Association between body condition and production parameters of dairy cows in the experiment with use of BCS camera

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Abstract. Dairy production effectiveness in the farm depends on many technical, technological and biological factors. State of the dairy cow condition constitutes one of the most important element in the assessment of dairy herd and production indices. Including access to modern technical solution to assess body condition of dairy cows, i.e. BCS camera, some results of observation in the herd with 362 cows were collected to find any relationship between BCS index and milk yield per cow including 5 lactation groups and cows differed in age as well as four seasons. Basing on data collected in the period of 11 months it was found that cows with the BCS index lower than 2.9 showed the highest daily milk production. Increase in BCS index was associated with decrease in amount of produced milk per day. The statistical analysis showed significant effect of lactation period, age of animals and season on BCS results in the considered dairy cow production cycle.

Key words: BCS, camera, cow, index, milk yield.

INTRODUCTION

Factors that affect the condition of cows are age, housing system, physiological state, production cycle and season (Borkowska, 2000). That is why it is important to constantly monitor the condition of dairy cows at various stages of the production cycle (Bewley & Schutz, 2008). A tool that can be included as a valuable solution for farmers in cow assessment is body condition monitoring. This tool allows farmer to assess the balance of feed and the adequacy of nutrition in relation to the physiological state of the animal. Excessive fatness as well as emaciation complicate the accumulation of metabolic energy in adipose tissue and muscle tissue. In practice, a fat cow is doomed to emaciation because the body is too overloaded (Januś et al., 2012).

Problems most often occur in the perinatal period, i.e. about 100 days after calving, when feed intake is not able to cover energy needs. At that time, fat reserves are not sufficient enough. This may cause metabolic diseases such as ketosis, acidosis, fatty liver, or labour paralysis. The results of conducted research have shown that in the case of these animals milk production does not bring sufficient results compared to the results

of cows in good condition and reproduction efficiency is also reduced (Sablik et al., 2014).

The method most commonly used to monitor the condition of cows is the non-invasive method based on the five-point BCS scale (Guliński, 1996). The main purpose of this assessment is to attempt to visually determine the thickness of the fat layer under the skin. Many scientific studies have been conducted and these studies showed a significant relationship between the condition of animals and their productivity, fertility and overall health (Berry et al., 2002).

Due to genetic conditions, dairy cows at the peak of lactation release most of their energy. This is due to high milk production (Wójcik et al., 2012). Early stage of lactation is a period in which the animals have a negative energy balance, the energy consumed with the feed is unable to fully cover the demand. In the early lactation phase, due to the negative energy balance, the animal can produce up to 7 kg of milk using fat reserves. This phenomenon has a negative effect on the health and condition of the cows. In order to maintain proper milk production, energy deficiencies are supplemented with adipose tissues, which means that the mass of dairy cows can be dramatically reduced to even 2 kg per day (Delaby et al., 2009). Therefore, many factors indicate that proper management of energy reserves significantly affects the level of milk production, animal health and dry matter intake.

In the research carried out by Contreras et al. (2004) it was found that dairy cows with a low BCS (body condition score) index, i.e. below 3 points during the dry period produced significantly more milk after calving in comparison with animals characterized by the condition rated above 3 points. Moreover, the milk fat content was also higher. This thesis was also confirmed by Waltner et al. (1993). During the tests, a decrease in milk production by about 230 kg was observed in group of cows whose condition exceeded 4 points on the BCS scale.

Based on the research of many authors, it can be concluded that the level of milk production and lactation efficiency significantly affect the condition of cows (c McCarthy et al., 2007).

The purpose of the research was to find a relationship between the condition of cows and season, lactation number, lactation period and milk yield, using a BCS camera system.

MATERIALS AND METHODS

Research on the assessment of the body condition of dairy cows was carried out within the period from April 15, 2018 to March 15, 2019 on a farm in the Lower Silesian region (Poland). On April 15, 2018 the cattle herd included 623 animals, while on the day of the end of the research period there were 571 heads of cattle. The animals were kept in a free-stall barn with individual stalls covered with rubber mats. There was a side-by-side milking parlor (2×16). Cows were milked three times a day. A group of 362 Holstein-Friesian cows was evaluated in the research. In 2018 the average annual milk yield per cow was just over 10,000 kg.

The animals were fed complete feeds in the TMR system. Feed doses were prepared separately for each technological group according to the feeding standards corresponding to daily milk production.

