





Original Article

# Effectiveness of the use of the Vytelle system in evaluating bulls in Kazakhstan

## Eficácia da utilização do sistema Vytelle na avaliação de touros no Cazaquistão

N. Kazhgaliyev<sup>a</sup> , S. Issabekova<sup>a\*</sup> , K. Shaikenova<sup>a</sup> , D. Senkebayeva<sup>a</sup> , K. Omarova<sup>a</sup>  and A. Makhanbetova<sup>a</sup> 

<sup>a</sup>S. Seifullin Kazakh Agrotechnical University, Department of Technologies of Production and Processing of Livestock Products, Astana, Kazakhstan

### Abstract

This article presents the results of the introduction of Canadian digital technologies Vytelle GrowSafe in the beef cattle breeding of Kazakhstan to assess Residual Feed Intake (RFI). The experiments were carried out with Qazaq Aqbas Breed in the Privet Farms of North Kazakhstan (Akmola and Pavlodar farms). As part of the ration in Akmola farm for a bull of 350 kg of weight, are contained 77 MJ or 7.6 kg of DM, in Pavlodar farm for a bull weighing 290 kg contains 65 MJ or 6.5 kg of DM. Studies have shown that in the Akmola farm the RFI index ranged from -2.08 to +2.88, in the Pavlodar farm from -1.89 to +2.06. According to the results of research in the Akmola farm, the RFI assessment show, 7 out of 26 bulls are suitable for breeding sale, in the Pavlodar farm out of 55 bulls 18. The assessment of the productive effect of feed on RFI, mainly (by 80%), coincided with the assessment of the ratio of gain to consumed dry matter, and some bulls showed deviations in terms of residual average daily live weight gain and the corrected value of the ratio of feed costs to live weight gain, which led to incomplete manifestation of the productive potential of the consumed feed.

**Keywords:** beef cattle breeding, Qazaq Aqbas breed, residual feed intake, Vytelle, GrowSafe, weight, welfare.

### Resumo

Este artigo apresenta os resultados da introdução das Tecnologias Digitais Canadianas Vytelle GrowSafe na criação de bovinos de corte no Cazaquistão para avaliar a ingestão residual de alimentos (RFI). Os experimentos foram realizados com a raça Qazaq Aqbas nas fazendas de alfeneiros Akmola e Pavlodar, no Norte do Cazaquistão. Na fazenda Akmola, a ração para um touro de 350 kg contém 77 MJ ou 7,6 kg de DM, já na fazenda Pavlodar, para um touro pesando 290 kg, a ração contém 65 MJ ou 6,5 kg de DM. Estudos demonstraram que o índice RFI variou de -2,08 a +2,88 e de -1,89 a +2,06 na exploração agrícola de Akmola e Pavlodar, respectivamente. De acordo com os resultados da pesquisa na fazenda Akmola, a avaliação da RFI mostra que 7 entre 26 touros são adequados para venda de reprodução, enquanto na fazenda Pavlodar são 18 touros entre 55. A avaliação do efeito produtivo dos alimentos para animais na RFI, principalmente (em 80%), coincidiu com a avaliação do rácio de ganho em relação à matéria seca consumida. Alguns touros apresentaram desvios em termos de ganho de peso vivo diário médio residual e do valor corrigido do rácio entre os custos dos alimentos para animais e o ganho de peso vivo, o que levou a uma manifestação incompleta do potencial produtivo dos alimentos consumidos.

**Palavras-chave:** criação de bovinos de corte, raça Qazaq Aqbas, ingestão residual de alimentos, Vytelle, GrowSafe, peso, bem-estar.

## 1. Introduction

The basis of any animal breeding is selection and selection, which is preceded by the collection of reliable information about the productive indicators of animals. With individual and daily collection of information, based on special software, cloud technologies, digital animal identification, etc. the quality of the processed data is much higher (the human factor is minimized). Selection for a moderately inherited trait of residual feed intake (RFI) is a more effective method of breeding livestock for feed productivity than selection for feed costs per unit of live

weight gain, which allows, with consistent introduction into the practice of fattening livestock, to increase the productive effect of feed and increase the profitability of the industry. RFI is increasingly used to analyze feed efficiency in animal husbandry, and in beef cattle it is one of the most commonly used traits (Aalhus et al., 2014; Tultabayeva et al, 2023).

Improving feed efficiency in cattle is a major challenge in beef production systems, as efficient feed conversion by animals can reduce feed costs and increase the productivity

\*e-mail: nurlybay.kazhgaliyev@bk.ru

Received: August 7, 2023 – Accepted: September 11, 2023



This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

of beef cattle. RFI can be a tool to measure the effectiveness of animal feed, and the choice for efficient or low RFI in cattle has been proposed in some studies by foreign scientists (Ahola et al., 2011; Alberta, 2018; Koch et al., 1963; Tokysheva et al., 2022).

