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EFFECT OF CHANGES IN BODY CONDITION SCORE ON THE MILK YIELD OF HOLSTEIN-FRIESIAN AND BROWN SWISS COWS

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Abstract

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The effect of BCS at calving, loss of BCS, the duration of loss after calving and the reached minimum BCS during lactation on milk yield for 305 days have been studied. The object of study are 37 cows, of which 20 Holstein and 17 Brown Swiss ones. The cows from both breeds are reared together with the same technology and nutrition. The body condition score of cows has been recorded on a monthly basis by using a 5-grade scoring system and accuracy of recording up to 0.5 points. BCS at calving, loss of BCS and the duration of loss after calving have significant effect on milk yield. The reached minimum BCS during lactation has no significant effect. In the Holstein cows BCS before calving is lower (2.8 points), loss of BCS is greater (1.95 points) and longer (3.8 months compared to the Brown cows (3.0, 1.75 and 2.8, respectively). Cows from both breeds with higher BCS (≥3.5 points), with greater loss of BCS after calving (≥2.5 points) and longer loss of BCS at the beginning of lactation (≥5 months) have the highest milk yield for a 305-day lactation.

Key words: body condition score, loss of body reserves, minimum body condition score, milk yield for 305 days, dairy cows
Abbreviations: BCS – body condition score; LS means - leas square means

Introduction

Cows have physiological ability of providing nutritional substances from their body tissues by losing "body condition" for about 40 to 100 days after calving and afterwards they again restore the lost body reserves (Koenen et al., 2001; Coffey et al., 2004; Pryce and Harris, 2006). What has focused the interest specifically to these mechanisms in dairy cows in the last 50 years is the intensive transgeneration genetic selection towards increase of the total milk yield per lactation and at the beginning of lactation (Dillon, 2006). The differences in the degree of genetic improvement and the managing factors in the different countries and cattle populations bring different results in that field in the studies of numerous authors. (Coffey et al., 2004; Pryce et al., 2001; McCarthy et al., 2007; Roche et al., 2007; Macdonald et al., 2008; Roche, 2007).

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The energy balance of dairy cows is usually negative at the beginning of lactation as a result of which body reserves are mobilized (Tamminga et al., 1997). Although negative energy balance is normal from a physiological point of view, its degree and duration are adversely related to productivity, health status and reproductive qualities of cows (Butler and Smith, 1989; Domecq et al., 1997; Senator et al., 1996; Veerkamp et al., 2000; De Vries et al., 2000; Pryce et al., 2001).

The objective of the study is to investigate the effect of BCS at calving, the loss of BCS, the duration of loss after calving and the reached minimum BCS during lactation on milk yield for 305 days in cows from two breeds – Holstein and Brown Swiss, reared under the same conditions.

Material and Methods

The study comprises 37 cows, of which 20 Holstein and 17 Brown Swiss ones at the farm of the Agricultural Institute Stara Zagora.

Cows from both breeds are reared together with the same technology and nutrition. The tearing technology is free rearing with individual cubicles for rest. Lactating cows are allowed daily to walk in a yard, which provides them with an opportunity for exercise. Milking is twice a day in a milking parlor. Cows are divided in three technological groups according to their physiological status, dry ones, I (up to day 150 of lactation) and II lactation period, respectively. Pregnant cows, two months before calving, are placed in the dry cows group.

Nutrition is based on full-ration mixture comprising maize silage, alfalfa haylage, concentrated fodder and vitamin and mineral additives. Concentrated fodder during lactation is according to the average milk yield of the group. All rations have been prepared according to the current cattle feeding rates.

Milk yield and milk composition data have been taken from the official control register of the farm productivity.

Age of cows has been recorded as number of lactation and animals have been grouped in the following classes, respectively – I; II and III and further lactations.

For the objective of the experiment the body condition of cows has been recorded on a monthly basis and a 5-point scoring system has been used (Edmonson et al., 1989). Body condition scores (BCS) have been recorded with an accuracy of up to 0.5 points. The experiment includes all dry cows for the period from December 2008 to April 2009 and pregnant heifers for two months before calving. Calving of cows were respectively in the spring and part of the summer of 2009. In this way the factors year and season of calving are equal and not included in the models.

