The assessment of morphological features in Hereford cattle

K M Dzhulamanov\textsuperscript{1}, N P Gerasimov\textsuperscript{1}, A N Ruchay\textsuperscript{2}, V I Kolpakov\textsuperscript{1} and E B Dzhulamanov\textsuperscript{1}

\textsuperscript{1}Federal Research Centre of Biological Systems and Agro-technologies of the Russian Academy of Sciences, 29, 9 Yanvarya Str., Orenburg, 460000, Russia
\textsuperscript{2}Chelyabinsk state university, 129, Brat’ev Kashirinykh Str., Chelyabinsk, 454001, Russia

E-mail: nick.gerasimov@rambler.ru

Abstract. The purpose of the study was to compare the morphological characteristics of Hereford mature herd of different body types at various stages of ontogenesis. Work was carried out in LLC “AF Kalininskaya” of Chelyabinsk region on two groups (\(n = 15\) individual search) of Hereford cows which are daughters from sires of different body conformation type. Newborn offspring from tall parents were characterized by significant (\(P < 0.01-0.001\)) superiority of body length and chest girth characterizing the axial part of the skeleton, and the development of altitudinal measurements characterized the growth of the peripheral skeleton. Later intergroup differences became less noticeable in the linear growth of heifers, which was associated with the limiting factor of dams’ milk productivity, as well as with the pronounced precocity of compact animals. Intensive development of body measurements ended at 15 months of age in animals with compact body type. They reached fully formed skeletal structure at the age of 5 years in terms of basic measurements. Tall individuals have the ability for a longer linear growth up to 6 years of age. The pronounced precocity of compact animals was confirmed by the variability of body volume and area of animals. The results of the study proved that the most noticeable differentiation of cows into body types occurs at later stages of ontogenesis.

1. Introduction

At the present stage, the Herefords’ improvement in Russia is carried out with the participation of imported breeding material, mainly from Canada. Large-scale introduction of artificial insemination into the practice of herd reproduction using deep-frozen sperm, as well as embryo transplantation from leaders of the breed contributed to the formation of a large type of exterior and increase in live weight in domestic Hereford herds. The specified intra-breed dynamics became possible due to the multidirectional strategy of selection work in Russian and foreign practice of beef cattle breeding.

For a long period, the priority selection strategy in Russia was the breeding of early-ripening types of beef cattle, which resulted in the formation of compact short-growing animals. Hereford individuals of the compact type showed a high growth rate only for a short period and reached economic maturity at an earlier age. Youngsters of compact type was characterized by early age of intensive fat deposition that causes to less efficient use of feed. On the contrary, Herefords of a tall exterior type showed longevity of weight growth, i.e. the ability for a long period to maintain a high growth rate, mainly due to muscle tissue.

The intrabreed variability of Herefords on the exterior-constitutional types is an important tool in the breed improving [1]. The ranking of beef cattle on body types is based on a scoring, which is determined
depending on the size of hip height [2]. In addition, the magnitude of absolute linear measurements and the severity of meat traits can serve as a reliable indicator of weight growth and direction of animal’s productivity [3, 4]. Thus, a high correlation was found between hip height and variability of live weight when Hereford bulls were tested for their own productivity [5]. It is possible to predict the value of live weight for the development of exterior measurements in beef cattle [6]. Combining the mating scheme of parental pairs, taking into account the severity of the body type, can have a significant effect on weight and linear growth of descendants, which largely determines the efficiency of industry [7]. The search for the optimal variant of mating system of parental pairs has significant potential for increasing the productive traits in beef cattle [8]. Thus, at present time selection and breeding work with Hereford cattle in Russia has been reoriented towards increasing the height growth and late maturity in animals.

The aim of the study was the morphological characteristics of Hereford mature herd of different body conformation types at various stages of ontogenesis.

2. Materials and methods

The researches were carried out on two groups \((n = 15\) individuals) of Hereford cows, which are the daughters from sires of different body conformation type, in LLC “Agrofirma Kalininskaya” of Chelyabinsk region. Experimental groups were formed from newborn heifers: group I - the offspring from parents of tall exterior type, group II - daughters with compact exterior. The justification of age-related growth standards for bulls, cows and heifers by exterior type and selection were conducted according to the hip height and weight and linear growth of Hereford cattle of different body conformation types (Table 1).

| Group                | Body conformation type |          |          |
|----------------------|------------------------|----------|----------|
| Bulls                | Compact                | Medium   | Tall     |
|                      | 135 ≤ h                | 135 < h < 140 | h ≥ 140 |
| Cows                 | 130 ≤ h                | 135 < h < 135 | h ≥ 135 |
| Heifers (15 months of age) | 114 ≤ h               | 114 < h < 120 | h ≥ 120 |

Notation: \( h \) – hip height, cm

The feeding and maintenance were the same for all group sof experimental animals in accordance with traditional technology in beef cattle breeding. Suckling heifers were reared with dams during the preweaning period. Youngsters were weaned at the age of 8 months. The rations for growing heifers and cows of breeding groups were balanced by age periods and the planned level of average daily gain from own-produced feeds.

