as an indicator for marking the time of grazing. Pasture production was estimated before and after grazing using an automatic vehicle scale. The samples of herbs and mixed concentrate were taken every two weeks for the analysis of nutrients (DM, NDF, ADF, CP, ME, water-soluble carbohydrates and ash), as stipulated by the regulations in force, within the feed analysis laboratories of D.S.V.S.A. (Veterinary and Food Safety Department) Dolj and the Faculty of Agronomy of Craiova. Pasture samples were also taken to simulate grazing height.

Animal measurements and samples

Milk production was recorded twice a day using automatic flow meters (DeLaval, milking system). Milk samples were taken every two weeks at the morning and evening milking and were analysed for the determination of milk fat and protein and the number of NCS somatic cells, with a Lactoscan SCC.

Milk production was corrected to 4% fat content (LC 4%) to compare milk production between herds with different milk compositions. The body weight was recorded at weekly intervals, immediately after the morning milking, with an electronic cattle scale, and the physiological condition (scale 1 to 8) was visually recorded monthly by the same observer.

In the intensively monitored herd (n = 80 cows), blood samples were collected weekly, immediately after morning milking, from calving to 63 days postpartum, for analysis of urea, glucose and fatty acids. Samples with anticoagulant were placed on ice immediately after collection, while serum samples were kept at room temperature until the rennet formed. The samples were centrifuged to separate plasma and serum and were frozen at -20ºC. The samples were subsequently analysed for glucose and urea concentrations in plasma by enzymatic colorimetry with a self-analyser within D.S.V.S.A. Dolj.

The composition of milk was measured at two weeks, during the first 9 weeks of lactation. As such, in odd weeks they were averaged to calculate the composition of milk for even weeks. Milk samples were taken from a quarter of each cow 3 times a week during milking, from calving to 120 days postpartum, divided into 4 aliquots with samples and frozen at -20ºC, until analysed.

The data obtained from both sets of data with 180 or 80 cows, was statistically processed, starting from the premise that the variance-covariance structure between times has a first-order autoregressive correlation. Before the analysis, the normal distribution of variables was evaluated and the data was transformed when necessary.

RESULTS AND DISCUSSIONS

Lactation performance (n = 180 cows)

The average lactation performance of Pr and Pm cows is shown in Table 2. Pm cows had milk production per lactation 38% higher than previous milk production per lactation, while Pr cows had milk production only 8% higher. Pm cows had a higher milk protein content (P = 0.04), but a lower milk fat content (P = 0.03) than Pr cows; therefore, milk fat and protein productions were 23 and 34% higher (P < 0.001) in Pm and Pr cows, respectively.

Table 2. Milk yield, components and content in fed cows (n = 180 cows)

	Nutrition system			P
	Pr	Pm	ESD	
Previous production of lactating milk (l/cow)	5,873	5,945	138	0.397
Milk production (l/cow per lactation)	6,353	8,181	248	<0.001
Yield LC4% (l/cow per lactation)	6,748	8,466	246	<0.001
Milk fat content (%)	4.39	4.23	0,01	0.037
Milk protein content (%)	3.11	3.20	0.05	0.042
Milk fat production (kg/cow per lactation)	286.4	354.1	11.6	<0.001
Milk protein yield (kg/cow per lactation)	202.1	270.9	6.7	<0.001

Pm - high production; Pr - restricted production; ESD - standard error of the difference; LC4% - fat-corrected milk production (4%).

Productive performance at the beginning of lactation (n = 78 cows)

At the beginning of lactation, milk production and milk composition were significantly different (P < 0.05) between herds (Figure 1). Milk production from Pm cows reached a peak of 34.9 l of LC4%/cow/day at about 7 weeks postpartum, while milk yield for Pr cows was 29.6 l of FCM/cow/day at about 4 weeks postpartum. Despite differences in milk production at the peak of lactation, the average daily yield of FCM from calving to 9 weeks postpartum was only about 4 l higher (P <0.001) in Pm cows (Figure 2).

