CHANGES IN THE BODY CONDITION AND DAILY MILK YIELD OF COWS DURING LACTATION DEPENDING ON THE LEVEL OF FAT RESERVES BEFORE CALVING

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Abstract. The aim of the study was to analyse the effect of the level of fat reserves accumulated in the bodies of cows before parturition on changes in their body condition and daily yield after calving. The study was carried out in five herds of Polish Black-and-White Holstein-Friesian cows and included 242 cows in which 4890 body condition scores were determined before calving and during 435 lactations and dry periods. In addition, 4430 test-day milking results were analysed. Statistical calculations were performed in SAS software (GML procedure). The statistical model took into account the effect of body condition before parturition on the rate of changes in daily milk yield in kg FPCM and on body condition score (BCS) during lactation. We found that in cows that accumulated insufficient fat reserves before parturition, daily yield did not increase at the beginning of lactation. Moreover, body condition scores did not decrease in these cows. The highest daily yield at the beginning of lactation, and subsequently the highest rate of its decline, were noted in the cows whose BCS before calving was at least 3.5 pts. A score of 3.5 before calving was found to be the most beneficial for productivity up to the 6th month of lactation, as well as for the release of energy from fat tissue after calving and subsequent replenishment of reserves.

Key words: body condition of cows, daily milk yield, course of lactation, changes in body condition

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INTRODUCTION

Adequate preparation of a cow for parturition and lactation includes the accumulation of fat reserves in the body. During the first few weeks of lactation cows ingest too little feed to meet all of the needs of the organism. For this reason fat reserves accumulated in the body are exploited to meet the cow's high nutritional demands. As a consequence, body weight decreases and body condition worsens. A negative energy balance occurs, which means that the cow gives more products (expressed as their energy value) than it gains in food [Barej 1990, Gearhart et al. 1990]. During the first two months of lactation an adult cow should not lose more than 0.5–1 point in the BCS scale. Greater losses in body condition after calving are usually associated with reduced milk production and metabolic problems [Remppis et al. 2011].

From the third month after calving cows should begin to replenish their lost energy reserves, as the energy from fodder is able to substantially surpass the energy expenditures required for milk production [Guliński 1996]. From this moment the body condition of the cows must be constantly controlled, as sharp fluctuations or a failure to accumulate enough fat by the dry period, will be reflected in the next lactation [Guliński 1996, Adamski and Kupczyński 2005]. Remppis et al. [2011] report that the body condition of cows during the period near calving affects not only the subsequent production and composition of milk, but also reproductive indicators and the incidence of diseases.

The aim of the study was to analyse the effect of the level of fat reserves accumulated in cows before parturition on changes in their body condition and daily yield after calving.

MATERIAL AND METHODS

The study was carried out on 5 farms in the Lublin region where Polish Blackand-White Holstein-Friesian cows were kept. The herds varied in size (from 20 to 73 head), but their mean annual yield was similar (about 7500 kg of milk). The body condition of all cows was assessed on days of test-day milking using the 5point BCS scale [Wildman et al. 1982]. The analysis included a total of 242 cows, in which 4890 body condition scores were determined before calving and during 435 lactations and dry periods. Yield in kg FPCM (fat and protein corrected milk) was calculated on the basis of 4430 test-day milking results, using the following formula [Subnel et al. 1994]:

FPCM (kg) = $[0.337 + 0.116 \times fat(\%) + 0.06 \times protein(\%)] \times milk$ (kg)

Analysis of variance was used to estimate the effect of the level of fat reserves accumulated in the cows before parturition (BCS up to 2.5; 3.0; 3.5 and >3.5) on changes in body condition and daily FPCM yield after calving. Statistical analysis was performed using the GML procedure in SAS software [SAS[®] User's Guide 2006], and significance of differences between means was determined using Scheffe's test.

RESULTS AND DISCUSSION

During lactation, the processes of catabolism and anabolism (as well as the relationships between them) are reflected in the thickness of subcutaneous fat. The change in the thickness of this fat reflects the rate of lipolysis or adipogenesis and the energy balance [Staufenbiel et al. 2003]. The data presented in Table 1 show that in the cows with the lowest body condition score before parturition (up to 2.5) lipolysis did not take place during lactation, as body condition increased in these cows from the first month after calving, though only slightly. The means calculated for this group of cows already showed an upward trend (BCS from 1.82 to 1.88) in the first three months after parturition, and the changes during this period were 3.2% in total. From the third month of lactation body condition scores were observed to increase in this group. Despite the fact that from months 3 to 10 of lactation the highest increase in mean scores (by 0.62) was noted in this group, and the rate of changes was highest (by 33.0%), in the tenth month after calving these cows had the lowest fat reserves. Their body condition was assessed at BCS 2.50 and was significantly different (P \leq 0.01) than the scores for cows that had higher scores before calving.