The study of morphological features carried out by measurements at birth, at 8 and 15 months, at 2, 3, 5 and 6 years of age in cows of different body conformation type. A Lidtin measuring stick, measuring compass and measuring tape were used to measure the animals. Ten basic measurements were taken: withers height, hip height, oblique length of the body, chest width, chest depth, chest girth, hip width, hip joint width, backside half-girth, metacarpus girth. The volume and area of the body were calculated based on data for individual measurements using the formulas

\[
V = \text{chest depth} \times \text{oblique length of the body} \times \frac{\text{chest width} + \text{hip width}}{2}
\]

where \( V \) – volume of the body, \( m^3 \).

\[
S = \text{oblique length of the body} \times \frac{\text{wither height} + \text{hip height}}{2}
\]

where \( S \) – area of the body, \( m^2 \).

Animal maintenance and experimental studies were performed in accordance with the instructions and recommendations Russian Regulations, 1987 (Order No. 755 on 12.08.1977 the USSR Ministry of Health) and “The Guide for Care and Use of Laboratory Animals (National Academy Press Washington, D.C. 1996)” . Efforts have been made to minimize animal suffering and to reduce the number of samples.
used in the studies. Methods of basic statistic and ANOVA were used for experimental data processing using office software “Microsoft Office Excel” (“Microsoft”, USA) and “Statistica 10.0” (“StatSoftInc.”, USA).

The effect of heredity was determined by the formula:

$$\eta^2 = \frac{\sigma^2_g}{\sigma^2_p}$$

where $\sigma^2_g$ – variance of the trait determined by heridity; $\sigma^2_p$ – total variance of the trait.

3. Results

Newborn descendants from tall parents differed by a significant advantage ($P < 0.01$) in basic measurements characterizing the development of the axial and peripheral parts of the skeleton (Table 2). Thus, the superiority for the withers height was 2.7 cm (3.97%), hip height – 4.2 cm (5.99%), oblique length of the body – 4.3 cm (7.54%), chest width – 1.7 cm (13.93%), chest depth – 2.3 cm (10.88%), chest girth – 3.1 cm (4.44%), hip width – 1.6 cm (11.94%), hip joint width – 1.6 cm (9.82%), backside half-girth – 2.6 cm (5.88%), metacarpus girth – 1.3 cm (15.85%).

Table 2. Linear measurements of Hereford heifers with different body conformation type, cm (M±SE)

| Measurement                      | Body conformation type | Tall | Compact |
|----------------------------------|------------------------|------|---------|
|                                  | At birth | 8 months | 15 months | At birth | 8 months | 15 months |
| Withers height                   | 70.7±0.47***          | 99.6±0.95 | 121.3±1.26 | 68.0±0.38 | 98.5±0.78 | 119.5±0.49 |
| Hip height                       | 74.3±0.44***          | 105.1±0.89 | 125.5±1.16 | 70.1±0.43 | 104.6±0.62 | 123.3±0.29 |
| Oblique length of the body       | 61.3±0.42***          | 108.7±0.93 | 130.7±1.53 | 57.0±0.44 | 107.7±0.82 | 128.5±0.64 |
| Chest width                      | 13.9±0.24***          | 29.1±0.56 | 40.1±0.75  | 12.2±0.17 | 29.1±0.68 | 39.1±0.74  |
| Chest depth                      | 26.5±0.27***          | 44.9±0.80 | 60.9±0.77  | 23.9±0.23 | 45.3±0.47 | 59.9±0.85  |
| Chest girth                      | 72.9±0.65**           | 140.8±1.09 | 164.1±1.71 | 69.8±0.56 | 140.5±0.93 | 162.9±1.81 |
| Hip width                        | 15.0±0.20***          | 29.8±0.40 | 40.4±0.64  | 13.4±0.21 | 30.3±0.61 | 39.9±0.60  |
| Hip joint width                  | 17.9±0.25***          | 31.9±0.63 | 44.0±0.88  | 16.3±0.25 | 32.3±0.56 | 43.0±0.68  |
| Backside half-girth              | 46.8±0.24***          | 84.0±0.92 | 101.5±1.34 | 44.2±0.28 | 83.3±0.93 | 96.8±0.83  |
| Metacarpus girth                 | 9.5±0.13***           | 15.5±0.13* | 18.5±0.13* | 8.2±0.11 | 15.1±0.09 | 18.1±0.09  |

