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For effective production of beef, in addition to having high-yielding animals and high-quality feed, organizing their use rationally is necessary. Different breeds of animals have different live weights, and the rates for feeding beef cattle are calculated mainly based on their live weights, which is an incorrect approach. Because the animals in a herd can have the same live weight and still have different energy needs depending on their body condition, the rates for feeding animals should be adjusted not only according to their live weight but also by taking into account the animals' body condition. Therefore, animals regrouping depending on their body condition becomes necessary in beef production. This reduces expenditure on expensive fodder as feed costs approximately 60% of the cost of beef production. This study aimed to determine the relationship between the live weight and body condition scores of the cows to establish how much the live weight changes when the body condition score is changed by 1 point and adjust the feeding levels based on the body condition of the cattles. The study included the Hereford and Kazakh White headed breeds. Correlation and regression analyzes were performed. A highly positive correlation was established between the live weight and the body condition score of the cows (r = 0.93 for the Herefords and r = 0.95 for the Kazakh White headed breed), thus allowing the calculation of regression coefficients between the traits. Thus, this study revealed that monitoring the body condition of the cows, grouping the animals according to their body condition, and adjusting the feeding level depending on the animals' body condition scores are the necessary techniques for achieving economic efficiency in the "cow–calf" system of beef production.

: meat cattle, fatness, live weight, body condition score, feeding level

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Although the technology of beef production seems involve a simple production technique, organized beef production requires sufficient availability of animals with high potential for beef production, obtaining a calf from each cow yearly, establishment of good feeding conditions that satisfy the nutritional needs of the cattle, and infrastructure with comfortable maintenance conditions. However, in practice, this is not enough for a successful production process, and herd management is required, which involves a combination of the basic technological processes and the stages that constitute the basis of production. Herd management determines the sequence of implementation of the individual stages and operations and ensures that the different techniques of the entire technology work together properly, resulting in economically efficient and profitable beef production (Blasi et al., 2008; Whittier et al., 1993).

Errors in herd management reduce the efficiency of ongoing activities and can be extremely expensive for the producer. For competent management decisions to be taken, a tool is required that enables the animals' energy reserves to be determined quickly and accurately because only this information allows positive adjustments in feeding to be made on time, together with grouping of the cattle. According to many scientists, the live weight and body condition score of the beef cattle can serve as an indicator of the size of energy reserves of the body as well as of the general condition of the animals. In turn, weight and body condition scores are significantly influenced by the level of feeding of the cattle (Anderson et al., 2007; Ensinitas and Lardy, 2010; Selk, et al, 1988).

Cattle with the same live weight can have different body conditions and vice versa because the live weight varies over fairly wide ranges depending on the contents of the gastrointestinal tract, the weight of the fetus, and the amount of amniotic fluid. Thus, the live weight of cattle cannot serve as an indicator to determine the energy reserves of the body. Many studies have reported that the body condition score of animals is a more appropriate indicator of the energy reserves of their bodies (Flickety and Coomander, 2009; Hardin, 1990; Mathis et al., 2002).

The body condition score of animals reflects the amount of energy reserves in the body deposited as fats and partly as proteins in muscle fibers.

To express the energy reserves numerically, a number of livestock body condition scoring systems have been adopted worldwide, both in zootechnical science and in practice. In Canada and Europe, a 5-point system is adopted for assessing the body condition scores of the beef cattle, whereas in the USA, a 9-point system is used (Legoshin and Sharafeeva, 2015; Berry et al., 2002; Hardin, 1990; Metzner et al., 1993)

Cows should be inseminated once a year and calve, a calf to be raised so that beef can be obtained from it. A calf is the only product obtained from a beef cow. It is, therefore, necessary to pay utmost attention to issues of reproduction. Ideally, every cow should calve annually. To maintain the 12-month interval between calving, a cow must be fertilized 80–90 days after calving because the duration of a cow's pregnancy is 272–280 days (depending on the breed and the gender of the fetus). Our earlier studies conducted on beef cows showed that in the early-maturing Angus breed, the duration of pregnancy is 272–273 days, whereas in the Limousin breed in which fetus development is slower, the period of intrauterine development is 278–280 days (Khakimov, 2015).

The calving interval also depends on the duration of the service period. Numerous studies have shown that the duration of the service period depends on the body condition of the beef cows. For example, according to Eversoul et al., only 46% of cows with a body condition score of <3 points come in season 60 days after calving, whereas 61% of cows with a body condition score of 4 points and 91% of cows with a body condition score of 5 points come in season 2 months after calving (Eversole et al., 2007).

