

Automatic cattle weighing on pastures with behavioral analysis during drinking



Rashit Uskenov^a  | Arman Mirmanov^a  | Igor Tretyakov^b   | Saule Bostanova^a 

^aS.Seifullin Kazakh Agrotechnical University, Kazakhstan.
^bEconomic Policy Analytical Center LLP, Kazakhstan.

Abstract Livestock body weight (BW) and average daily weight gain (ADG) are primary indicators of beef cattle productivity. The conventional method of weighing involves moving the cattle to a weighing location, which is labor-intensive, stressful for the animals and has a negative impact on their growth. An alternative approach is to use special weighing platforms attached to the drinkers to weigh the animals. This method enables daily monitoring of BW and ADG without incurring additional labor costs or stress. In this study, an experimental weighing platform, previously developed at KazATU and named after S. Seifullin, was employed to measure livestock's partial body weight (PBW). The weighing platform recorded the weights of the animals on the front legs at one-second intervals, allowing for subsequent calculation of the animals' total weight. However, due to significant weight fluctuations observed when the animals were on the platform, the accuracy of calculating the weight based on a simple average of the one-second measurements was questionable. Hence, an algorithm was developed to determine live weight by analyzing the primary data from the scales and identifying moments of animal immobility during drinking. The calculated results were compared with both mean and median values and data from Kazakhstan's information base of selection and breeding work (IBSBW). The experimental method exhibited a stronger correlation ($r = 0.925$) with the actual IBSBW data compared to the mean method ($r = 0.887$) or the median method ($r = 0.921$).

Keywords: digital data collection, farm animals, Internet of Things

1. Introduction

According to the FAO organization, a 70% increase in food production is necessary by 2050 to sustain the projected population of 9.1 billion (FAO 2009). Beef cattle breeding plays a crucial role in agriculture and food provision, particularly in regions like Kazakhstan, where beef is a staple in the daily diet. The Bureau of National Statistics of the Republic of Kazakhstan reports that meat production in 2021 reached 1231.2 tons, with beef constituting a significant portion of it, supported by a cattle population of 9192.4 thousand heads (Agency for Strategic Planning and Reforms of the Republic of Kazakhstan Bureau of National Statistics 2022). However, current beef production in Kazakhstan only accounts for 79-84% of the 1990 levels, indicating the potential for increasing production. Accurate information on the live weight and average daily gains (ADG) of growing animals is crucial for performance monitoring and genetic assessments to achieve sustainable genetic gain (Macneil et al 2021).

Traditionally, farmers rely on periodic weighing using mechanical or electronic scales to monitor cattle body weight. However, conducting frequent weighings on pastures using this conventional method is labor-intensive and risky, allowing for measurements only once every 2-4 weeks. Consequently, it becomes difficult to identify and address weight-related issues timely. Precision livestock technologies leverage information technology in livestock production

(Alexy et al 2022). Remote livestock weighing in pastures has shown promising results compared to traditional methods (Charmley et al 2006).

In previous studies, an experimental weighing platform (EWP) was developed as an attachment to cattle drinkers, along with software for collecting, storing, and analyzing primary data. The EWP utilizes electronic ear tags (RFID) to identify individual animals. Once an animal is identified on the EWP, the control unit records weight readings from four load cells installed at the platform's base every second. The collected information is automatically transmitted via the internet to the data service and stored in a database for further analysis. One of the objectives of this study was to develop an algorithm that accurately determines animal mass using per-second data while considering the swaying motion of the platform during cattle drinking.

2. Materials and Methods

2.1. Hardware and software

The stress-free automatic weighing platform (Figure 1), developed at S. Seifullin KATU (Mirmanov et al 2021), was field tested at the "North Kazakhstan Agricultural Experiment Station" in Northern Kazakhstan. Each platform was equipped with four Mavin NA3 load cells, capable of measuring weights up to 350 kg, combined with a balancer, allowing for a total measured weight of up to 1400 kg with a

measurement error of up to 0.02%. The platform was tared and calibrated using a known mass of 100 kg.

Animal identification on the weighing platform was achieved using radio frequency tags, which have various applications in automating the recording of cattle data (Hutu et al 2009; Williams et al 2019).