The body condition score of cows before calving was recorded within the period from 7 to 10 days before calving. The minimum recorded score is 2 and the maximum one - 4, the cows with these scores being single cases in both breeds. The predominant number of cows are within the limit of 2.5 – 3.5 point. To obtain greater approximation cows have been divided in the following classes according to BCS before calving: 1st class – 2 and 2.5 points; 2d - 3 points and 3rd class – 3.5 and 4 points.

During lactation body condition has been recorded on a monthly basis. From the recorded BCS values during lactation the reached minimum BCS has also bee taken and the month in which it was reached has also been recorded. Based on the recorded minimum BCS values three classes have been formed: 1st class – 1 point; 2nd class – 1.5; and 3rd class - 2 and more points. The month of reaching the minimum BCS or the duration of loss of body reserves varies from first to seventh lactation month. To achieve greater approximation cows have been divided in the following classes according to the duration of loss of BCS: 1st class – from calving to II lactation month; 2nd class – III and IV and 3-rd class – V and further lactation months.

Based on BCS before calving and the reached minimum BCS during lactation the loss of BCS has

been calculated, which has also been subdivided into classes as follows: 1-st class – loss of 1.5 and less point; 2-nd class – loss of 2 points and 3-rd class – loss of 2.5 and more points.

The results have been processed through Stat Soft 1984-2000 Inc (Copyright 1990-1995 Microsoft Corp.)

Since the studied body condition traits are interrelated in varying degree, their inclusion in one and the same model for evaluation of their effect shall not be correct, so an identical model has been used for each of them (models I to IV, Table 2), as follows:

$$Y_{ijkl} = \mu + P_i + L_j + F_k + e_{ijkl}$$

Where:

Y_{ijkl} is the dependable variable (the studied trait); μ is the population mean; P_i is the effect of the breed, L_j is the effect of the number of lactation, F_k is the effect of each of the studied BCS traits (BCS at calving, minimum BCS for the lactation, loss of BCS and duration of loss of BCS) and e_{ijkl} is the random residual effect.

The data have been analyzed by using the computer program LSMLMW by Harvey (1987). Through variance analysis (ANOVA) for each model the least square mean (LSM) and the least square estimates (LSE) have been obtained by classes of the fixed factors, comprising the sum total of squares calculated as divergence from the mean value of the trait obtained through the model.

Results

On Table 1 the statistical data about productivity and the studied body condition traits of cows have been presented by breeds. The average milk yield for 305-day lactation of Holstein cows is higher than that of the Brown Swiss ones by 970 kg (P<0.01). However, in Brown Swiss cows the milk composition traits have higher values both for percentage of milk fat and milk protein (P<0.05 and P<0.001),

All BCS values are higher in the Brown Swiss cows compared to these for the Holstein. The average BCS at calving is 3 points, the minimum BCS – 1.68 points in the Brown Swiss cows, while in the Holstein they are 2.8 and 1.4 points, respectively. Loss of BCS from calving to reaching minimum BCS during lactation is higher in the Holstein cows, almost 2 points, compared to 1.7 points in the Brown Swiss cows. A difference, although not statistically significant, is recorded in the duration of loss of BCS after calving as well. In the Holstein cows the loss continues by an average of one month longer than in the Brown Swiss cows.

The results from the analysis about the effect of the controlled factors on milk yield for 305-day lactation are presented in Table 2. From all controlled factors included in the study the factor breed has had a significant effect (P<0.05). No significant effect of the number of lactation has been recorded although there is logical difference in milk yield of cows by lactations. The cause could be due to the fact that cows from both breeds with different milk yield and also different body condition during one the same lactation have been included.

Table 1
Descriptive statistics for studied traits by breeds

Traits	Holstein cows n = 20 x ± Sx	Brown Swiss cows n = 17 x ± Sx
Milk yield for 305 days, kg	6262.2 ± 1066.4**	5291.7 ± 966.4**
% milk fat	3.88 ± 0.40*	4.21 ± 0.33*
% milk protein	3.32 ± 0.11***	3.48 ± 0.08***
BCS at calving	2.80 ± 0.66	3.00 ± 0.58
Minimum BCS	1.40 ± 0.42*	1.68 ± 0.39*
Loss of BCS	1.95 ± 0.56	1.70 ± 0.44
Duration of loss, months	3.8 ± 2.11	2.8 ± 1.67