The body condition of cows assessed at 3.0 before calving decreased by 0.26 from the first to third month of lactation, i.e. 12.1%. In the third month after calving the mean score in this group was BCS 2.14. This level of fat reserves in the cows assessed at 3.0 before calving persisted for the next two months (BCS 2.15), and the scores increased successively from months 6 to 10. The rate of changes in this group up to month 10 of lactation was 22%. A substantial increase in body condition scores in this group was noted in lactation extended beyond 10 months. The body condition of cows from months 11 to 15 of lactation was on average 2.76, and in subsequent months 3.06.

The rate of loss of fat reserves up to the third month after calving was higher in the group of cows whose BCS before parturition was 3.5 (a loss of 0.46 points, or 19.2%), and the highest in the case of scores over 3.5 (0.66–24.1%). In the case of cows whose BCS before parturition was 4 or higher, the loss of body condition between the dry period and the third month of lactation was even higher, at 1 BCS point. This should be regarded as detrimental. Kim and Suh [2003] found that

- Table 1. Changes in body condition in successive months after calving depending on the level of fat reserves in cows before parturition (body condition in month 3 of lactation = 100%)
- Tabela 1. Zmiany kondycji w kolejnych miesiącach po wycieleniu w zależności od stanu rezerw tłuszczowych krów przed porodem (kondycja w 3. miesiącu laktacji = 100%)

Month after calving, groups Miesiące po wycieleniu, grupy	Body condition (BCS) before parturition Kondycja (pkt. BCS) przed porodem								
	up to 2.5, $n = 66$ do 2,5, $n = 66$		3.0, n = 99		3.5, n = 137		>3.5, n = 133		
	BCS pkt. BCS	changes, % zmiany, %	BCS pkt. BCS	changes, % zmiany, %	BCS pkt. BCS	changes, % zmiany, %	BCS pkt. BCS	changes, % zmiany, %	
Months of lactation Miesiące laktacji									
-1(1)	1.82 ^A	-3.2	2.40 ^B	12.1	2.85 ^c	19.2	3.40 ^D	24.1	
-2(2)	1.83 ^A	-2.7	2.22 ^B	3.7	2.51 ^c	5.0	2.96 ^D	8.0	
-3(3)	1.88 ^A	100.0	2.14 ^B	100.0	2.39 ^c	100.0	2.74 ^D	100.0	
-4(4)	1.99 ^A	5.8	2.15 ^B	0.5	2.39 ^c	0.0	2.75 ^D	0.4	
- 5 (5)	2.03 ^A	8.0	2.15 ^B	0.5	2.49 ^c	4.2	2.75 ^D	0.4	
-6(6)	2.17^{Aa}	15.4	2.30 ^{Ab}	7.5	2.52 ^в	5.4	2.82 ^c	2.9	
-7(7)	2.20^{Aa}	17.0	2.37 ^{Ab}	10.7	2.58 ^B	7.9	2.84 ^c	3.6	
- 8 (8)	2.24 ^A	19.1	2.46 ^B	15.0	2.63 ^c	10.0	2.87 ^D	4.8	
-9(9)	2.38 ^A	26.6	2.56 ^B	19.6	2.70 ^c	13.0	2.94 ^D	7.3	
- 10 (10)	2.50 ^A	33.0	2.61 ^A	22.0	2.80 ^B	17.2	3.05 ^c	11.3	
- 11-15 (11)	2.76 ^A	46.8	2.76 ^A	29.0	2.95 ^B	23.4	3.23 ^c	17.9	
-≥16 (12)	2.91 ^A	54.8	3.06 ^A	43.0	2.98 ^A	24.7	3.47 ^D	26.6	
Dry period (13) Zasuszenie (13)	2.90 ^A	54.3	3.12 ^в	45.8	3.09 ^B	29.3	3.56 ^c	29.9	
	S	ignificance Istotność	of differen różnic po	nces betwee między gruj	n groups: pami:				
at $P \le 0.01$ przy $P \le 0.01$	1, 2, 3- 4, 5-6 6, 7, 8- 9, 10-	-5 to 13; 5 to 13; -9 to 13; -12, 13	1-2 to 6 and 9 to 13; 2-7 to 13; 3, 4, 5-8 to 13; 6, 7-10 to 13; 8, 9-11, 12, 13		1-2 to 8 and 10; 2-3, 4, 9 to 13; 3, 4-6 to 13; 5, 6, 7-9 to 13; 8, 9-11 to 13; 10-13		1–2 to 11; 2, 3, 4, 5, 6, 7, 8–11, 12, 13		
at P \leq 0.05 przy P \leq 0,0	9, 10–11;	11-12, 13	2–3, 4 6, 7 10–11 11–1	4, 5, 6; -8, 9; , 12, 13; 12, 13	5-7, 8;	9–10, 11	9–11,	12, 13	