Notation: means differ with significance: * - $P<0.05$, ** - $P<0.01$, *** - $P<0.001$

However, intergroup differences became less noticeable by the age of weaning, and the rank of animals distribution had changed in some measurements. Heifers of compact type had a slight superiority in development of chest depth by 0.4 cm (0.89%; $P > 0.05$), hip width – 0.5 cm (1.68%; $P > 0.05$) and hip joint width – 0.4 cm (1.25%; $P > 0.05$). Thus, unequal intensity of linear growth was manifested by young of different exterior-constitutional types at the stage of suckling rearing, which is associated with the limiting factor of maternal milk production, as well as with pronounced precocity of compact animals.

The leadership of tall heifers in the development of body measurements was restored by the age of 15 months. A statistically significant difference was found in metacarpus girth by 0.4 cm (2.21%; $P < 0.05$) and backside half-girth by 4.7 cm (4.86%; $P < 0.01$). Minimal differences were established for the development of chest and pelvic part.

Further observations of the linear growth indicate an increase in intergroup difference with age of experimental animals (Table 3). Thus, first-calf heifers (age 2 years) of tall body type had a significant advantage in hip height by 2.5 cm (1.98%; $P < 0.05$), oblique length of the body – by 3.8 cm (2.88%; $P < 0.05$) and backside half-girth – by 4.8 cm (4.81%; $P < 0.01$). However, the animals of the compact exterior were slightly inferior to their contemporaries in development of thoracic and pelvic skeleton.
due to the intensive growth of their latitudinal measurements.

Table 3. Linear measurements of Hereford cows with different body conformation type, cm (M±SE)

| Measurement                  | Body conformation type |
|------------------------------|------------------------|
|                              | 2 years | 3 years | 5 years | 6 years | 2 years | 3 years | 5 years | 6 years |
| Withers height               | 124.7±  | 127.8±  | 129.9±  | 130.8±  | 122.6±  | 124.9±  | 125.8±  | 126.0±  |
|                              | 0.99    | 0.94*   | 0.95*** | 1.02*** | 0.52    | 0.56    | 0.46    | 0.39    |
| Hip height                   | 128.6±  | 131.7±  | 133.1±  | 133.5±  | 126.1±  | 128.3±  | 129.1±  | 129.3±  |
|                              | 0.97*   | 0.84**  | 0.75*** | 0.72*** | 0.36    | 0.52    | 0.45    | 0.40    |
| Oblique length of the body   | 135.9±  | 140.5±  | 143.2±  | 144.0±  | 132.1±  | 134.7±  | 135.7±  | 136.1±  |
|                              | 1.45*   | 1.33*** | 1.28*** | 1.23*** | 0.66    | 0.61    | 0.58    | 0.47    |
| Chest width                  | 42.4±   | 44.5±   | 45.8±   | 46.2±   | 41.2±   | 42.8±   | 43.5±   | 43.7±   |
|                              | 0.64    | 0.68    | 0.63*   | 0.57**  | 0.68    | 0.71    | 0.68    | 0.63    |
| Chest depth                  | 65.1±   | 69.0±   | 70.8±   | 71.4±   | 63.5±   | 64.8±   | 66.3±   | 66.5±   |
|                              | 0.67    | 0.74**  | 0.68*** | 0.61*** | 0.79    | 0.83    | 0.74    | 0.65    |
| Chest girth                  | 170.1±  | 175.3±  | 178.4±  | 179.3±  | 168.5±  | 172.2±  | 173.7±  | 173.8±  |
|                              | 1.60    | 1.56    | 1.55*   | 1.52*   | 1.72    | 1.55    | 1.60    | 1.55    |
| Hip width                    | 42.8±   | 44.9±   | 46.3±   | 46.8±   | 42.1±   | 44.0±   | 44.6±   | 44.7±   |
|                              | 0.66    | 0.67    | 0.69    | 0.66*   | 0.65    | 0.70    | 0.62    | 0.54    |
| Hip joint width              | 46.2±   | 48.1±   | 49.1±   | 49.5±   | 45.0±   | 46.7±   | 47.2±   | 47.3±   |
|                              | 0.81    | 0.70    | 0.65    | 0.59*   | 0.73    | 0.76    | 0.68    | 0.59    |
| Backside half-girth          | 104.6±  | 107.5±  | 109.7±  | 110.4±  | 99.8±   | 102.1±  | 103.0±  | 103.1±  |
|                              | 1.28**  | 1.24**  | 1.29*** | 1.24*** | 0.85    | 0.81    | 0.77    | 0.65    |
| Metacarpus                   | 19.5±   | 20.3±   | 20.9±   | 21.3±   | 19.1±   | 19.7±   | 20.3±   | 20.5±   |
| girth                        | 0.17*   | 0.18    | 0.18*   | 0.25*   | 0.15    | 0.23    | 0.23    | 0.19    |