Each day during the research period assessment of the condition of cows on a five-point scale with an accuracy of 0.1 point was carried out using a DeLaval BCS 3D camera (Fig. 1). The camera was mounted above the selection gate (Fig. 2) and as a result it was possible to take three-dimensional photos of each milked cow after leaving the milking parlour. The software calculated the cow body condition based on photography. The three-dimensional camera analyzed 32,000 extreme points of the cow's back profile. The specific places included in the assessment there were: base of the tail, sciatic tumors, lumbar vertebrae, cruciate ligaments, and short ribs. The used 3D camera took 30 photos per second. The animal health status was assessed using DelPro software cooperating with the camera with a low error rate below 0.1% of the standard deviation.

Figure 1. DeLaval BCS camera.
Source: www.delaval.com and own photo.

The processed data support the decision-making process regarding herd management, and also facilitate consultations with a nutritional advisor and veterinarian. The system also generates extensive reports (Fig. 3) that the farmer can individually modify and select only the data that interests him.

Figure 2. DeLaval BCS camera mounted above the selection gate.
Source: Lesiakowski, 2016.

Figure 3. Example report generated via DeLaval DelPro system.
Source: Own study.

All collected data were generated in the form of reports using the DelPro system, then saved in Excel. The results. of the BCS (body condition score) assessment were recorded every 30 days for each animal individually Daily and monthly milk productivity values were also assigned to the appropriate cows.

The time when the condition of dairy cows was assessed in the research included four periods corresponding to the seasons of the year:

- Spring (W): months April - June,
- Summer (L): months July - September,
- Autumn (J): months October - December,
- Winter (Z): months January - February.

In each analyzed season, cows of different ages were identified including their lactation number. The next factor grouping the animals was the lactation period (Table 1).

On the basis of the collected and compiled data, the following indices were calculated: average BCS values, daily milk production and milk production for three months for cows in each group (including season, lactation number and lactation period). Then the test results obtained from the DelPro system were used to statistical analysis. Correlation coefficients between variables were determined. Using the ANOVA test, the significance of the influence of various factors on the condition of cows characterized by the BCS value was determined. The effect of season, cow age, and lactation period on the BCS score was assessed. Changes in the average milking test were also assessed depending on the condition of the animals. Results were statistically analyzed using Statistica v.13 software (StatSoft Polska, Cracow, Poland).

Table 1. The reproduction status of cows included in particular lactation period

Period of lactation	Stage of lactation
0–50 days	After calving
51–90 days	Beginning of lactation
91–200 days	Middle of lactation
201–300 days	End of lactation
> 300 days	Dried

Source: Own study.

RESULTS AND DISCUSSION

Basing on the collected data during the experimental period it was found that the distribution of dairy cow condition assessments on the BCS five-point scale was equivalent to the normal distribution (Fig. 4). The average assessment of the condition of the animals in the analyzed period was 2.99 points, whereas the standard deviation amounted to 0.15 points.

Analyzing the distribution of dairy cow condition assessments, it was found that 34% of all BCS values are grades between 3.01 and 3.25 points, while 32% of the observations were grades in the range of 2.76–3.00
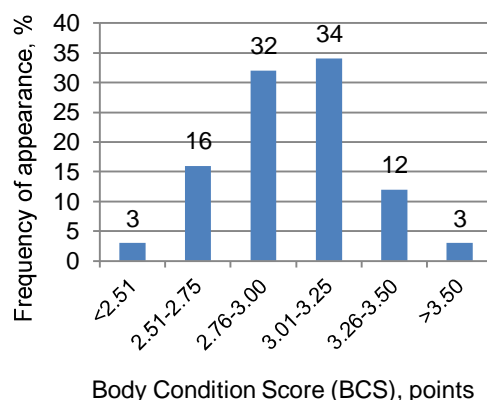
Figure 4. Distribution of dairy cow condition assessments on the BCS scale.
Source: Own study.

points. In other studies, which consisted of visual assessment of the condition of dairy cows, the most frequently used assessment was 3.25 points and this result constituted 33.14% of the total BCS values (Gołębiewski, 2017). Percentage of animals with a BCS condition < 2.5 points was 3%. The same result was achieved in the case of cows that showed high energy reserves. According to Markusfeld et al. (1997) excessively emaciated animals are characterized by condition on the BCS scale not higher than 2.5 points, while excessively fat cows reach BCS values > 3.5 points. In the research carried out by Van Os et al. (2019) cows scoring ≤ 2.0 were considered thin. The vast majority of the condition assessments, i.e. 78% were in the range of 2.76–3.5 points.