An additional section was developed in the "herd management system to access the cattle weighing data." The software enables the display of information for each

weighing, including the scale's serial number, start time and duration of weighing, RFID ear tag number, number of data points per second, the average weight per weighing, and more (Figure 2).

Data from the database were uploaded and prepared for analysis using SQL queries (Itzik Ben-Gan 2016). Data visualization, analysis, and calculations were performed using the tools available in MS Excel (Hossain 2021).



Figure 1 Experimental weighing platform.

РЕЕСТРЫ		Разовое взвешивание						
<ul style="list-style-type: none"> Сотрудники Стада Группы животных Контрагенты ПОГОЛОВЬ КРС ЗООТЕХНИЧЕСКИЕ СОБЫТИЯ ОТЧЕТЫ ОБОРУДОВАНИЕ Smart-кормушки Smart-весы Взвешивание от весов Состояние smart-весов 		СЕРИЙНЫЙ НОМЕР ВЕСОВ	ВРЕМЯ	RFID НОМЕР	ЖИВОТНОЕ	КОЛИЧЕСТВО ДАННЫХ	СРЕДНЕЕ ЗНАЧЕНИЕ	
		pcf_model_6	15.09.2022 14:22:15-14:23:22 (67,714 секунд)	50103003bd94	KZT183804352 Ласточка, 0048 KA0859349	39	132.6	
[127.4, 119.4, 128.6, 126.6, 126.5, 125.8, 129.6, 127.7, 125.9, 128.4, 130.9, 133.2, 154.2, 148.1, 152.7, 162.9, 157.2, 150.4, 148, 145.9, 146.4, 148.4, 147.1, 137.2, 161.3, 144.2, 132, 120.6, 118.6, 114.2, 91.6]								
		pcf_model_6	15.09.2022 21:49:22-21:50:58 (95.406 секунд)	50103003bc95	KZT183797599 Килька, 0273 KA0859488	55	313.765454545454	
[283.6, 305.3, 303.9, 299.3, 297.2, 306.9, 306.9, 307.9, 300.9, 294.1, 300.5, 300.3, 301.2, 306, 301.3, 305.3, 324.7, 298.5, 298.7, 317.1, 304.3, 303.5, 324.9, 329.8, 329.1, 333.3, 324.9, 322.3, 322.3, 321.8, 321.4, 320.7, 321.9, 319.6, 320.5, 320.5, 319.9, 320.2, 321.5, 322.9, 323.6, 324, 325.6, 320.4, 320.3, 321, 324.8, 278.7]								

Figure 2 User interface of the developed software.

2.2. Cattle were involved in the experiment

The EWP was tested on a group of cattle in a pasture enclosed by an electric shepherd fence. The group consisted of 30 cows of the Kazakh white-headed breed (Nasambaev et al 2020), born in January 2020. At the time of testing, the cows' ages ranged from 30 to 31 months. The watering of animals on the pasture occurred 2-3 times a day, with the cows being brought from the pasture to the drinker. Other water sources were excluded due to the absence of reservoirs and the pasture's electric shepherd fencing. According to Kazakhstan's Information Base of Selection and breeding work (IBSBW), the cows were inseminated in August 2021, two months before the weighings. This circumstance aimed to minimize the significant effect of pregnancy on the animal's weight, as noted by other researchers (Semakula 2021). Calves of different ages were also present on the pasture but were excluded from the analysis due to their

presence on the platform with all four legs. In some cases, two calves were observed simultaneously on the platform.

2.3. Series of tests

The testing of the EWP and data collection were conducted in multiple stages, during which minor improvements were made to the platform's design. Cattle RFID numbers matched the cattle's national identification numbers (KZ-tags) used in Kazakhstan. Thirty different RFID numbers were matched with 30 animals using KZ-tags. Statistical data on the weighing results are presented in Table 1.

2.4. Mathematical methods

To analyze the data, autoregressive analysis (AR-) of time series, averaging methods (MA-) for moving averages, and linear approximation of data were employed to identify trends in the dynamics of animal weights (Shumway et al 2010).