Means in rows with different superscript letters differ significantly at $P \le 0.01$ (capital letters) or $P \le 0.05$ (lower case letters).

Średnie w wierszach oznaczone różnymi literami różnią się istotnie przy: $P \le 0.01$ (wielkie litery) lub $P \le 0.05$ (małe litery).

mastitis and metabolic diseases (including displacement of the abomasum, milk fever and ketosis) were more frequent ($P \le 0.01$) in cows that lost 1.0 to 1.5 BCS

in the first four months of lactation. Moreover, according to Drackley [1999], excessive mobilization of lipids from fat tissue is linked to higher frequency of health problems in the transitional period. Mobilization of fatty acids from fat tissue in order to meet nutritional needs in early lactation is a natural biological phenomenon. However, an increase in unesterified fatty acids in the blood leads to accumulation of triglycerides in the liver, steatosis and functional impairment. A fatty liver cannot derive an adequate amount of glucose for metabolism, which plays a key role in feed intake regulation, fertility and immunity [Mulligan and Doherty 2008].

In the case of pre-calving scores considered optimal (BCS 3.5), from the fifth month after calving fat the cows' fat reserves increased, and up to the tenth month of lactation mean body condition scores increased on average by 0.41, i.e. by 17.2%. A positive energy balance and deposition of fat were also observed (as in the other groups) during extended lactations and during the dry period, as during lactations extended beyond 10 months and in the dry period mean body condition scores increased by an additional 0.29 points. In the group of cows that had the highest BCS before calving (>3.5), body condition increased from the 6th month of lactation, attaining (in comparison with the other groups) the highest values in all stages of lactation and during the dry period. In the second period of pregnancy and the initial phase of the dry period mainly anabolic processes take place in the cow, which then change to catabolic reactions towards the end of pregnancy and during early lactation [Remppis et al. 2011]. The need to accumulate fat reserves in late lactation and during the dry period is unquestioned. Mobilization of accumulated reserves in early lactation is an additional source of energy needed to compensate for the negative energy balance resulting from limited feed intake. On the other hand, high body weight before calving may lead to metabolic disorders. The rate of fat tissue metabolism and lipolysis depend on the amount of energy needed to secrete milk, net energy consumption, genotype, and hormonal regulation [McNamara 1991].

The course of lactation is one of the factors influencing milk yield and characterizes the persistence of lactation [Salamończyk and Guliński 2011]. Persistence of lactation is directly linked to the activity of mammary gland cells after its peak and indirectly determined by a number of factors, both exogenous and endogenous. After the peak of lactation, milk yield gradually declines, and the dynamics of this indicator depend on breed, diet, age, mammary gland disorders, milking frequency, and the length of lactation and of the dry period [Dekkers et al. 1998, Capuco et al. 2003]. In studies by Topolski et al. [2008] and Salamończyk and Guliński [2011], the most even and gentle decline in lactation persistence in successive months was noted in cows with an intermediate level of production. Januś et al. [2007] found that the course of lactation is influenced by the body condition of cows during the dry period. In this study, the lowest rate of decline in milk yield was observed in cows considered to be thin during the dry period. However, over the entire lactation period they had the lowest milk yield and did not attain satisfactory body condition for the subsequent phases of the production cycle.