Analyzing results obtained in the research, it is possible to indicate some differences in the BCS index value depending on the age of the tested animals, the season of the year and the lactation period of cows in the analyzed period. Based on the correlation matrix, Table 2 summarizes the correlation coefficients for the BCS index given in points.

Table 2. Correlation coefficient between the BCS index and the variables ($p < 0.05$)

Variable	Season	Lactation number	Lactation period	Daily milk productivity	Milk production
BCS	r = - 0.18	r = - 0.17	r = 0.54	r = - 0.66	r = - 0,67

Source: Own study.

The carried out statistical analyses showed some relationships between considered variables. Correlation coefficients were calculated for five variables. It is possible to indicate that daily milk yield and milk production were correlated to the highest degree with the BCS index. The correlation coefficient between the mentioned variables was r = -0.66 for average daily milk productivity and r = -0.67 for milk production, respectively. The average BCS indices were negatively correlated with these variables, i.e. higher milk yield resulted in a decrease in the BCS index (given in points) and a deterioration in the condition of cows. The difference between the minimum and maximum value of the features for the average daily milk production was 34 kg, while in the case of milk production the result was 1,015 kg. The lactation period was also characterized by a significant correlation with the result of r = 0.54. In the case of the lactation number, a low relationship was found at r = -0.17. The analyzed features were significant at $p < 0.05$. The lactation number connected with the age of dairy cows and the season of the year were poorly correlated with BCS.

Significant differences in the assessment of the BCS index between heifers after first calving and older cows were observed in the analyzed period (Fig. 5). The animals in first lactation showed significantly higher values of the BCS index in comparison witholder cows. The diversity of average values of animal condition assessments in the first lactation was about 0.1 point, whereas for older cows the amplitude of diversity increased to 0.2 points. The curve of changes concerning cow condition during the examined period for animals in fifth and higher lactation decreased the fastest way and reached the lowest value amounted to 2.85 points in the winter. In the study carried out by Gołębiewski (2017), a significantly higher level of body condition was also observed for heifers after first calving in comparison with older cows. It was indicated that heifers after first calving were characterized by a significantly higher fat content than older cows. The obtained results of observations are similar with reports given by other authors

(Ruegg & Milton, 1995; Domecq et al., 1997; Dechow et al., 2003: Mao et al., 2004; Lee & Kim, 2006; Friggens et al., 2007; Roche et al., 2007). The condition of dairy cows tends to decrease with subsequent lactation (Waltner et al., 1993; Coffey et al., 2002) and such changes were recorded in the presented own studies.
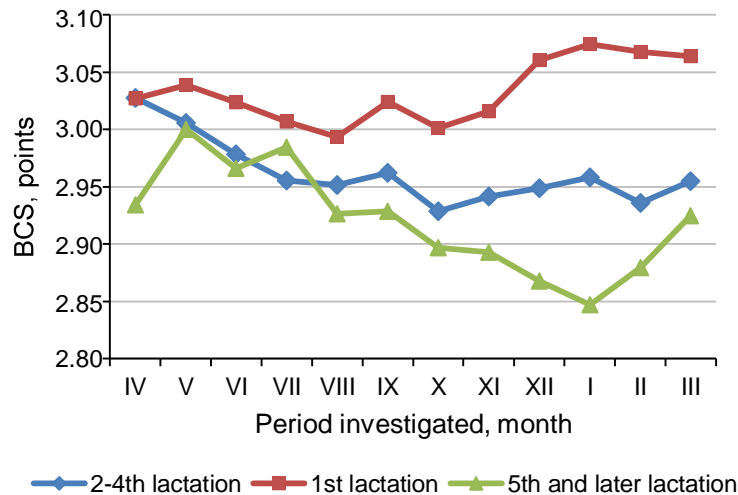

Figure 5. Changes in the BCS index for cows in first lactation and more lactations.
Source: Own study.

Table 3. Analysis of variance of the factors influencing the body condition score (BCS)

Factor	Sum of Squares	Degrees of freedom	Mean Square	F-Ratio	P-Value
Main variables					
Season	0.1112	3	0.0371	5.4	0.002667
Lactation number	0.2335	4	0.0584	8.6	0.000027
Period of lactation	1.5451	4	0.3863	56.6	0.000000
Interactions					
Season*Lactation number	0.0553	12	0.0046	0.7	0.765308
Season*Period of lactation	0.0758	12	0.0063	0.9	0.528741
Lactation number* Period of lactation	0.1544	16	0.0096	1.4	0.175204
Error	0.3273	48	0.0068	-	-

Source: Own study.