Available research information indicates that RFI is a moderately inherited trait, selection with a low RFI will result in offspring that consume less feed at the same level of productivity as offspring of cattle with a high RFI (Baker et al., 2006).

Vytelle GrowSafe Continuous Weight Monitoring and Feeding Technology allows you to accurately identify cattle with high or low RFI values in less time than traditional RFI testing, as collecting several separate weight measurements will allow you to generate more accurate weight gain charts in a shorter time. This will not only improve the accuracy of average daily weight gain calculations, but also shorten the overall testing period, allowing the farmer to run more tests per year. Since 1990, Vytelle GrowSafe technology has been laying the foundation for all farm efficiency by reducing feed consumption, greenhouse gas emissions, manure and the entire environmental impact of meat production. The database currently has data on 140,000 animals of 24 breeds and over 32,000 RFI phenotypes.

The calculation of RFI requires the simultaneous measurement of both feed intake and animal weight gain. RFI is a measure of feed productivity, measured as the difference between an animal's actual feed intake and its expected feed intake for a given level of production (Berry and Crowley, 2012). Differences in RFI are often explained by differences in animal welfare requirements. Cattle with a low RFI value are considered to be highly productive, and animals with high RFI values are considered to be low productive (Arthur et al., 2001; Crews Junior et al., 2003). The impact of this genetic application on the quality characteristics of the carcass will only be successful if it does not adversely affect the final meat product (Berry and Crowley, 2012; Arthur et al., 2001; Schenkel et al., 2004).

Goal of the Research. Creation of integrated systems in beef cattle breeding based on the applied digital technologies of the system for individual accounting of feed intake and individual stress-free weighing of animals Vytelle GrowSafe.

Novelty. For the first time, comprehensive studies were carried out to assess the young growth of the Qazaq Aqbas Breed, their conditions of keeping and feeding, meat productivity and breeding qualities with Canadian Vytelle GrowSafe technology.

## 2. Material and Methods

Scientific and economic experiments on the introduction of digital technologies for testing bulls of the Qazaq Aqbas Breed for their own productivity using Vytelle in 2021-2022. Studies to identify the ability of the animal organism to more fully realize the potential productive effect of feed were carried out on the platform of the integrated system Vytelle at the feedlot Akmola region and Pavlodar region. Research consisted of two periods, the adaptation period was 10-14 days, and the study itself was 49 days.

The capacity of the platform in each farms is 64 heads for eight feeders. We studied the Canadian digital technology using the system of individual evaluation of feed intake and individual stress-free weighing of animals. Two farms are engaged in the raising and fattening of cattle of the Qazaq Aqbas Breed.

The farm feeds are harvested on their own, they were sent to an accredited laboratory for chemical analysis (Seifullin University Feed Analysis Laboratory). Feeding is carried out with TMR. The composition of the feed and the nutritional value of the ration in two farms is shown in the Table 1 below.

In connection with the above material, the use of the Vytelle system in assessing the productivity of meat animals using the RFI method to increase meat production, especially beef, is one of the most pressing problems in the field of animal husbandry.

Feed for analysis was given in order to adjust the rations. After analyzing the feed, farmers and consultants determined that there was overfeeding of the animals. The main feeds on experimental farms are corn silage, compound feed and farmers include premixes in their ration. Initially, feeding was carried out 3 times a day, but since there was a lot of food left, Canadian experts recommended giving food twice a day. In the morning 70% of the ration and in the evening 30%. As can be seen from the table, from the difference in the nutritional value of the rations of different regions, the amount of components of the rations is almost the same. In the Akmola farm, the feed is more nutritious and at the rate of ME per bull with a live weight of 350 kg, 77 MJ is required, the farm gave them 21.3 kg of TMR it will be 7.6 kg of DM. In the Pavlodar farm, the weight of bulls is almost 60 kg less, but at the same time, from a lower quality of feed, they give more feed at a rate of ME 65 MJ, is obtained about 22 kg TMR or 6.5 kg DM. It can be concluded that the ration is highly nutritious and balanced in terms of the content of especially important components, most crucial, the conditional humidity is achieved, which ensures high quality of feed.

**Table 1.** The composition of the feed and the nutritional value of the ration.

Feed	Farms	
	Akmola	Pavlodar
Corn silage, kg	19	19
Compound feed, kg	2.3	2.6
Premix, g	100	100
Ration contain, %		
DM	35.9	30.2
XP	20.0	19.3
XL	2.3	2.2
XF	30.42	30.07
Ash	5.30	5.68
Ca	0.68	0.69
P	0.27	0.31

The number of bulls of the Qazaq Aqbas Breed, tested for their own productivity using the Vytelle system are shown in Table 2.