Table 2

Analysis of the variance of controlled factors for milk yield for 305 days lactation

Variation sources	Degrees of freedom (n – 1)	Milk yield for 305 days							
		I model		II model		III model		IV model	
		F	P	F	P	F	P	F	P
Total for the model	37	2.85	*	1.29	-	3.04	*	2.73	*
μu - y μ	1	0.459	-	0.002	-	0.02	-	0.08	-
Breed	1	7.23	*	4.51	*	3.08	*	3.87	*
Number of lactation	2	0.146	-	0.03	-	0.28	-	0.30	-
BCS at calving	2	3.86	*	-		-		-	
Minimum BCS	2	-		0.10	-			-	
Loss of BCS	2	-		-		4.33	*	-	
Duration of loss of BCS	2	-		-				3.56	*

From the traits related to BCS only the reached minimum BCS during lactation has no significant effect on milk yield for 305 days lactation. The other traits, such as BCS at calving, loss of BCS and the duration of loss after calving have significant effect ($P<0.05$).

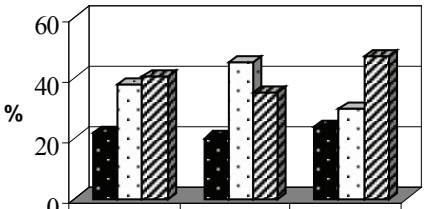
From the total number of cows, predominant is the relative share of cows with high body condition score at calving – 3.5 – 4 points, 40.5 % (Figure 1). The next group according to BCS at calving is the one with 3 points – 37.8 % and the smallest is the share of cows with low body condition score – 2.5 and 2 points, 20.7%. Considered by breeds, the lowest is the share in cows with low body condition score at calving in both breeds. In the Holstein the relative share of cows with medium body condition score at calving is higher - 45 % (BCS 3 points), while in the Brown Swiss cows predominant is the number of these with high body condition score before calving from 3.5 – 4 points (47.1 %).

On Figure 2 LS means (leas square means) about the effect of the body condition score of cows before calving on their milk yield for normal lactation has been presented. Cows from both breeds with low body condition score at calving from 2 and 2.5 points have the lowest milk yield for 305 days after calving. More pronounced is that difference in the Brown Swiss cows. In them the milk yield of cows with low body condition score (≤2.5 points) is by about 1400 kg lower than that of cows with BCS ≥3.5 points. In Holstein cows that difference is less – only 876 kg, although their milk yield as a whole is greater.

On Figure 3 the relative share of cows is presented according to loss of BCS after calving by breeds. A clear difference is noticed in the relative share of cows from both breeds for the various classes of loss of BCS after calving. In the Holstein cows the greatest is the relative share of cows with the greatest loss of BCS – 2.5 and more points – 55%, while in the Brown Swiss cows the highest is the relative share of cows with loss of 2 points. In the Brown Swiss cows the smallest is the share of cows with great loss of points – 2.5 and more, only 17.6 %.

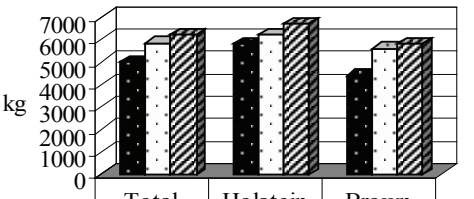
Loss of BCS after calving has a significant effect on milk yield for 305 days lactation (Figure 4). The highest is the milk yield of cows with the greatest loss of BCS after calving in both breeds.

On Figure 5 the relative share of cows according to duration of loss of BCS after calving has been presented (in months) in both cattle breeds. Holstein cows are almost equally distributed by duration of loss of BCS after calving – by 30-35 % in each class. In Brown Swiss cows the greatest is the relative share of those with loss of BCS



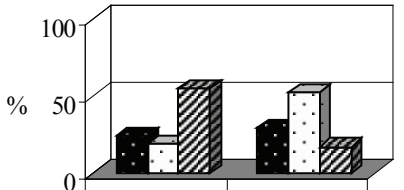
	Total	Holstein	Brown
≤ 2.5	21.7	20	23.5
3	37.8	45	29.4
≥ 3.5	40.5	35	47.1

Fig. 1. Distribution of cows (in %) depending on the body condition score at calving