Table 1 Quantity of initial data for tested platform versions.

Platform Version	Total weighings	RFID numbers	Animals found in IBSBW	Data points
pcf_model_10 (from 1 to November 5, 2022)	35	21	15	1248
pcf_model_5 (16 to September 24, 2022)	41	21	18	1787
pcf_model_6 (16 to September 24, 2022)	39	29	24	1530
pcf_model_7 (September 27 to October 5, 2022)	76	32	23	2608

Not all pasturing cows were found in the IBSBW.

3. Results

Studies confirmed that animals exhibited normal behavior after installing additional equipment for measuring water intake and body weight without significant stressful situations. All animals required a period of adaptation and habituation to the equipment, which took up to 3 days. After this adaptation period, cows consumed water 1-3 times daily. Monitoring the daily body weight (BW) dynamics allows for the timely prevention of livestock diseases, as a decrease in BW over several days raises concerns about the well-being of the animals on the pasture.

Conventional weighing methods involve restraining animals on mechanical scales, waiting for the balance to stabilize, and recording readings. The data processing for the experimental weight platform (EWP) follows the same principle, determining periods of stability on the scales and calculating the weight. Williams et al (2020) noted that the average drinking time for a cow is 45.8 ± 24 seconds. For this study, weighings lasting from 15 to 90 seconds were selected, as shorter weighings were deemed unreliable, and longer ones showed signs of mixed data from multiple animals. Therefore, 247 weighings with 15 to 90 seconds durations were chosen for further analysis (Figure 3).

The collected initial data, representing weight levels every second during animal weighing, were visually presented as line charts and analyzed to identify common patterns. This analysis allowed for the classification of weighings into several groups: "perfect," "normal," and "extreme." Mathematically, this can be defined as follows: Let S be the standard deviation in a section of the weighing graph, S_{max} be the maximum value of the standard deviation in the section considered "ideal," and N_{min} be the minimum length of a plot section to be considered flat.

"Perfect" weighings are characterized by a long-lasting flat section with relatively minor fluctuations ($S \leq S_{max}$) (Figure 4).

Interpretation: The animal stood on the platform with its front legs, drank water from the drinker, and left without unnecessary movements or scale oscillations. The rise at the beginning and fall at the end of the graph correspond to the moments when the animal entered and exited the EWP. The smooth section of the graph represents the time when the animal drank water.

"Normal" weighings are characterized by one or more flat sections ($S \leq S_{max}$) with a minimum duration (N_{min}) and possible large fluctuations in other sections of the graph where $S > S_{max}$ (Figure 5).

Interpretation: The animal drank water while occasionally changing its position, being disturbed by something, or being interfered with by another animal, leading to temporary fluctuations in the EWP.

"Extreme" weighings refer to weighings where no "perfect" sections were identified. In any section of the weighing graph with a length $\leq N_{min}$, fluctuations exceed S_{max} (Figure 6).

Interpretation: The animal continuously changed its position on the EWP, and reliable determination of the weight through "extreme" weighing is impossible due to the large variation in values ($S \gg S_{max}$).

Water consumption increases the recorded body weight (PBW) due to the mass of consumed water. According to Troy (2015), the average water requirement for cows weighing 450 kg is 36 liters per day at an ambient temperature not exceeding 5 °C. Thus, a cow can consume up to 25 liters of water when drinking twice daily. The drinking process lasts an average of half a minute, with an absorption rate of 18 to 25 liters of water per minute, equivalent to 0.3 - 0.41 liters per second. Therefore, an increase in BW of 350 g/sec is possible during drinking, corresponding to a rise in PBW of 200 g/sec. For further calculations, consider the drinking speed as $V_{drink} = 0.2$ kg/sec.

To select a significant section of the graph, the moment of drinking by a cow can be defined as a section of smooth weight growth on the scales with a minimum required duration of N_{min} and without significant fluctuations in values ($S < S_{min}$).

To eliminate the influence of drinking on the measured PBW, we transform the initial scale data using the following regression formula: $w_i^{\Delta} = w_i - D_s * i$, where w_i represents the value of the i -th level of the initial time series, and D_s is the rate of drinking water. The transformed raw data will visually appear as shown in Figure 7.