The condition for conducting an RFI study is that 50% of the animals must have a negative RFI and 50% a positive RFI, so the difference between the number of bulls at the beginning and end of the experiment is different. Animals that did not meet the requirements were discarded in the initial period of the experiment. As can be seen from the table in the Akmola farm, 30 heads were selected at the beginning, by the end of the experiment 26 remained. In the Pavlodar farm, 9 heads were removed from the group and at the end of the experiment it was 55 out of 64. Evaluation of bulls in two farms is carried out in different age of animals, in Akmola farm at the age of 11-12 months, and in Pavlodar farm 8-9.

The weight of the bulls was recorded by a non-contact electronic RFID of the scales in the In-pen Weighing System. Evaluation for feed eaten was carried out by daily weighing of the given feeds, gain and RFI. During the evaluation period, the following were controlled (Glossary of Terms):

Start Wt.: Trial start weight with start date

End Wt.: Trial end weight with end date

ADG: average daily gain

DMI: dry matter intake, an animal's average daily dry matter intake during test.

Raw F:G: feed to gain ratio, also referred to as feed conversion ratio (FCR). F:G ratio refers to the amount of feed consumed per unit of weight gain on a dry matter basis.

Adj. F:G: adjusted feed to gain ratio, accounts for differences in animal age and size during test.

RFI: is a measure of feed efficiency calculated as the difference between an animal's actual feed intake and its predicted feed intake, for a given level of production.

RFI Rank: an animal's numerical rank of its phenotypic RFI within the trial group.

RADG: residual average daily gain, the difference between an animal's actual weight gain and its predicted gain based on its dry matter intake, body weight maintenance and fat cover.

RADG Rank: an animal's numerical rank of its phenotypic RADG within the trial group.

The weight of the bulls was recorded by a non-contact electronic RFID of the scales in the In-pen Weighing System. Evaluation for feed eaten was carried out by daily weighing of the given feeds, gain and RFI. Statistical analysis was carried out using SPSS 20.0 for Windows.

### 3. Results and Discussion

#### 3.1. Akmola farm

At the beginning of the study, there were 30 bulls with an average age of 11-12 months on the Akmola farm, which is typically when the farm owner performs evaluations on the bulls. The data capture system was used to evaluate the bulls, however, the system disregarded animals that did not meet the requirements for measurement, such as eating and drinking frequency, activity, etc. By the end of the evaluation period, 26 bulls were included in the RFI assessment, with 4 bulls excluded from consideration.

Comparative indicators for evaluating the own productivity of bulls in Akmola farm are shown in Table 3.

The average weight of bulls at the beginning of the trail was  $358.27 \pm 9.54$  kg, the deviation from the average was 47.69 kg. Gross growth of bulls for 49 days of the experiment was 48.32 kg, thus their weight at the end of the trail was  $406.59 \pm 11.38$  kg. ADG in the group ranged from 1.72 kg to 0.14 kg, and averaged  $0.93 \pm 0.07$  kg. DMI during the trail period was at the level of  $9.39 \pm 0.30$  kg, if in terms of one kg of gain, then this indicator will be 10.1 kg DMI. Raw F:G in group was  $13.06 \pm 2.05$ , ranging from 5.59 to 53.82, strong fluctuation is negative for bull, a lower value is desirable. At the same time Adj. F:G adjusted for weight and age was also in such values -  $13.55 \pm 2.38$ . When RFI is used as a genetic selection tool, the resulting progeny will consume less feed for the same level of production. RFI is independent of growth, body

**Table 2.** Number of bulls for testing using the Vytelle system.

Farms	Age, month	Number of bulls	
		Beginning	End
Akmola	11-12	30	26
Pavlodar	8-9	64	55

**Table 3.** Comparative indicators for evaluating the own productivity of bulls in Akmola farm.

Indicators	$X \pm m_x$	$\delta$	min	max
StartWt, kg	$358.27 \pm 9.54$	47.69	279.41	459.12
EndWt, kg	$406.59 \pm 11.38$	59.60	302.08	534.61
ADG, kg	$0.93 \pm 0.07$	0.36	0.14	1.72
DMI, kg	$9.39 \pm 0.30$	1.51	6.78	12.01
Raw F:G	$13.06 \pm 2.05$	10.23	5.59	53.82
Adj. F:G	$1355 \pm 2.38$	11.88	5.76	58.92
RFI	$0.00 \pm 0.22$	1.08	-2.08	+2.88
RADG	$0.00 \pm 0.06$	0.30	-0.58	0.66

size and other performance traits, selection for animals with low RFI will lead to reduced feed intake and improved feed efficiency without compromising body size, carcass quality or growth. Lower RFI values are more favorable, cattle with low RFI values are more efficient than cattle with high RFI values. The maximum RFI value in this farm was +2.88 and the minimum was -2.08. RADG relatively had the same deviations from the mean -0.58...0.66. The RFI Ranking and RADG Ranking indicators had the same values and amounted to 13.5 ± 1.5.