Based on the analysis of variance (Table 3), the significance of the impact of the lactation period on the BCS value, i.e. the fat level of dairy cows was demonstrated. Changes in the condition of cows and the average daily performance in relation to the lactation period are shown in Fig. 6. Including increase in milk yield per cow, a decrease in the condition of animals was observed. The average BCS value of cows after calving was 2.95 points, while the average daily milking reached 41.1 kg of milk per cow. In the early lactation, i.e. up to 90 days after calving, there was an increase in daily milk production by 2.18 kg per cow at the decreased body condition, which drop to 2.85 points. Kulpys et al. (2009) recorded the similar trends. Studies carried out by Januś &

Borkowska (2005) showed that after calving, there is a sudden increase in the cow's demand for nutrients. This effect is caused by an increase in milk production in the first days of lactation. Losses of body condition during this period are caused by the phenomenon of fat concentration as a result of not preparing the body to collect such large amounts of feed to meet nutritional needs.
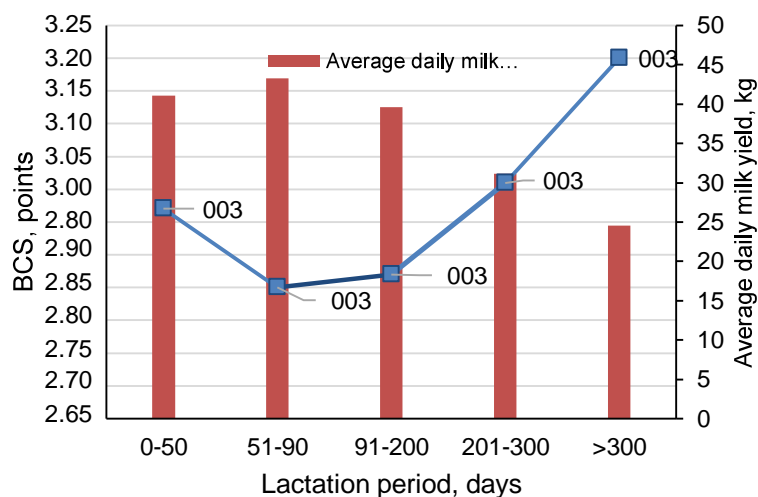

Figure 6. Changes in the condition of cows and daily milk production in relation to the lactation period.
Source: Own study.

After 90 days there was observed a slow increase in body condition state. During the middle part of lactation cows supplemented their energy reserves, which indicated a positive balance. Milk production gradually decreased. After 200 days of lactation, the BCS index value increased rapidly to 3.2 points during the dry period. The average daily milk production decreased by almost half in comparison with the early lactation period.

Based on the analysis of variance (Table 3), the significance of the effect of lactation number on the average condition state of dairy cows was indicated. The condition state of dairy cows decreased with subsequent lactation. Waltner et al. (1993) and Coffey et al. (2002) recorded similar trends. The research results showed that the cows produced less milk at the highest BCS index. Analysis of variance also showed a significant impact of the season on the condition state of cows. There was a downward trend in the BCS score from April to December. In the experiment carried out by Jankowska & Sawa (2004) it was shown that the condition of heifers after first calving was slightly worse than older cows in the spring, while in the other periods the tendency was reversed. These observations were similar with the presented own investigation (Fig. 5). The season and the associated thermal conditions, especially heat stress are among the important factors determining the physiological state and productivity of dairy cows (Herbut et al., 2019).

Variables included in the analysis of cow condition, i.e. lactation number, period of lactation and milk yield per cow constitute also important elements of complex approach to dairy herd efficiency assessment (Luik-Lindsaar et al., 2019), evaluation of

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lifetime milk productivity (Cielava et al., 2017) and assessment of dairy cow herd indices associated with different milking systems (Gaworski et al., 2018). So there is possible to find common area for further research, where cow condition can be considered in connection with many factors creating dairy system in the farm.

CONCLUSIONS

The use of the system with a BCS camera allows for quick and easy assessment of the condition of cows. The automatic BCS index measurement method saves the time in comparison with performing a visual or tactile tests. It is the system that supports the farmer in daily activities concerning management of a dairy herd.

Basing on the analysis of research results regarding the assessment of the dairy cow condition obtained with help of the BCS camera, the following conclusions can be given:

1. Results of the analysis of variance of the BCS index for cows clearly show that the factors deciding about differentiation in assessment of the cow condition are: lactation period, lactation number and season. No significant effect on the BCS index of cow was found for two considered together factors.