This transformation is applied during the search for the flattest section of the graph but not in the PBW calculation step. To find the flattest section of the graph, we calculate the standard deviation S_{ij} for all its subsections with a length greater than N_{min} and select the section with the



minor standard deviation (determining the indices of the initial and final levels).

The standard deviation is calculated using the well-known formula:

$$S = \sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2},$$

where: $\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i = \frac{1}{n} (x_1 + \dots + x_n)$

N_{min} is the integer part of the number of data points divided by 3. If $N_{min} > 10$, it is taken as 10. In the previous example (Figure 7), a section with W (9, 19) will be chosen.

When determining the weight based on the selected flat area, a linear approximation of the data is performed,

followed by calculating the value at the zero point. The change in the animal's mass during drinking can be expressed by the simple formula: $BW_t = BW_0 + D_s * t$, where BW_0 is the initial weight of the animal, D_s represents the drinking speed, and BW_t is the weight of the animal at time t . The values of BW_0 and D_s are determined using the least squares method (Altman et al 2015), which finds the linear dependence coefficients that minimize the function of two variables a and b : $F(a, b) = \sum_{i=1}^n (y_i - (ax_i + b))^2$. In this case, variable a corresponds to BW_0 , and variable b corresponds to V_{drink} .

The calculation result is shown in Table 2, presenting the average PBW of animals obtained through three methods: the average value (AV), the median value (MV), and the described experimental method (EM).

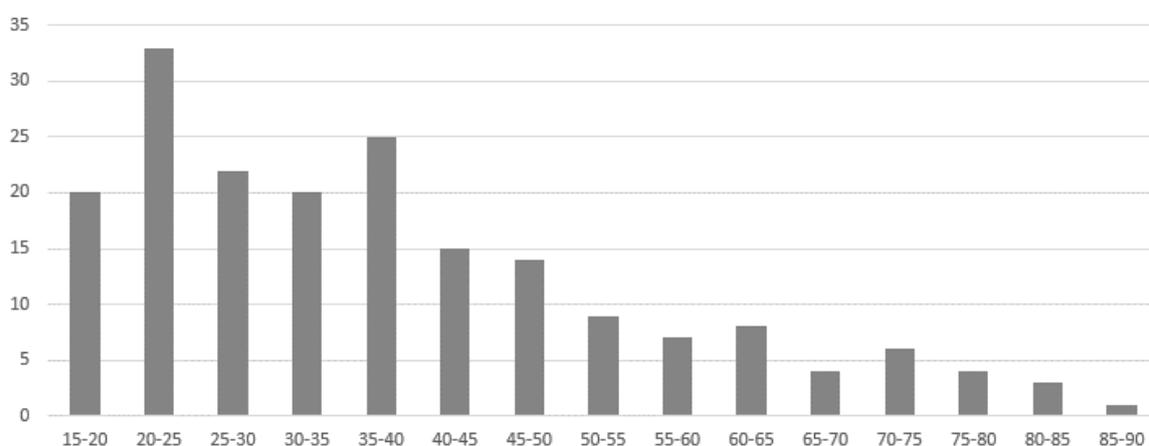


Figure 3 Distribution of weightings selected for analysis by duration (in seconds).

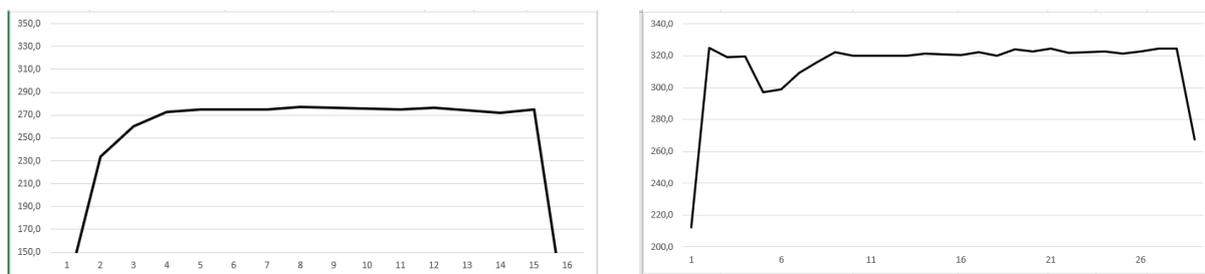


Figure 4 Examples of "Perfect" weightings.