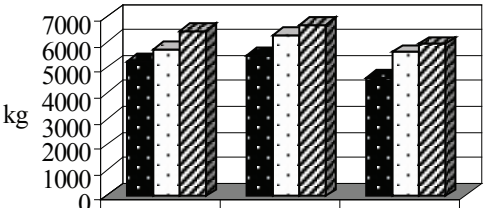
	Total	Holstein	Brown
≤ 2.5	5000.3	5824.4	4387.3
3	5833.1	6197	5592.9
≥ 3.5	6217.5	6700.5	5787

Fig. 2. Effect of Body Condition Score at calving on milk yield in 305 days lactation



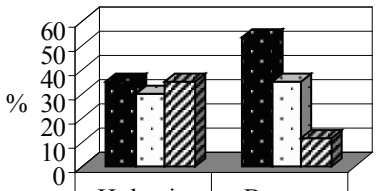
	Holstein	Brown
≤ 1.5	25	29.4
2	20	53
≥ 2.5	55	17.6

Fig. 3. Relative share of cows according to loss of BCS after calving by breeds



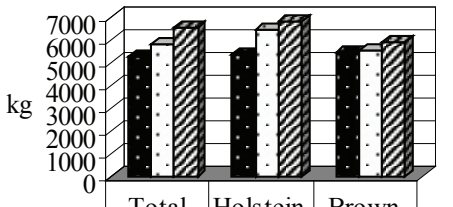
	Total	Holstein	Brown
≤ 1.5	5240.7	5473.7	4610.2
2	5710.7	6258.5	5605.4
≥ 2.5	6422.4	6648.3	5932.4

Fig. 4. Effect of loss of BCS after calving on milk wield for 305 days lactation



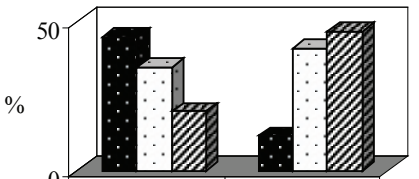
	Holstein	Brown
≤ II-nd	35	52.9
III-rd и IV-th	30	35.3
≥ V-th	35	11.8

Fig. 5. Relative share of cows according to duration of loss (in months) of BCS after calving by breeds



	Total	Holstein	Brown
≤ II-nd	5244.7	5371.9	5449.8
III-rd и IV-st	5812.5	6449.5	5581.1
≥ V-st	6538	6862.6	5935.3

Fig. 6. Effect of the duration of loss of BCS after calving on milk yield for 305 days lactation



	Holstein	Brown Swiss
1	45	11.8
1,5	35	41.2
2	20	47

Fig. 7. Relative share of cows according to reached minimum BCS after calving by breeds

up to the II lactation month – 52.9 %, and cows with longer loss of BCS up to and after V lactation month are only 11.9 %.

With regard to duration of loss of BCS after calving in cows from both breeds there is a tendency for higher milk yield in those with longer loss of BCS and that is more clearly shown in the Holstein cows? In them cows with loss of BCS up to the II lactation month have produced 1490.7 kg less milk that these with duration of loss up to and after the V lactation month. In the Brown Swiss cows that difference is only 485.5 kg (Figure 6).

Regardless of the fact that minimum BCS during lactation does not have reliable effect on milk yield for 305 days lactation, Figure 7 presents the allocation of cows as relative share depending on reached minimum BCS by breeds. The clearly opposite tendency regarding the allocation of cows from both breeds is evident from the data. In the Holstein cows the highest is the percentage of cows that had reached minimum BCS during lactation – 45 %, and the lowest – of those with minimum BCS 2 and more points. In the Brown Swiss cows the greatest is the relative share of cows with high minimum BCS - 2 and more points, the cows that reached the lowest BCS – 1 point are only 11.8 %. However, a similar tendency in milk yield according to the minimum BCS is not reported in none of the two breeds.

Discussion

The higher milk yield of Holstein cows is related to lower BCS values, greater and longer loss of BCS at the beginning of lactation compared to the Brown Swiss breed. Pryce et al. (1999) state that selection aimed at productivity only results in lower BCS compared to cows with average genetic potential for milk yield. Veerkamp et al. (2001) reported negative genetic correlation between productivity and BCS. The authors found out that at each 1000 kg of milk yield increase, decrease of BCS by 0.38 points is recorded.