This means that many important production indicators, such as fertilization after the first insemination, duration of the service period, duration of the estrus and sexual cycles, interval between calving, and milking capacity of cows, depend on the body condition of beef cows. When cows are severely emaciated (body condition score: <4 points), their resistance to various diseases decreases, thus leading to a decrease in reproductive functions (Eversole et al., 2007; Herd and Sprott, 1993).

Cows with a body condition score of 1 point are extremely emaciated, i.e., their lives are at risk and immediate measures are needed to restore their body condition to normal levels to save their lives.

Animals with a body condition score of 8-9 points are inactive, their internal organs exhibit high visceral fat accumulation, and springing cows and heifers can have difficulty during calving due to the presence of large deposits of adipose tissue in the pelvic region and in the maternal passages.

In farms, the average body condition score of most healthy cows is 3-7 points over the year. Before calving, it is desirable to raise the body condition score of the cows to 5-7 points. Depending on their physiological state, a cow's body condition score may decrease either during the breeding season or after calving because some of the energy accumulated in the form of fat deposits is utilized in milk production. Subsequently, with balanced feeding, the live weight of the cow can be restored, and the cow can regain good health with sufficient body condition by the end of pregnancy, thus ensuring the normal growth and development of the fetus (Nisley and Parsons, 2010; Parish and Rinehart, 2007).

When assessing the feeding level of the animals, many cattle breeders make the mistake of focusing only on the live weight of animals. In beef cows, live weight should not be the only indicator of the feeding level.

In a herd, cows differ in age, linear size, terms of pregnancy, health status, and the quantity and quality of the feed received (by filling the gastrointestinal tract). When assessing the animals' feeding quality, determining the level and balance of feeding only by their live weight can lead to distorted results, whereas determining the feeding levels by the body condition of the animals is a more reliable and accurate tool.

A number of problems that directly affect the most important economic indicators of beef production are related to the cows body condition. In emaciated animals, the sexual cycle is absent or inferior, which impedes the identification of the estrus cycle stage, thus reducing the results of the fertilization of the females after the first insemination. This leads to an extension of the service period and the estrus season, and as a result, to an increase in the calving interval. A poor body condition reduces the resistance of the body and increases the susceptibility to various diseases. In addition, in cows with low body condition , a decrease in milking capacity is observed, which in turn leads to a reduction in the energy available for the growth and vitality of calves.

In cows with a body condition scores of 8-9 points, the reproductive functions and motor activity are also reduced, which leads to an increase in the number of cows facing difficulties with calving. Cows overfeeding leads to an increase in feed costs and a decrease in the production efficiency because feed costs constitute 60%–65% of the total production costs. In addition, fatter cows always displace the weaker cows at the feeding table, often making them to starve.

Thus, studying the relationship between the body condition of the cows and their live weights with the aim of adjusting feeding programs is important because of the economic significance. Our analyses, in contrast to those of other authors, are justified by the identification and application of correlation and regression coefficients between the live weights and the body condition scores and thus allow the necessary changes in feeding programs of cows to be established accurately, depending not only on the breed and live weight but also on the cattle body condition. Using this technique, every researcher or beef producer can calculate the magnitude of the regression and determine necessary changes in the feeding program for the breed or for individual herds.

This study aimed to identify the relationship and regression between the body condition of beef cows and their live weights and to establish the optimal feeding level of the cows 90–100 days before calving.

The objectives of this study included determining the correlation and regression coefficients between the live weights and the body condition scores of beef cows, determining by how many kilograms the live weight should change to alter the body condition score by 1 point, and establishing changes in the feeding levels of cows to restore the normal body condition before calving.

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The study group comprised 100 cows of the Hereford and White headed breeds each. Correlation coefficients between the live weight and the body condition scores of cows were determined as the coefficient of phenotypic correlation for large samples, and regression coefficients were determined according to the following formula:

$$R_{x\backslash y} = r \cdot (\delta_x : \delta_y),$$

where r is the correlation coefficient between the live weight and body condition score, and δ_x and δ_y are the deviations from the arithmetic mean values of both parameters.

The feeding level of the cows was determined according to the rates developed for feeding beef cows by Kalashnikov (2003).

The digital material obtained during the study was processed statistically using Plokhinsky's method; significance was determined using Student's t-test.