2. Animals in first lactation showed significantly higher BCS values in comparison with older cows. The diversity of average values of assessments of the condition of cows in first lactation was about 0.1 point, while for older cows, the amplitude of diversity increased to 0.2 points.

3. It was confirmed that the cows in first lactation produced smallest amount of milk at the highest BCS score. The average condition was 3.05 points while the daily average milk production was about 35 kg per cow. Older cows in fifth and higher lactation had the lowest condition state with an average value of 2.92 points and milk production amounted to 36 kg. Cows in third lactation were characterized by the highest milk productivity.

4. The carried out investigation showed that cows with low energy reserves obtained significantly better results in daily milk production compared to other animals. Animals with less than 2.9 points were producing on average 44 kg of milk, while the lowest results were achieved by cows with a BCS index less than 3.5 points. High BCS values, regardless of the season of the year, contributed to declines in milk production.

REFERENCES

Berry, D.P., Buckley, F., Dillon, P.G., Evans, R.D., Rath, M. & Veerlmp, R.F. 2002. Genetic parameters for level and change of body condition score and body weight in dairy cows. *Journal of Dairy Science* **85**(8), 2030–2039. doi: 10.3168/jds.S0022-0302(02)74280-X

Bewley, J.M. & Schutz, M.M. 2008. An interdisciplinary review of body condition scoring for dairy cattle. *The Professional Animal Scientist* **24**(6), 507–529. doi: 10.15232/S1080-7446(15)30901-3

Borkowska, D. 2000. The influence o seleeted factors on physical condition of cows bred on individual farms. *Medycyna Weterynaryjna* **56**(11), 743–745 (in Polish).

Cielava, L., Jonkus, D. & Paura, L. 2017. Lifetime milk productivity and quality in farms with different housing and feeding systems. *Agronomy Research* **15**(2), 368–375.

Coffey, M.P., Simm, G. & Brotherstone, S. 2002. Energy balance profiles for the first three lactations of dairy cows estimated using random regression. *Journal of Dairy Science* **85**(10), 2669–2678. doi: 10.3168/jds.S0022-0302(02)74352-X

Contreras, L.L., Ryan, C.M. & Overton, T.R. 2004. Effect of dry cow grouping strategy and prepartum body condition score on performance and health of transition dairy cows. *Journal Dairy Science* **87**(2), 517–523. doi: 10.3168/jds.S0022-0302(04)73191-4

Dechow, C.D., Rogers, G.W., Klei, L. & Lawlor, T.J. 2003. Heritabilities and correlations among body condition score, dairy form and selected linear type traits. *Journal of Dairy Science* **86**(6), 2236–2242. doi: 10.3168/jds.S0022-0302(03)73814-4

Delaby, L., Faverdin, P., Michel, G., Disenhaus, C. & Peyraud, J.L. 2009. Effect of different feeding strategies on lactation performance of Holstein and Normande dairy cows, *Animal* **3**(6), 891–905. doi: 10.1017/S1751731109004212

Domecq, J.J., Skidmore, A.L., Lloyd, J.W. & Kaneene, J.B. 1997. Relationship between body condition scores and milk yield in a large dairy herd of high yielding Holstein cows. *Journal Dairy Science* **80**(1), 101–112. doi: 10.3168/jds.S0022-0302(97)75917-4

Friggens, N.C., Berg, P., Theilgaard, P., Korsgaard, I.R., Ingvartsen, K.L., Lovendahl, P. & Jensen, J. 2007. Breed and parity effects on energy balance profiles through lactation: Evidence of genetically driven body energy change. *Journal of Dairy Science* **90**(11), 5291–5305. doi: 10.3168/jds.2007-0173

Gaworski, M., Leola, A., Kiiman, H., Sada, O., Kic, P. & Priekulis, J. 2018. Assessment of dairy cow herd indices associated with different milking systems. *Agronomy Research* **16**(1), 83–93. doi: 10.15159/AR.17.075

Gołębiewski, M. 2017. Study on the suitability of the modified body condition scoring in dairy herd management, with particular emphasis on its impact on production, repro-duction and animal health. *Wydawnictwo SGGW, Warszawa*, 152 pp. (in Polish).

Guliński, P. 1996. Praktyczna ocean kondycji krów mlecznych. *Przegląd Hodowlany* **11**, 4–5 (in Polish).