The relative share of the cows with average BCS before calving is predominant, while at the same conditions is recorded higher relative share of the Brown Swiss cows with high BCS. Samarutel et al. (2006) also point out that in primiparous Holstein cows the share of cows with medium body condition score before calving is predominant – BCS from 3.25 to 3.75 points, lean cows with BCS $\leq$ 3.0 are 28 % and these with high body condition score $\geq$ 3.75 points are 26%.

More pronounced difference in milk yield is recorded for the Brown Swiss cows with low and high BCS (1400 kg) compared to Holstein cows – only 876 kg. That shows the greater possibilities of the Holstein cows for mobilization and use of their body reserves for milk production which often results in extenuation of the organism with subsequent reproductive and health problems (Harrison et al., 1990; Waltner et al., 1993). With reduced body reserves the Brown Swiss cows react by decreasing the milk yield for preserving the organism.

After calving cows normally suffer from loss of body reserves used by the organism for milk production at the beginning of lactation. This is the period of negative energy balance on the cow organism. The degree of loss of body reserves depends on a number of factors, such as degree of body condition at calving, nutrition after calving, level of milk production, etc.

In our study was determined higher relative

share of the Holstein cows with high loss of BCS after calving - 55% (($\geq$2.5 points), and only 17.6% for the Brown Swiss cows. Highest relative share for the Brown Swiss breed have cows with BCS loss of 2 points. This is largely explained by the differences in the milk yield of the two breeds.

Harrison et al. (1990) found greater negative energy balance at the beginning of lactation in cows selected for high milk yield compared to the ones with average milk yield.

Koenen et al. (2001) found that the average loss of BCS after calving is greater in the Holstein, respectively 1.2 compared to that in the Red-and-White cows – 1 point. That difference is due to the different productivity, which is by 1000 kg higher in the Holstein (8003 kg compared to 6975 kg). Other authors also report a positive correlation between loss of BCS and milk yield (Gallo et al., 1996).

In the study by Samarutel et al. (2006) only primaparous cows of the same herd have been included for a period of 5 years. For the first 30 days after calving cows have lost an average of 0.49 points of BCS, the lean ones have lost 0.25 points, the ones with medium body condition – 0.48, those with good body condition – 0.60 points. The average duration of the period from calving to the lowest value of BCS for the lean cows is 37 days, for the ones with medium body condition – 49 and for those with good body condition - 53 days. For the period from calving until reaching the lowest body condition score lean cows had lost 0.41 points, the ones with medium body condition – 0.76 and the ones with good body condition – 1.05 points.

Ruegg and Milton (1995) also point that cows with better body condition have been losing live weight for a longer time after calving. On average the studied cows have lost 0.80 points after calving and for the first week and around calving itself they had lost 0.25 points. The loss of BCS has taken place till the 50^{-th} – 90^{-th} day of lactation.

All that comes to show that it is better to provide sufficient body reserves at calving in order to use them afterwards for milk production.

The degree of loss also depends on the breed characteristics, such as level of selection, milk productivity, etc.

That tendency is clearly shown in cows from both breeds. In loss, unlike BCS before calving, the difference between cows with low and high loss is almost the same in cows from both breeds, 1174.6 kg in the Holstein and 1322.2 kg in the Brown Swiss cows, respectively. That shows that greater effect on milk yield is exerted by the loss or use of body reserves than the provided ones at calving. Selection for higher BCS after calving would have a more beneficial effect on milk yield than selection for reducing the loss body reserves. Veerkamp et al. 2001 also point out that loss of BCS is a very important factor for dairy cows than BCS value itself.

Although the negative energy balance is normal from a physiological point of view, its degree and duration is negatively related to the health status and fertility of dairy cows (Butler and Smith, 1989; Domecq et al., 1997; Senatore et al., 1996).

One third of the Holstein cows have prolonged loss of BCS – till 5-th month of lactation, or till 150 day of lactation. For the Brown Swiss cows highest is the relative share of those with BCS losses to the 2nd month of lactation – 52.9%. The cows with prolonged BCS loss till and after 5th month of the lactation are only 11.9%.