Intensive linear growth of tall body type cows was confirmed by the increasing difference relative to peers at the age of 3 years. Thus, the superiority in withers height reached 2.9 cm (2.32%; P < 0.05), hip height – 3.4 cm (2.65%; P < 0.01), oblique length of the body - 5.8 cm (4.31; P < 0.001), chest depth – 3.6 cm (5.50; P < 0.01), backside half-girth - 5.4 cm (5.29%; P < 0.01).

Minimal changes in absolute sizes of the main traits indicated the completion of linear growth and the formation of exterior in compact cows by the age of 5 years. In contrast, linear growth continued until the age of 6 years in tall animals, and an increase in the measurements of exterior was 0.4-0.9 cm during the analyzed period. Relative longevity provided them with a significant advantage in the development of the studied body measurements. Thus, the highly significant (P < 0.001) advantage was achieved in withers height by 4.8 cm (3.81%), hip height - 4.2 cm (3.25%), oblique length of the body - 7.9 cm (5.80%), chest depth - 4.9 cm (7.37%), and backside half-girth - 7.3 cm (7.08%).

The ability of tall animals to maintain an intense linear growth for a long time can be judged by the change in body volume with age (Figure 1).

Thus, the volume of their body increased by 228.67% after weaning to 6 years of age, which is higher than their peers by 54.0% (P < 0.001). It should be noted that the maximum increase in body volume was recorded in the group of tall individuals at different age stages relative to 6-year-old animals, except for the interval from birth to 6 years. The studied indicator increased in compact cows by 0.73% over the last year of linear growth control, conceding to analogues by 1.55% (P < 0.05).
Figure 1. Variability of body volume in heifers and cows with different body conformation type

Analysis of the data recorded the same body volume in heifers of different body types at 8 months of age, amounting to 0.150 m$^3$. Subsequently, tall animals consistently increased intergroup differences in size both in absolute and relative terms. Thus, if the difference between exterior types was 0.020 m$^3$ (6.31%) by the end of puberty (15 months), then it reached 0.031 m$^3$ (8.54%) at the age of first calving (2 years). At later stages of ontogenesis, a significant discrepancy was found in the value of studied parameter: at 3 years – 0.056 m$^3$ (14.18%; $P < 0.01$), at 5 years – 0.073 m$^3$ (17.85%; $P < 0.001$), at 6 years – 0.081 m$^3$ (19.66%; $P < 0.001$).

Changes in surface area of animal body confirmed the pronounced precocity of individuals of compact body type (Fig. 2). The superiority of representatives of tall exterior has been established at all stages of linear growth control. The minimum advantage was fixed at the age of 8 months - 0.020 m$^2$ (1.83%; $P > 0.05$). Subsequently, the intergroup difference increased, reaching a maximum value at 6 years - 0.167 m$^2$ (9.61%; $P < 0.001$).

Analysis of phenotypic variability of body measurements in animals of different body types allowed to determine the heritability of traits at different stages of ontogenesis (Table 4). At the same time, the maximum effect of hereditary factor on the exterior parameters was established in newborn animals – 32.16-68.49% ($P < 0.01-0.001$). The genotype had the least impact on the development of chest girth in newborn heifers. This is consistent with the patterns of skeleton development in cattle: intensive formation occurs in the peripheral part of skeletonin the early stages of ontogenesis. The variability of exterior traits was minimally determined by an organized factorat the time of weaning the young stock from mothers (8 months). Heritability coefficients were in the range of 0.01-18.00% ($P > 0.05$, $P < 0.05$) in this period. Then, the heredity realization in phenotype increased with the development of animals, reaching its highest value at 6 years of age, with a parameter variation of 18.36-56.26% ($P < 0.05-0.001$).
Figure 2. Variability of body area in heifers and cows with different body conformation type.