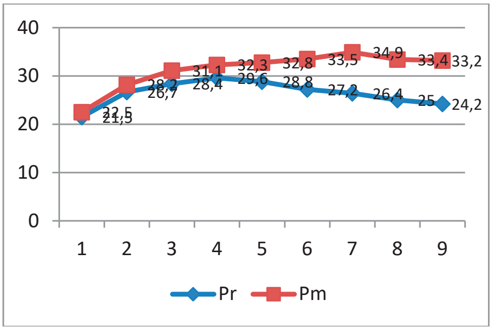

Figure 1. Milk production (l/day)

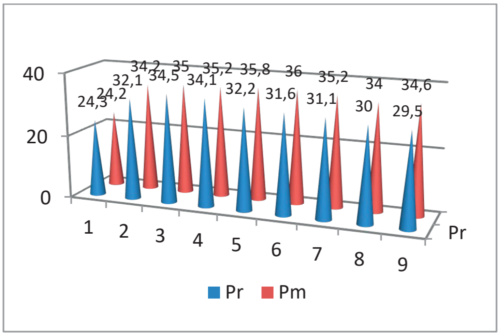

Figure 2. Yield LC4% (l/cow/day)

The protein content of milk was similar (P > 0.05) between herds, peaking at 5 weeks of lactation and then slowly increasing to 9 weeks of lactation (Figure 3). Milk fat content decreased in both herds up to 9 weeks of lactation, but the rate of decline was slightly faster in Hp cows than in Rp cows (Figure 4). Both milk protein yield and milk fat yield were higher (P < 0.05) in Pm cows than in Pr cows from week 4 to 9 postpartum.

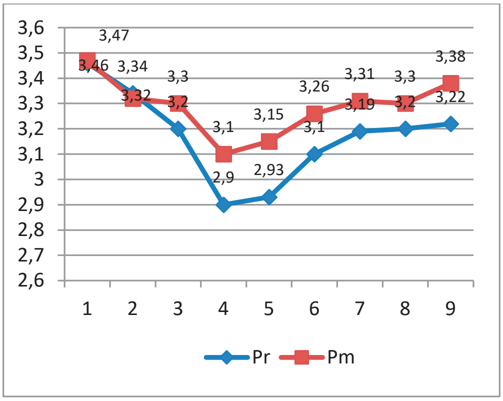

Figure 3. Milk protein content (%)

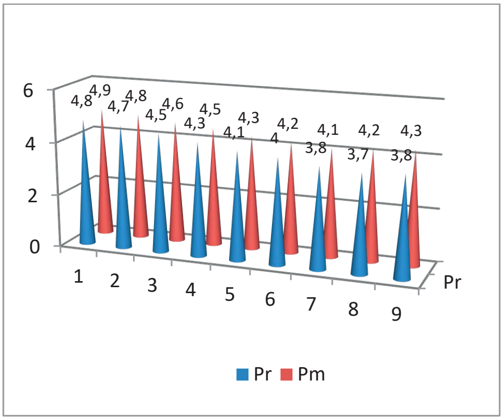

Figure 4. Milk fat content (%)

Energy balance and metabolic changes (n = 78 cows)

Body weigh (BW) and BCS (body condition scoring) decreased similarly at the beginning of lactation in both herds ($P > 0.05$). Pm cows lost 0.56 BCS units and 17.9 kg weight, and Pr cows lost 0.67 BCS units and 23.9 kg weight, from calving to 9 weeks postpartum. The estimated average energy balance during the first 9 weeks postpartum was significantly less negative ($P < 0.001$) in Pm cows than in Pr cows (Figure 5); estimated trend of negative energy balance (BEN) was -28 MJ/cow at 2 weeks postpartum in Hp cows, compared to -47 MJ/cow at 3 weeks postpartum in Rp cows. Changes in metabolites in circulation in cows at the beginning of lactation and their interactions with the feeding system and the postpartum week are shown in Figure 6.