Koenen et al. (2001) record BCS in the Holstein and Brown Swiss cows by a 9-point grading system and they state that it corresponds to the 5-point one by using 0.5 point scores. Cows included in the study have different percentage of participation of the Holstein and authors point out that by increasing the percentage of the Holstein, the average BCS value is reduced. For both breeds an average BCS after calving of 5.6 points is reported, the lowest value being in the 11^{-th} week after calving.

Losses are greater and for longer period in cows with higher milk yield. In low yield cows the lowest BCS is at about the 3^{-rd} month after calving and in high yield ones – at the 4^{-th}. High yield cows

lose twice as much body reserves compared to low yield ones. Cows with milk yield ≤ 6000 kg reach the minimum BCS on the 86-th day and the ones with milk yield above 12000 kg – on the 117-th day by losing from the beginning of lactation 0,38 and 0,64 points, respectively (Gallo et al., 1996).

The genetic correlations between losses of live weight and BCS after calving are from –0.70 to –0.91. Phenotypic correlations between milk yield and losses of BCS are greater between higher productivity and higher losses (Dechow et al., 2002).

Kadarmideen and Wegmann (2003) also found that the average of LS mean for BCS by periods of lactation shows that cows lose body reserves up to the 5-th month after calving and after that they store it till the end of lactation.

This is probably due to the fact that the reasons for reaching the minimum BCS are different. Some of the cows had very low BCS before calving, others – great and longer loss of BCS after calving, etc.

The clearly opposite tendency regarding the allocation of cows from both breeds is evident from the data. In the Holstein cows the highest is the percentage of cows that had reached minimum BCS 1 during lactation – 45 %, and the lowest – of those with minimum BCS 2 and more points. In the Brown Swiss cows the greatest is the relative share of cows with high minimum BCS - 2 and more points, the cows that reached the lowest BCS – 1 point are only 11.8 %. However, a similar tendency in milk yield according to the minimum BCS is not reported in none of the two breeds.

All this shows that minimum BCS during lactation is not necessarily linked to higher milk yield. Clearer and positive is the effect of the provided body reserves before calving, the amount of body reserves used for milk production (loss of BCS).

Conclusion

BCS at calving, loss of BCS and the duration of loss of BCS at the beginning of lactation have significant effect on milk yield for 305 days lactation. The reached minimum BCS at the beginning of lactation has no significant effect on milk yield.

In the Holstein cows the average BCS at calving is lower (2.8 points), the loss of BCS is greater (1.95 points) and longer (3.8 months) compared to the Brown Swiss cows (3.0, 1.75 and 2.8, respectively).

Cows from both breeds have higher BCS (≥3.5 points) with greater loss of BCS after calving (≥2.5 points) and longer loss of BCS at the beginning of lactation (≥5 months) have the highest milk yield for 305 days lactation.

Holstein cows use better the stored body reserves – at greater amount and longer, for milk production compared to the Brown Swiss cows.

References

Butler, W., and R. Smith, 1989. Interrelationships between energy balance and postpartum reproductive performance in dairy cattle. *Journal of Dairy Science*, **72**: 767-783.

Coffey, M., G. Simm, J. Oldman, W. Hill and S. Brotherstone, 2004. Genotype and diet effects on energy balance in the first three lactations of dairy cows. *Journal of Dairy Science*, **87:** 4318-4326.

Dechow, C., G. Rodgers and J. Clay, 2002. Heritability and correlations among body condition score loss, body condition score, production and reproductive performance. *Journal of Dairy Science*, **85**: 3062-3070.

De Vries, M. and R. Veerkamp, 2000. Energy balance of dairy cattle in relation to milk production variables and fertility. *Journal of Dairy Science*, **83**: 62-69.

Dillon, P., 2006. A comparison of different dairy cow breeds on a seasonal grass-based system of milk production. 2. Reproduction and survival. *Livestock Production Science*, **83:** 35-42.

Domecq, J., A. Skidmore, J. Lloyd and J. Kaneene, 1997. Relationship between body condition score and conception at first artificial insemination in a large dairy herd of high yielding Holstein cows. *Journal of Dairy Science*, **80:** 113-120.

Edmonson, A., I. Lean, L. Weaver, T. Farver and G. Webster, 1989. A body condition scoring chart for Holstein dairy cows. *Journal of Dairy Science*, **72:** 68-78.