Table 4. Heredity of linear measurements, body volume and body area in Hereford heifers and cows with different body conformation type, %

| Measurement         | Age                  |
|---------------------|----------------------|
|                     | At birth  | 8 months | 15 months | 2 years | 3 years | 5 years | 6 years |
| Withers height      | 42.14***  | 2.63     | 5.59      | 10.86   | 19.57*  | 35.45***| 41.03***|
| Hip height          | 61.37***  | 0.66     | 10.82     | 16.72*  | 30.66** | 42.24***| 48.90***|
| Oblique length of the body | 64.55***  | 2.58     | 5.57      | 17.41*  | 36.50***| 50.05***| 56.26***|
| Chest width         | 53.46***  | 0.02     | 2.73      | 5.54    | 10.12   | 17.78*  | 24.08** |
| Chest depth         | 64.35***  | 0.65     | 2.63      | 7.87    | 27.24** | 41.41***| 51.79***|
| Chest girth         | 32.16**   | 0.19     | 0.73      | 1.63    | 6.75    | 13.88*  | 18.89*  |
| Hip width           | 52.17***  | 1.87     | 1.31      | 1.80    | 2.80    | 10.35   | 18.36*  |
| Hip joint width     | 44.61***  | 0.56     | 2.78      | 4.13    | 6.74    | 12.36   | 20.81*  |
| Backside half-girth | 63.77***  | 0.92     | 24.28**   | 25.76** | 32.63***| 41.83***| 49.17***|
| Metacarpus girth    | 68.49***  | 18.00*   | 18.00*    | 13.28*  | 10.67   | 15.72*  | 18.85*  |
| Body volume         | 61.09***  | 0.01     | 4.41      | 10.54   | 26.24** | 40.13***| 50.28***|
| Body area           | 63.20***  | 2.43     | 7.92      | 18.25*  | 35.08***| 49.67***| 56.12***|
In addition, the heritability of particular measurements of the exterior is uneven. Relatively low genotype determination was established with the development of chest width – 24.08% ($P<0.01$), chest girth – 18.89% ($P<0.05$), hip width – 18.36% ($P<0.05$), hip joint width – 20.81% ($P<0.05$) and metacarpus girth – 18.85% ($P<0.05$). Other measurements are highly significant ($P<0.001$) determined by the factor of hereditary nature.

Animals had a higher live weight with the maximum indices of the body format, representing the ratio of body length to the withers height, chest index – the chest width to the chest depth. Differences in live weight in cows of different body types had a significant impact on the change in the body volume.

4. Conclusion

The analysis of linear growth testifies to the characteristic features in the development of heifers and cows of different exterior-constitutional types. Thus, the most intensive skeleton formation in heifers of a compact body type lasts up to 15 months of age. They had a fully formed skeletal structure at the age of 5 years. Tall individuals are capable of longer linear growth up to 6 years of age. The pronounced precocity of compact animals is confirmed by the study of the dynamics of body volume and area in animals. The results of the study prove that the most noticeable differentiation of cows into body types occurs at later stages of ontogenesis.

Acknowledgments

This work was supported by the Russian Science Foundation, grant no. 17-76-20045.

References

[1] Dickenson H H 1984 The influence of Line 1 in the Hereford breed Proc. Ft. Keogh Livestock and Range Research Laboratory (Miles City MT)
[2] BIF 1996 Guidelines for uniform beef improvement programs 7th ed (Colby: Kansas State Univ.) pp 17–20
[3] Alderson G L H 1999 The development of a system of linear measurements to provide an assessment of type and function of beef cattle Animal Genetic Resources Information 25 45–55
[4] Bene S, Nagy B, Nagy L, Kiss B, Polgár J P and Szabó F 2007 Comparison of body measurements of beef cows of different breeds Arch. Tierz. 4 363–73
[5] Zerbino P J and Frahm R R 1983 Relationships of on-test hip height with growth and carcass traits of Hereford calves Animal Sci. Res. Report 177–80
[6] Ozkaya S and Bozkurt Y 2009 The accuracy of prediction of body weight from body measurements in beef cattle Archiv Tierzucht 52(4) 371–7
[7] Arango J, Cundiff L V and Van Vleck L Dale 2002 Comparisons of Angus-, Braunvieh-, Chianina-, Hereford-, Gelbvieh-, Maine Anjou-, and Red Poll-sired cows for weight, weight adjusted for body condition score, height, and body condition score J. Anim. Sci. 80 3133–41
[8] Kolstad B W 1993 Economic values of performance traits in maternal and paternal strains of beef cattle (Masters Thesis) 114 p