In the case of the cows with the lowest BCS before parturition (up to 2.5), from the first month of lactation a systematic decrease in milk yield in kg FPCM was observed (Table 2). This production, which immediately after calving was 26.6 kg FPCM, systematically decreased in successive months of lactation. In this group there was no peak in yield in the second month of lactation, which could have been because the cows were not adequately prepared for milk production before parturition. In comparison with the first month after parturition, in the second month FPCM yield decreased by 5.1%, and in subsequent months, up to month 10, the monthly decrease in productivity ranged from 2.4 (months 2–3) to 6.3 kg (months 8–9). Inadequate preparation for lactation in this group is also indicated by a number of significant differences (P < 0.01 and P < 0.05) with respect to FPCM production in the remaining groups. In comparison with the cows whose BCS before parturition was 3.0, the differences in yield in the first three months of lactation ranged from 0.9 to 2.4 kg and were insignificant. From the 8th month after calving the differences between groups were smaller and only a few of them were significant at $P \le 0.05$.

In the case of cows with body condition scores of 3.0 before parturition, FPCM production up to the second month after calving increased insignificantly (by 0.2 kg, 0.7%). From months 2 to 10 of lactation this yield decreased by a total of 8.8 kg FPCM, and the average monthly rate of decrease in yield was about 4%. The most favourable course of lactation was observed in cows whose BCS before parturition was 3.5 pts. In the case of these lactations, an increase in milk yield of 0.5 kg FPCM was noted in the second month after calving in comparison with the first – an insignificant difference. From the third month of lactation the rate of the decrease in yield was about 4.4% per month. A higher rate of decline from the second to tenth month of lactation (on average 4.8% per month) was observed in the cows that accumulated the greatest fat reserves before parturition (BCS >3.5). In this group daily milk yield increased only minimally (by 0.1 kg FPCM) in the second month in comparison to the first.

The lower fat reserves before parturition (BCS up to 3) were probably the result of inadequate energy consumption, which resulted in lower yield at the beginning of lactation. A link between the level of energy consumption during the dry period and yield after parturition is indicated by research by McNamara et al. [2003] and Urdl et al. [2007]. In the study by Urdl et al. [2007], cows receiving 75% of their energy demand during the dry period produced on average 25.3 kg of milk per day during lactation. In cows receiving 100% and 125% of their energy

- Table 2. Changes in milk production in kg FPCM in successive months of lactation depending on the level of fat reserves in cows before parturition (FPCM yield in month 2 of lactation = 100%)
- Tabela 2. Zmiany w produkcji mleka w kg FPCM w kolejnych miesiącach laktacji w zależności od poziomu zapasów tłuszczu u krów przed wycieleniem (wydajność FPCM w miesiącu 2. laktacji = 100%)

	Body condition (BCS) before parturition Kondycja (pkt. BCS) przed porodem										
Month after calving (groups) Miesiące po wycieleniu (grupy)	up to 2.5 (n = 66)		3.0 (n = 99)		3.5 (n = 137)		>3.5 (n = 133)				
	BCS pkt. BCS	changes, % zmiany, %	BCS pkt. BCS	changes, % zmiany, %	BCS pkt. BCS	changes, % zmiany, %	BCS pkt. BCS	changes, % zmiany, %			
Months of lactation Miesiące laktacji	l										
-1(1)	26.6 ^A	5.1	27.5 ^A	-0.7	28.8 ^B	-1.7	29.0 ^B	-0.4			
-2(2)	25.3 ^A	100.0	27.7 ^A	100.0	29.3 ^в	100.0	29.1 ^B	100.0			
-3(3)	24.7 ^A	-2.4	26.1 ^A	-5.8	28.1 ^B	-4.1	27.9 ^в	-4.1			
-4(4)	23.7 ^A	-6.3	25.1 ^B	-9.4	26.5 ^c	-9.6	26.1 ^c	-10.3			
- 5 (5)	22.9ª	-9.5	23.8 ^b	-14.1	24.8 ^c	-15.4	24.4 ^c	-16.2			
-6(6)	21.5 ^A	-15.0	23.1 ^B	-16.6	23.4 ^B	-20.1	22.2 ^c	-23.7			
-7(7)	20.5 ^A	-19.0	22.5^{Ba}	-18.8	21.7 ^в	-25.9	21.2 ^{Bb}	-27.2			
- 8 (8)	19.9ª	-21.3	21.1 ^b	-23.8	20.8	-29.0	20.2	-30.3			
- 9 (9)	18.2ª	-28.1	20.0 ^b	-27.8	19.6	-33.1	19.5	-33.0			
- 10 (10)	17.4ª	-31.2	18.9 ^b	-31.8	19.1 ^b	-34.8	18.0	-38.2			
– 11–15 (11)	17.6	-30.4	18.0	-35.0	16.5	-43.7	16.9	-41.9			
- ≥16 (12)	16.3	-35.6	14.8	-46.6	15.6	-46.8	14.7	-49.5			
		Significa Istoti	nce of diffe ność różnic	rences betv pomiędzy g	veen groups grupami:	:					
$ at P \le 0.01 przy P \le 0.01 $	1–2 to 12; 2–3 to 12; 3–4 to 12; 4–5 to 12;		1, 2–3 to 12; 3–4 to 12;		1, 2, 3–4 to 12; 4–5 to 12;		1, 2–3 to 12; 3–4 to 12;				
	5-6 to 12; 6-7 to 12; 7-8 to 12; 8-9 to 12; 9-10 to 12; 10, 11-12		4–5 to 12; 5,6–7 to 12; 7–8 to 12; 8–9 to 12; 9–10 to 12; 10,11–12		5-6 to 12; 6-7 to 12; 7-8 to 12; 8-9 to 12; 9, 10-11, 12		4–5 to 12; 5–6 to 12; 6–7 to 12; 7–8 to 12; 8–9 to 12; 9–10 to 12;				
at $P \le 0.05$	_		_		1–2, 3; 2–3		10–11, 12; 11–12 –				