Harrison, R, S. Ford, J. Young, A. Conley and A. Freeman,

1990. Increased milk production versus reproductive and energy status of high producing cows. *Journal of Dairy Science*, **73:** 2749-2758.

Harvey, W. R., 1987. User`s guide for LSMMW PC-1 version, Mixed model least-squares and maximum likelihood computer program. *Ohio State Uniersity.*, Columbus. (USA)

Gallo, L., P. Carnier, M. Cassandro, R. Mantovani, L. Bailoni, B. Contiero and G. Bittante, 1996. Change in body condition score of Holstein cows as affected by parity and mature equivalent milk yield. *Journal of Dairy Science*, **79:** 1009-1015.

Kadarmideen, H., R. Thompson, M. Coffey and M. Kossaibati, 2003. Genetic parameters and evaluations from single-and multiple-trait analysis of dairy cow fertility and milk production. *Livestock Production Science*, **81:** 183-195.

Koenen, E., R. Veerkamp, P. Dobbelaa, and G. De Jong, 2001. Genetic analysis of body condition score of lactating Dutch Holstein and Red-and-White heifers. *Journal of Dairy Science*, **84:** 1265-1270.

Macdonald, K., G. Verkerk, B. Thorrold, J. Pryce, J. Penno, L. McNaughton, L. Burton, J. Lancaster, J. Williamson and C. Holms, 2008. A comparison of three strains of Holstein-Friesian grazed on pasture and managed under different feed allowances. *Journal of Dairy Science*, **91:** 1693-1707.

McCarhy, S., D. Berry, P. Dillon, M. Rath, and B. Horan, 2007. Influence of Holstein-Friesian strain and feed system on body weight and body condition score lactation profiles. *Journal of Dairy Science*, **90:** 1859-1869.

Pryce, J., M. Coffey and G. Simm, 2001. The relationship between body condition score and reproductive performance. *Journal of Dairy Science*, **84:** 2508-1515.

Pryce, J. and B. Harris, 2006. Genetics of body condition score in New Zealand dairy cows. *Journal of Dairy Science*, **89:** 4424-4432.

Pryce, J., L. Nielsen, R. Veerkamp and G. Simm, 1999. Genotype and feeding system effects and interactions for health and fertility in dairy cattle. *Livestock Production Science*, **57:** 193-201.

Roche, J., 2007. Milk production responses to pre- and post-calving dry matter intake in grazing dairy cows. *Livestock Production Science*, **110**: 12-24.

Roche, J., D. Berry, J. Lee, K. Macdonald and R. Boston, 2007. Describing body condition score change between successive calvins: A novel strategy generalizable to divers cohorts. *Journal of Dairy Science*, **90:** 4378-4396.

Ruegg, P. and R. Milton, 1995. Body condition scores of Holstein cows on Prince Edward Island, Canada: Relationships with yield, reproductive performance and disease. *Journal of Dairy Science*, **78:** 552-564.

Samarutel, J., K. Ling, H. Jaakson, T. Kaart and O. Kart, 2006. Effect of body condition score at parturition on the production performance, fertility and culling in primiparous Estonian Holstein cows. *Veterinarija ir zootechnika.* **36** (58): 69-74 (Esti).

Senatore, E., W. Butler and P. Oltenacu, 1996. Relationships between energy balance and post-partum ovarian activity and fertility in first lactation dairy cows. *Animal Science*, **62:** 17-23.

Tamminga, S., P. Luteijn and R. Meijer, 1997. Changes in composition and energy content of liveweight loss in dairy cows with time after parturition. *Livestock Production Science*, **52:** 31-38.

Veerkamp, R., J. Oldenbroek, H. Van der Gaast and J. Van Der Werl, 2000. Genetic correlations between days until start of luteal activity and milk yield, energy balance, and live weights. *Journal of Dairy Science*, **83:** 577-583.

Veerkamp, R., E. Koenen and G. De Jong, 2001. Genetic correlations among body condition score, yield, and fertility in first-parity cows estimated by random regression models. *Journal of Dairy Science*, **84:** 2327-2335.

Waltner, S., J. McNamara and J. Hillers, 1993. Relationships of body condition score to production variables in high producing Holstein dairy cattle. *Journal of Dairy Science*, **76:** 3410-3419.

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