The live weight of an animal is the main parameter indicating its development and body condition. Therefore, the correlation coefficient between the live weight and body condition of animals is important in determining the energy reserves of their bodies. We measured the live weight and calculated the correlation and regression coefficients for animals of two beef breeds. The variability of the live weight was determined, together with its mean square deviation, to calculate the coefficient of variability and the error of the arithmetic mean values (Table 1).

Kazakh White headed cows were slightly heavier than the Hereford cows by 6.8 kg, but this difference was not significant. The coefficients of variability ranged from 12.75% to 13.20%.

The average fatness scores were similar in both breeds and did not exceed 6 points (Table 2).

Live weight (M), kg	458.2	465.0
Mean square deviation (δ), kg	58.3	61.4
Coefficient of variability (C_V), %	12.75	13.20
Error of the arithmetic mean (m), kg	5.88	5.13

The body condition score of Hereford cows was 5.62 points, which was 0.17 points less than that of Kazakh White headed cows; this difference was only 3.02%. More interbreed variance was observed in the Kazakh White headed breed than in the Hereford breed. In the Kazakh White headed breed, the mean square deviation for body condition score exceeded that in the Hereford breed by 13.7%, and the coefficient of variability exceeded by 2.04%.

Body condition	5.62	5.79
Mean square deviation (δ). points	1.02	1.16
Coefficient of variability (C_V). points	19.6	20.0
Error of the arithmetic mean (m)	0.10	0.10

The difference between the errors of the arithmetic means of the two groups was 10.0%.

The correlation and regression coefficients were highly correlated (Table 3).

Correlation coefficients in both groups were positive and high ranging from 0.93 to 0.95, indicating that the live weight of animals is highly dependent on the body condition score. The calculated regression coefficients indicated that changing the body condition score by 1 point changed the live weight of the Hereford cows by 40.42 kg and that of the Kazakh White headed cows by 48.13 kg. These data enabled us to make necessary changes to the diets of feeding cows and to adjust the feeding program. In all cases, the correlation and regression coefficients were reliable at a confidence level of P > 0.95 and 0.999.

Depending on their health and linear dimensions, each cow gains or loses 40.4–48.1 kg of live weight when their body condition scores change by 1 point. For example, if the live weight of a cow is 450 kg with a body condition score of 6 points, by reducing the body condition score to 5 points, its weight will decrease to 402–410 kg. Similarly, when the body condition score is reduced by 2 points, the weight loss is 80–96 kg. Therefore, feeding levels should be adjusted in such a way that the cow can gain 80–96 kg of live weight. The cow also needs more energy and nutrients to increase its weight by 45–48 kg during the last 3 months of pregnancy for fetal and placental growth.

Correlation coefficient (r)	0.93	0.95
Regression coefficient (R)	40.42	48.13
Significance of correlation coefficient (td)	0.95	0.95
Significance of regression coefficient (td)	0.999	0.999

Recommendations for changing the live weight of cows 90–100 days before calving to achieve the desired body condition score of 5-7 points are provided in Table 4.

Normalizing the feeding level of a beef cow by taking into account the pregnancy and lactation periods, live weight, and other important factors allows the body's nutritional needs to be satisfied to the fullest possible extent and the rational use of feed resources. Dry cows with a live weight of 450–500 kg, those with body condition maintained at a proper level, and those that gave birth to a viable calf require 17–18 mJ of exchange energy and 1.90–2.20 kg of dry matter in terms of 1.73–1.82 energetic feed units (EFU) per 100 kg of live weight. The amount of digestible protein should be 85–90 kg per 1 EFU of diet (Kalashnikov, 2003).

Based on these figures, it is possible to calculate the changes in the feeding levels of cows based on their live weight and body condition scores and make prompt changes in the diets of animals (Tables 5 and 6).

To increase the body condition scores from 2 to 5 points, a cow requires an additional 2.5–2.9 EFU and 212.5–261.0 g of digestible protein. Accordingly, to reduce the body condition scores of cows from 9 points to the desired score of 5-7 points, it is necessary to reduce the nutritional value of rations by 0.8–1.6 EFU and by 68–144 g of digestible protein per day.