Herbut, P., Angrecka, S., Godyń, D. & Hoffmann, G. 2019. The physiological and productivity effects of heat stress in cattle – a review. *Annals of Animal Science* **19**(3), 579–593. doi: 10.2478/aoas-2019-0011

Jankowska, M. & Sawa, A. 2004. Kondycja krów czarno-białych z różnym udziałem genów rasy holsztyńsko-fryzyjskiej a ich użytkowość mleczna i rozpłodowa. *Zeszyty Naukowe Przeglądu Hodowlanego* **72**(1), 93–99 (in Polish).

Januś, E. & Borkowska, D. 2005. Zmiany kondycji krów oraz dziennej wydajności i składu mleka w przebiegu laktacji. *Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego* **1**(1), 75–84 (in Polish).

Januś, E., Borkowska, D., Wilgos, A. & Czaplicka, M. 2012. Evaluation of the relationship between body condition of high-yield Black-and-White Polish Holstein-Friesian cows and their productivity. *Annales UMCS Lublin – Polonia* **4**, 34–40.

Kulpys, J., Paulauskas, E., Pilipavicius, V. & Stankevicius, R. 2009. Influence of cyanobacteria *Arthrospira (Spirulina) platensis* biomass additives towards the body condition of lactation cows and biochemical milk indexes. *Agronomy Research* **7**(2), 823–835.

Lee, J.Y. & Kim, I.H. 2006. Advancing parity is associated with high milk production at the cost of body condition and increased periparturient disorders in dairy herds. *Journal of Veterinary Science* **7**(2) 161–166. doi: 10.4142/jvs.2006.7.2.161

Lesiakowski, R. 2016. Obora z pierwszą w Polsce kamerą BCS. *Hodowla i Chów Bydła* **2**, 58–61 (in Polish).

Luik-Lindsaar, H., Põldaru, R. & Roots, J. 2019. Estonian dairy farms' technical efficiency and factors predicting it. *Agronomy Research* **17**(2), 593–607. doi: 10.15159/AR.19.067

Mao, I., Sloniewski, L.K., Madsen, P. & Jensen, J. 2004. Changes in body condition score and in its genetic variation during lactation. *Livestock Production Science* **89**(1), 55–65. doi: 10.1016/j.livprodsci.2003.12.005

Markusfeld, O., Galon, N. & Ezra, E. 1997. Body condition score, health, yield and fertility in dairy cows. *Veterinary Record* **141**(3), 67–72. doi: 10.1136/vr.141.3.67

McCarthy, S., Berry, D.P., Dillon, P., Rath, M. & Horan, B. 2007. Influence of Holstein Fresian strain and feed system on body weight and body condition score lactation profiles. *Journal of Dairy Science* **90**(4), 1859–1869. doi: 10.3168/jds.2006-501

Roche, J.R., Berry, D.P., Lee, J.M., MacDonald, K.A. & Boston, R.C. 2007. Describing the body condition score change between successive calvings: A novel strategy generalizable to diverse cohorts. *Journal of Dairy Science* **90**(9), 4378–4396. doi: 10.3168/jds.2006-729

Ruegg, P.L. & Milton, R.L. 1995. Body condition scores of Holstein cows on Prince Edward Island, Canada: Relationships with yield, reproductive performance and disease. *Journal of Dairy Science* **78**(3), 552–564. doi: 10.3168/jds.S0022-0302(95)76666-8

Sablik, P., Kobak, P., Skrzypiec, A., Klenowicz, A. & Derezińska, D. 2014. Comparison of body condition scores in polish Holstein-friesian cows of black-and-white variety manager in different housing systems. *Zootechnica* **13**(1), 57–66.

Van Os, J.M.C., Weary, D.M., Costa, J.H.C., Hötzel, M.J. & von Keyserlingk, M.A.G. 2019. Sampling strategies for assessing lameness, injuries, and body condition score on dairy farms. *Journal of Dairy Science* **102**(9), 8290–8304. doi: 10.3168/jds.2018-15134

Waltner, S.S., McNamara, J.P. & Hillers, J. K. 1993. Relationships of body condition score to production variables in high producing Holstein dairy cattle. *Journal of Dairy Science* **76**(11), 3410–3419. doi: 10.3168/jds.S0022-0302(93)77679-1

Wójcik, A., Gołębiewski, M. & Nałęcz-Tarwacka, T. 2012. Kondycja krów mlecznych (BCS) a kształtowanie się parametrów produkcyjnych. *Przegląd Hodowlany* **10-12**, 9–12 (in Polish).