Means in rows with different superscript letters differ significantly at $P \le 0.01$ (capital letters) or $P \le 0.05$ (lower case letters).

Średnie w wierszach oznaczone różnymi literami różnią się istotnie przy: $P \le 0.01$ (wielkie litery) lub $P \le 0.05$ (małe litery).

demand during the dry period, daily milk yield was 28.2 and 29.4 kg, respectively. Diet during the dry period had no effect on milk composition; only lower concentration of lactose was observed in the milk of cows with the lowest energy level in their feed ration during the dry period. Holtenius et al. [2003] suggest that cows

fed in such a way as to reduce BCS during the dry period can have high milk yield in the next lactation if they are fed high quality TMR ad libitum after calving. They surmise that leaner cows entering lactation have a greater appetite, which enables them to consume more feed and to increase milk production, particularly if they receive a feed ration with a high energy level.

To sum up, cows that accumulated insufficient reserves before parturition did not increase their daily yield at the beginning of lactation. Body condition scores also did not decrease in these cows. The highest daily yield at the beginning of lactation, followed by the highest rate of its decline, were noted in the cows whose BCS before calving was at least 3.5. Body condition scores of 3.5 before parturition were determined to be the most beneficial for productivity up to the sixth month of lactation, as well as for the release of energy from fat tissue after calving and subsequent replenishment of reserves.

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ZMIANY KONDYCJI I DOBOWEJ WYDAJNOŚCI MLEKA W PRZEBIEGU LAKTACJI KRÓW W ZALEŻNOŚCI OD STANU REZERW TŁUSZCZOWYCH PRZED WYCIELENIEM

Streszczenie. Celem badań była analiza wpływu stanu rezerw tłuszczowych zgromadzonych w organizmach krów przed porodem na zmiany kondycji i dobowej wydajności mleka po wycieleniu. Badania przeprowadzono w 5 stadach krów phf cb. Objęto nimi 242 krowy, u których przed wycieleniem oraz w trakcie 435 laktacji i okresów zasuszenia wykonano 4890 ocen kondycji. W analizie wykorzystano także wyniki 4430 próbnych udojów. Obliczenia statystyczne wykonano w programie SAS (procedura GML). W modelu statystycznym uwzględniono wpływ kondycji przed porodem na tempo zmian dobowej wydajności mleka w kg FPCM oraz punktowych ocen kondycji w pkt. BCS w przebiegu laktacji. Stwierdzono, że krowy ze zbyt małymi rezerwami zgromadzonymi przed porodem, na początku laktacji nie zwiększały wydajności dobowej. Nie zmniejszały się także w ich przypadku punktowe oceny kondycji. Najwyższą dobową wydajność na początku laktacji, a następnie największe tempo jej spadku stwierdzono u krów z kondycją ocenioną przed wycieleniem na co najmniej 3,5 pkt. BCS. Za najkorzystniejsze dla produkcyjności do 6. miesiąca laktacji oraz dla uwalniania po wycieleniu energii z tkanki tłuszczowej a następnie odbudowywania rezerw uznano oceny przed porodem wynoszące 3,5 pkt. BCS.

Słowa kluczowe: kondycja krów, dobowa wydajność mleka, przebieg laktacji, zmiany kondycji

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