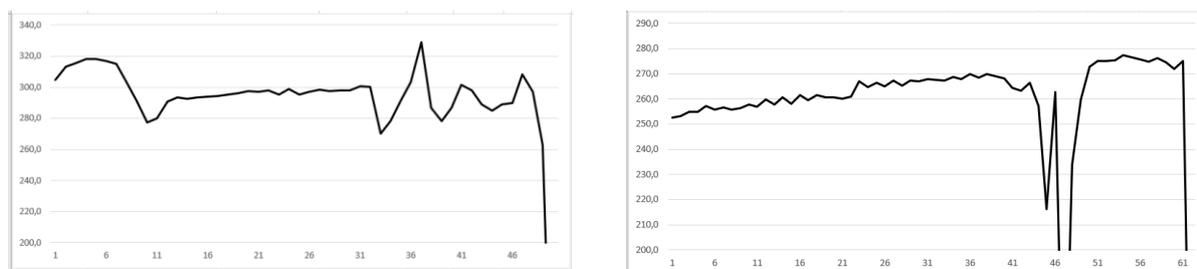


Figure 5 Examples of "Normal" weightings.

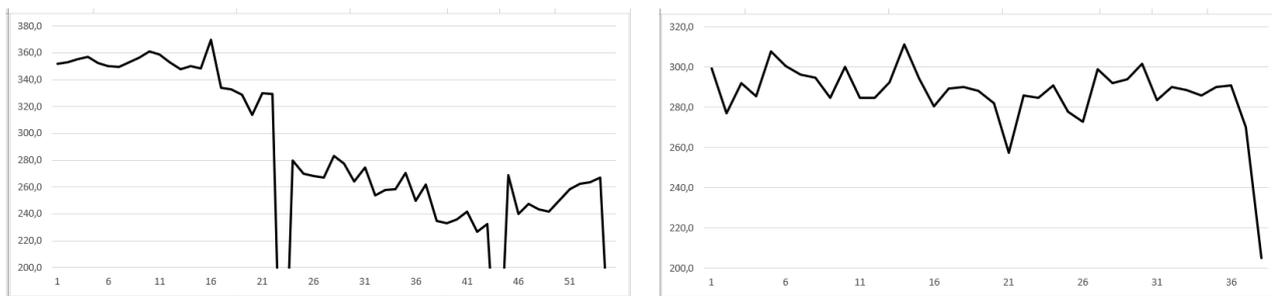


Figure 6 Examples of "Extreme" Weighings.

Table 2 Calculation results of average Partial Body Weight (PBW) using three methods.