1	5	Increase the live weight by 160–192 kg
2	5	Increase the weight by 135–160 kg
3	5	Increase the live weight by 90–135 kg
4	5	Increase the live weight by 70–90 kg
5	5	Increase the live weight by 45–48 kg for fetal and

		placental growth
6	5–7	Increase the live weight by 45–48 kg for fetal and placental growth
7	5–7	-
8	5–7	Reduce the live weight by 25–45 kg
9	5–7	Reduce the live weight by 45–90 kg

Body condition score	Desirable body condition score in calving	Changes in the norms of feeding
1	5	Norm of feeding + 3.02 EFU
2	5	Norm of feeding + (2.55–3.02) EFU
3	5	Norm of feeding + (1.70–2.55) EFU
4	5	Norm of feeding + (1.32–1.70) EFU
5	5–7	Norm of feeding + (0.85–0.91) EFU
6	5–7	Norm of feeding + (0.85–0.91) EFU
7	5–7	Norm of feeding
8	5–7	Norm of feeding – (0.47–0.85) EFU
9	5–7	Norm of feeding – (0.85–1.70) EFU

EFU: energetic feed units

1	5	+ 3.16	+ 3.02	+ 2.82	+ 2.77
2	5	+ 2.67–3.16	+ 2.55–3.02	+ 2.46–2.82	+ 2.34–2.77
3	5	+ 1.76–2.67	+ 1.70–2.55	+ 1.64–2.46	+ 1.56–2.34
4	5	+ 1.38–1.76	+ 1.32–1.70	+ 1.27–1.64	+ 1.21–1.56
5	5–7	+ 0.89-0.95	+ 0.85–0.91	+ 0.82–0.87	+ 0.78–0.84
6	5–7	+ 0.89–0.95	+ 0.85–0.91	+ 0.82–0.87	+ 0.78–0.84
7	5–7	Normal	Normal	Normal	Normal
8	5–7	– 0.50–0.89	– 0.47–0.85	– 0.46–0.82	– 0.43–0.78
9	5–7	– 0.88–1.78	– 0.85–1.70	– 0.82–1.64	– 0.78–1.56

EFU: energetic feed units

The feeding levels of cows, compared with the norm for cows with a different live weight, will depend on their body condition.

As mentioned above, changes in the live weight and cows body condition during the annual production cycle should be regarded as normal and practically inevitable. This is due to the different physiological states of cows. Because the reproductive functions of cows depend on their body condition , which, in turn, depends on feeding level, the first rational step to improve their body condition and reproductive functions is to regulate their feeding, taking into account the season of calving. Attaining a body condition score of ≥5 points and maintaining it throughout the production cycle is an indispensable requirement for the effective production of beef. Many producer experience a decline in their profits by overfeeding cows with normal body condition because only some cows require additional feeding and respond to increased feeding levels.

Maintaining optimal body condition in the cows (5-7 points) enables the achievement of maximum reproduction in the herd and the reduction of the feed cost for maintaining the breeding stock.

During winter, the cows lose some live weight even if their body condition is previously maintained at normal levels. This may be due to the availability of less or low-quality feed, which is cheaper, during winter; this positively affects the economy of the farm. Because herbivores naturally lose weight during the most difficult period of the year, a good body condition before the winter period and during lactation is advantageous for the successful wintering of livestock and preserving their high reproductive qualities.

The body condition scores of the cows should be evaluated thrice a year: after weaning the calves or during the annual judging of the livestock, just before calving, and 30 days before the breeding season.

Because cows should achieve optimal body condition by the time of calving, it is desirable to adjust the feeding level 90–100 days earlier. In many cases, this coincides with the weaning time of the calves. During this time, it is possible to influence the body condition of animals, e.g., by feeding the emaciated cows intensively or by limiting the feeding of obese cows. Thus, animals should be grouped according to their body condition (Parsons, 2009; Rasby, 2007).

By grouping and managing the cows based on their body condition score, the economy of production is improved. Grouping the animals by their body condition is a good method for making additional profit and a good management decision.

From an economic point of view, the body condition of cows should be increased during the summer grazing period, when the feed is cheap and complete. The use of natural forage grasslands plays a very important in reducing the maintenance costs of animals. Pastures should have good stands of grass that are sufficient for meeting the feed needs of cattle.

In a herd of cows, the animals will always have varying body condition. Excessive feeding of cows with a high body condition will lead to a decrease in profits because only some cows need additional feeding. Grouping the cows based on their body condition and feeding levels is mandatory to improve the economy of beef production. When calving is organized to be seasonal, it is the best to adjust the feeding programs 90–100 days before calving.

Our study showed that there is a high positive correlation between live weight and the body condition of cows, which allows the calculation of the regression coefficients between the body condition and live weight. Having a coefficient of regression, i.e., knowing how much the live weight changes when the body condition scores changes by 1 point, enables the adjustment of the feeding program of cows. This will reduce fodder expenses and increase reproduction in a breeding herd, which necessarily has a positive effect on the producer's profit.

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