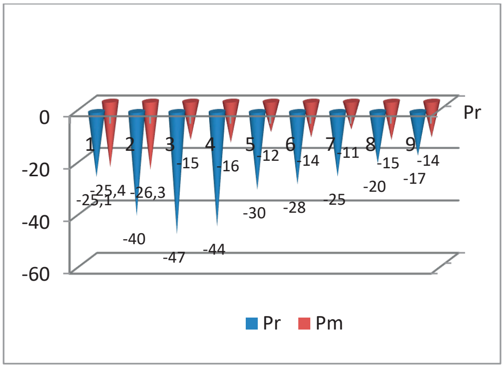

Figure 5. Energy balance (MJ/cow/day) in early lactating cows fed to achieve low (Pr) or high (Pm) milk

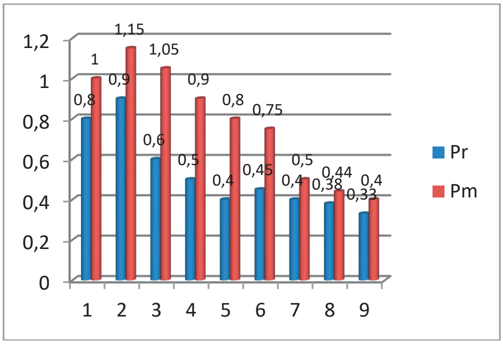

Figure 6. Concentrations of unsaturated fatty acids (mmol/l)

Changes in the concentration of non-esterified fatty acids indicated that both herds of cows had to rely on the mobilization of body reserves to meet the demand for nutrients for milk production, especially in the first 2 weeks postpartum. However, non-esterified fatty acid NEFA and β - hydroxybutyrate (BHBA) concentrations were lower ($P < 0.01$) in Pm cows than in Pr cows, reflecting a lower degree of fat reserve mobilization in the first ones (Figure 7). The glucose concentration was within the normal range in both herds, but was significantly higher ($P < 0.05$) in Pm cows compared to Pr cows between 3 and 5 weeks postpartum. In Pm cows, the concentration of IGF-I increased from calving to 9 weeks postpartum and was always significantly higher ($P < 0.001$) than in Pr cows at week 2 postpartum. Rp cows had an almost constant concentration ($P > 0.05$) of IGF-I for the same period (Figure 8).

The average urea concentration was within the normal range, but was significantly higher ($P < 0.001$) in Pm cows than in Pr cows (7.2 and 5 mmol/l, respectively), as expected from the composition of the diet. The effect of genetic merit was not significant ($P > 0.05$) for any of the metabolites measured. The calving season did not affect the concentrations of the metabolites measured, except that the concentration of IGF-I was higher ($P < 0.001$) in cows calving in early autumn than in cows calving in winter (80.2 vs. 58.7 ng/ml, respectively).

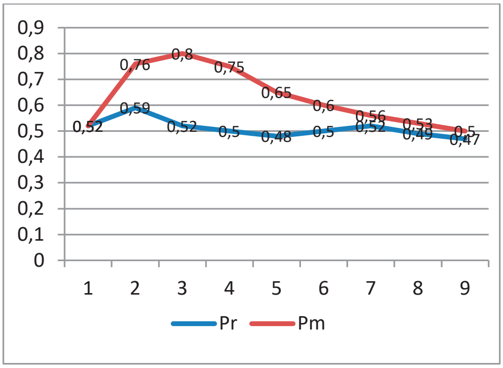

Figure 7. β-hydroxybutyrate (mmol/l)

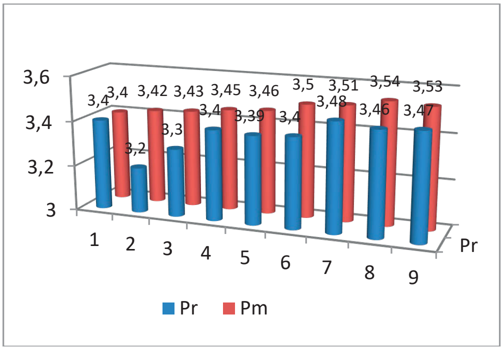

Figure 8. Glucose (nmol/l)