Animal ID	Avg (AV)	Std (AV)	Avg (MV)	Std (MV)	Avg (EM)	Std (EM)
KZT183519744	307.45	±14.31	313.47	±11.34	319.23	±5.78
KZT183797599	297.08	±9.49	297.45	±9.55	295.43	±12.35
KZT183797602	253.36	±16.66	258.20	±8.77	259.46	±0.96
KZT183804074	310.12	±7.24	315.68	±6.44	316.29	±8.50
KZT183804103	295.21	±5.34	299.85	±4.03	298.97	±2.22
KZT183804108	258.45	±12.40	273.20	±2.55	274.55	±1.69
KZT183804120	301.32	±6.17	305.60	±5.48	306.43	±5.35
KZT183804127	238.40	±8.72	238.90	±8.82	237.05	±9.86
KZT183804147	292.90	±4.41	296.90	±0.28	299.02	±5.28
KZT183804172	244.34	±8.61	248.30	±9.55	248.24	±9.36
KZT183804182	303.97	±6.14	308.75	±4.31	311.03	±1.01
KZT183804214	295.85	-	298.90	-	301.89	-
KZT183804216	278.98	±5.16	287.85	±7.23	291.11	±6.86
KZT183804223	363.96	±7.86	366.50	±8.77	367.79	±7.67
KZT183804232	294.35	±15.08	301.55	±15.77	312.38	±0.16
KZT183804234	264.04	±32.58	298.80	±12.59	301.20	±10.02
KZT183804238	286.86	±9.31	289.20	±11.16	289.77	±9.53
KZT183804259	324.73	±9.84	326.80	±3.54	330.59	±0.09
KZT183804265	265.12	-	271.60	-	276.11	-
KZT183804273	315.73	±6.89	316.46	±6.84	318.04	±9.01
KZT183804301	299.36	±15.66	304.25	±16.76	306.47	±17.86
KZT183804317	262.58	±9.29	268.17	±5.14	270.89	±1.97
KZT183804324	300.88	±9.32	314.70	±1.56	321.90	±4.77
KZT183804327	306.28	-	309.30	-	309.85	-
KZT183804352	272.94	-	272.10	-	270.96	-
KZT183804353	261.81	±1.31	268.20	±1.13	268.08	±2.00
KZT183804356	297.12	±1.10	300.73	±3.12	304.17	±3.90
KZT183804358	312.37	±1.80	320.10	±5.80	317.78	±9.81

A comparison is made between the calculated data and the IBSBW (Information IBSBW) records. Calculations were performed using the mentioned methods, and the BW recorded in IBSBW was compared with the calculated weights obtained from the EWP.

The external characteristics of cattle change significantly from birth to maturity. The proportions between the front and back of the body, the position of the animal's center of gravity, and the weight distribution between the front and hind legs also change accordingly. The BW



conversion factor from PBW for a specific case can be obtained using the formula $K = BW / PBW$, where BW and PBW represent the known values of the total and partial weight of the animal on a specific date. The average conversion factor for different ages and breeds can be

determined as $K_a = \frac{\sum_{i=1}^n \frac{BW_i}{PBW_i}}{n}$. Calculating these coefficients for the Kazakh white-headed breed would require a lengthy experiment with a large amount of data. Since this calculation cannot be performed based on the available data volume, an average value of 1.7 was chosen. This assumption is

acceptable, considering that all animals in the experiment were of the same breed and age.

Comparing the calculated weight data with the IBSBW data shows a correlation, as shown in Figure 8.

In summary, a test was conducted on the developed experimental weight platform (EWP) for weighing animals using their front legs. An algorithm was developed to determine the weight based on the most stable section of weight readings taken every second. The experimental method demonstrated a higher correlation ($r = 0.925$) between the determined weight and the actual IBSBW data compared to the mean method ($r = 0.887$) or the median method ($r = 0.921$).

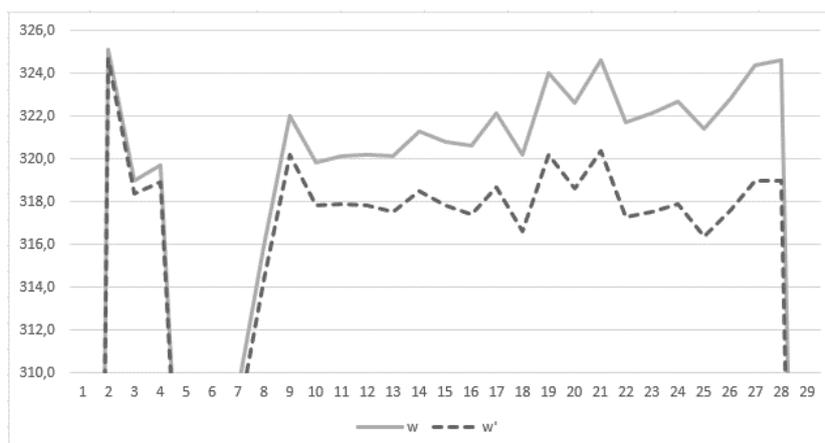


Figure 7 Example of data regression for animal drinking.