This study demonstrates that energy balance could be improved and fluctuations in key metabolites could be reduced when HF cows of average genetic merit were fed to increase milk production from a level of 5,945 l/cow per lactation when fed in a typical pasture system. In the pasture plus concentrates during milking variant, the production increases to 8,466 l of LC 4%/cow per lactation (SD = 1,162 l) when the cows received concentrated feed. The 30% increase in milk production did not affect reproductive performance, but the incidence of mastitis was increased. However, this characteristic must be followed by strict experiments on breeding indices in cows performing for milk production.

CONCLUSIONS

Milk production per cow in cattle with average production, fed on a typical pasture-based system, was improved by 30% during lactation when the energy intake was increased by offering a mixture of concentrated feed, and this led to an improvement in the estimated energy balance and a reduction in the mobilization of body reserves at the beginning of lactation. This achievement was without effect on the reproductive performance and health of cows, except for an increase in the incidence of mastitis that was associated with milking management.

Studies have found that HF cows, producing an average of 27.6 l/cow/day at first insemination, had lower reproductive performance than other lower milk producing breeds (25.6, 24.3 and French Normande, respectively).

These studies indicate a negative relationship between reproductive performance and milk yield, and this relationship appears to be true regardless of whether high milk yield has been achieved through improved management or genetic gain. However, the most likely reason for reduced fertility appears to be the greater need for high-producing cows to rely on body reserves to meet higher energy demands, which exacerbates changes in metabolic and hormonal factors during early lactation

He also found no effect on fertility when multiparous cows with high genetic merit were fed a grass-silage diet (winter feed) supplemented with concentrates in early lactation. Increasing concentrates (up to 14 kg/cow/day) in the diet reduced body condition loss and decreased stretch and NEB grade compared to cows supplemented with 5.5 kg/cow/day of concentrates.

It could be because the Rp cows in our study were less energy restricted. Although it was not possible to calculate the absolute level of energy restriction in these studies, our Rp cows received a level of concentrate similar to the highest level of concentrate fed in the other 2 studies. On average, at the start of lactation, Rp cows were fed approximately 90% of their energy requirement (estimated using actual milk production and energy provided in the diet), while Hp cows were fed 100% of their energy requirement of energy in relation to milk and the production achieved; therefore, differences in voluntary intake predominantly affected the level of energy intake of cows. This explanation is supported by the results who also found that when applied 5, 7 or 10 kg of concentrates/cow/day were fed to cows on pasture, reproductive performance did not differ between groups.

It was found that glucose concentration in early lactating cows increased rapidly if the cows were fed a high-energy diet. Despite the fact that the energy balance indicators used revealed significant differences in the mobilization of body reserves between herds, the changes in BW and BCS in Pm and Pr cows were similar. A higher level of energy supplementation (cows supplemented with 5.5 kg/cow/day rather than 1.4 kg/cow/day of concentrates) fed was also found to reduce the mobilization of body reserves and did not affect fertility. In that study, high genetic merit cows produced 8,707 or 6,014 l/cow per lactation, respectively, when fed high or low levels of concentrate, and these milk yields were similar to milk yield levels. from our study.

The performance of high and medium genetic merit HF cows at 3 different stocking rates and concentrate supplementation levels similar to ours (1.6 or 3.2 kg/cow per day) was also compared. They found reduced mobilization of body reserves at the higher level of supplementation, but found no difference in changes in BW and BCS during the first 20 weeks of lactation. The reason could be that in early lactation, changes in BW and BCS are poor indicators of energy balance.

Therefore, to maintain good reproductive performance, it is important to provide a diet that meets the cow's energy requirements, but additional energy is unlikely to improve fertility.

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