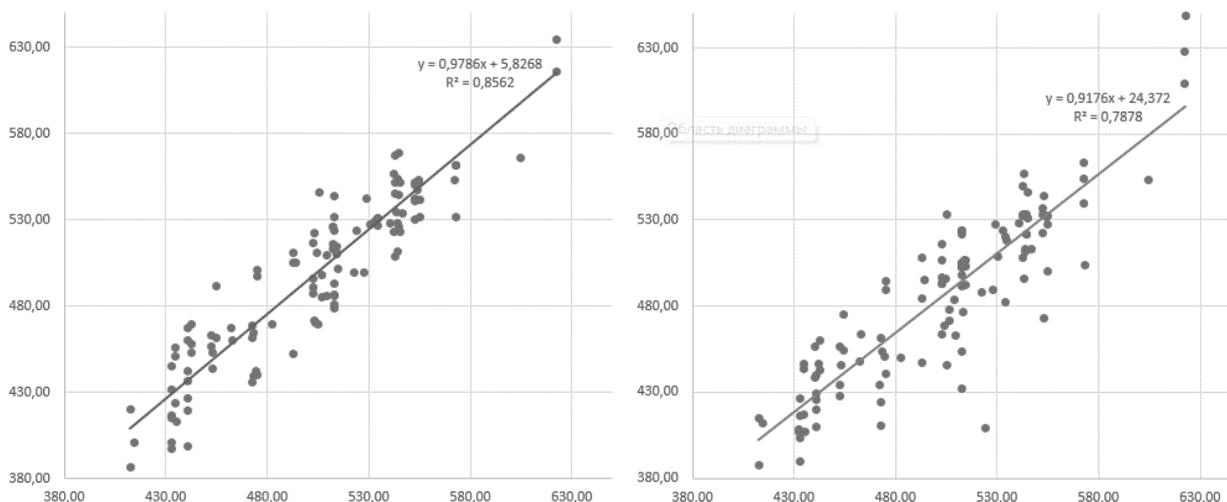


Figure 8 Correlation between calculated and measured animal weight: (a) Experimental Method (EM); (b) Calculation of Average Value (AV).

4. Discussion

The experimental method employed for determining the weight of an animal was found to be slightly more accurate than simply calculating the average value. This can be attributed to the significant variability in the body weight (BW) of cattle, which is influenced by various factors such as the time of weighing, ambient temperature, feed intake, and livestock handling (Watson et al 2013; Assatbayeva et al 2022). Daily weight fluctuations in Kazakh white-headed

breed cattle can reach up to 5% of the animal's weight, which, in the case of the considered livestock, can amount to ±25 kg. Additionally, since animals approach the drinker in an unknown state (empty or full, etc.), high accuracy in weight measurements cannot be expected unless the experiment is of sufficient duration. It is also important to consider individual genetic differences in animals, as they significantly contribute to the variability in animal weight, as noted by other researchers (Cho 2020).



Tracking the daily dynamics of animal body weight using the EWP would require more frequent weighing than the 2-3 times a day typically feasible in pasture studies. For instance, in other studies, animals were observed to drink as frequently as 9.2 ± 6.4 times a day, as mentioned by Benfield et al (2017), which would provide more data for calculating the weight of an animal. The developed equipment, software, and algorithms can be utilized in further research to automate weighing, monitor weight changes in livestock on pastures, and determine the developmental characteristics and behavior of animals in such environments.

Ethical considerations

Not applicable. We declare did not make invasive procedures or changes to normal animal keeping, feeding, etc. The cattle just kept living their usual grazing life during data collection.

Conflict of Interest

The authors declare no conflict of interest

Funding

The article was prepared as part of the scientific and technical program BR10865103, which focuses on developing and creating scientifically grounded Smart farms (herd horse breeding, beef cattle breeding) with the implementation of at least three digital solutions for each area of digitalization. The program aims to address the practical production challenges faced by agro-industrial complex entities and facilitate the formation of a comprehensive reference database to train employees of farms and peasant households and transfer digital knowledge to students in the learning process.

References

- Assatbayeva G, Issabekova S, Uskenov R, Karymsakov T, Abdrakhmanov T (2022) Influence of microclimate on ketosis, mastitis and diseases of cow reproductive organs. *Journal of Animal Behavior and Biometeorology* 10:1-6.
- Agency for strategic planning and reforms of the Republic of Kazakhstan bureau of National statistics (2022) Statistics of agriculture, forestry, hunting and fishing. <https://stat.gov.kz/official/industry/14/statistic/8>. Accessed on: April 5, 2023
- Altman N, Krzywinski M (2015) Points of Significance: Simple linear regression. *nature methods* 12:999-1000
- Alexy M, Haidegger T (2022) Precision Solutions in Livestock Farming - feasibility and applicability of digital data collection. doi: 10.1109/ICCC202255925.2022.9922883
- Benfield D, Garossino K, Sainz R, Kerley M, Huisma C (2017) 495 Conversion of high-frequency partial body weights to total body weight in feedlot cattle. *Journal of Animal Science*. doi: 10.2527/asasann.2017.495
- Charmley E, Gowan T (2006) Development of a remote method for the recording of cattle weights under field conditions. *Australian Journal of Experimental Agriculture*. doi: 10.1071/EA05314
- Cho H, Jeon S, Lee M, Kang K, Kang H, Park E, Kim M, Hong S, Seo S (2020) Analysis of the Factors Influencing Body Weight Variation in Hanwoo Steers Using an Automated Weighing System. *Animals*. doi: 10.3390/ani10081270
- FAO (2009) 2050: A third more mouths to feed. <https://www.fao.org/news/story/en/item/35571/icode>. Accessed on: April 2, 2023
- Hossain E (2021) MS Excel in Engineering Data. In: *Excel Crash Course for Engineers*, 1st edn. Springer Cham, 69-242. doi: 10.1007/978-3-030-71036-1_5.
- Hutu I, Ionescu F, Cimponeriu A, Chilintan M (2009) RFID technology used for identification and temperature monitoring of cattle. Conference: *Actualities in Animal Breeding and Pathology*. doi: 10.13140/RG.2.2.28941.90085
- Itzik BG (2016) *T-SQL Fundamentals (Developer Reference) 3rd Edition*. SolidQ, Washington.
- Macneil M, Berry D, Clark S, Crowley J, Scholtz M (2021) Evaluation of partial body weight for predicting body weight and average daily gain in growing beef cattle. *Translational Animal Science*. doi: 10.1093/tas/txab126
- Mirmanov Arman, Alimbayev A, Baiguanysh S, Nabiev N, Sharipov A, Kokholokov A, Caratelli D (2021) Development of an IoT Platform for Stress-Free Monitoring of Cattle Productivity in Precision Animal Husbandry. *Advances in Science, Technology and Engineering Systems Journal*. doi: 10.25046/aj060155
- Nasambaev E, Nugmanova AE, Tolep T (2020) Growth and development of young Kazakh white-headed breed of different genotypes. *Science Bulletin* 6:249-263.
- Semakula J, Corner-Thomas R, Morris S, Blair H, Kenyon P (2021) The Effect of Herbage Availability, Pregnancy Stage and Rank on the Rate of Liveweight Loss during Fasting in Ewes. *Agriculture* 11:543. doi: 10.3390/agriculture11060543
- Shumway RH, Stoffer D (2010) *Time series analysis and its applications: with R examples*, 3rd edn. Springer.
- Troy MW (2015) *Water Requirements for Beef Cattle*. <https://beef.unl.edu/water-requirements-for-beef-cattle>. Accessed on: April 15, 2023
- Watson A, Nuttelman B, Lomas L (2013) Impacts of a Limit-Feeding Procedure on Variation and Accuracy of Cattle Weights. *Journal of Animal Science*. doi: 10.2527/jas.2013-6349
- Williams L, Fox D, Bishop-Hurley GJ, Swain D (2019) Use of radio frequency identification (RFID) technology to record grazing beef cattle water point use. *Computers and Electronics in Agriculture*. doi: 10.1016/j.compag.2018.11.025
- Williams L, Moore S, Bishop-Hurley G, Swain D (2020) A sensor-based solution to monitor grazing cattle drinking behavior and water intake. *Computers and Electronics in Agriculture*. doi: 10.1016/j.compag.2019.105141