The system gave us a chart showing which animals had Favourable RFI - Above ADG. The RFI and ADG Distribution in Akmola Farm shown in the following Figure 1 shows in which segment of the diagram this or that animal was located.

According to this chart, out of 26 animals, only 7 animals with the RFI assessment are suitable for breeding sale (i.e., are in the Faivourable RFI - Above ADG segment). In other words, they have an effective RFI with a high ADG. At the same time, 2 bulls are in a borderline state, and the farmer was asked to decide whether bulls with such heredity are needed for the future herd. For 19 of the 26 bulls that did not fall into the effective RFI segment, a conclusion was given as unsuitable for breeding sale, such animals should be sold to farms that this level of Faivourable RFI would be acceptable.

### 3.2. Pavlodar farm

In a Pavlodar farm, the owner conducts an assessment at an early age, as he himself leads the fattening of animals not suitable for breeding. For scientific experience, it was interesting what level of RFI for younger animals of the Qazaq Aqbas Breed. Figure 2 shows experienced bulls in a Pavlodar farm.

The Pavlodar Farm conducts an early-age assessment of its animals, with a focus on fattening those that are not suitable for breeding. Initially, 64 bulls were eligible for RFI evaluation in the feedlot, however, following the application of the system for automatic culling, 55 animals remained for the duration of the experiment.

Table 4 presents the comparative indicators for evaluating the productivity of the bulls in the Pavlodar Farm.

The bulls were 8-9 months of age, with a live weight of 283.76 ± 4.85 kg at the beginning of the trial. The gross

gain was 36.5 kg and the live weight was 320.22 ± 5.22 kg by the end of the trial. The ADG was recorded at 0.61 ± 0.03 kg, with fluctuations ranging from 0.14 to 0.96 kg. The DMI was dependent on the dry matter content in the ration and, on average, was 7.36 ± 0.12 kg during the trial period. Interestingly, some animals required 10.06 kg of feed per 1 kg of gain, while others required only half of that or 5.41 kg. A low Raw F: G ratio is desirable and considering the limits of 56.59 to 7.3 at 14.49 ± 1.16, the level of this indicator on this farm was considered good. The Adjusted F: G ratio was also acceptable at 14.52 ± 1.07, with limits ranging from 6.79 to 46.65.

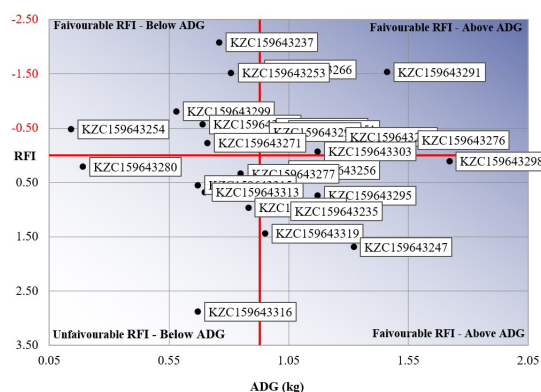


Figure 1. RFI and ADG Distribution in Akmola Farm.



Figure 2. Experienced bulls in Pavlodar farm.

Table 4. Comparative indicators for evaluating the own productivity of bulls in Pavlodar farm.

Indicators	X ± m <sub>x</sub>	δ	min	max
StartWt, kg	283.76 ± 4.85	35.62	223.15	394.33
EndWt, kg	320.22 ± 5.22	38.40	244.15	404.24
ADG, kg	0.61 ± 0.03	0.20	0.14	0.96
DMI	7.36 ± 0.12	0.89	5.41	10.06
Raw F:G	14.49 ± 1.16	8.51	7.3	56.59
Adj. F:G	14.52 ± 1.07	7.87	6.79	46.65
RFI	0.00 ± 0.11	0.79	-1.89	+2.06
RADG	0.00 ± 0.03	0.20	-0.57	+0.34

The RFI limits in the Pavlodar Farm were between -1.89 and +2.06, while the RADG limits ranged from -0.57 to +0.34. Although RADG and RFI contain similar components, the two concepts are different in their operation. RADG evaluates the differences in average daily gain by putting each animal's feed intake on the same playing field, while RFI evaluates the differences in feed intake by putting each animal's growth and body size on the same playing field. Cattle with higher RADG values are considered more desirable, as they demonstrate greater ADG for the same amount of feed. However, caution should be taken when evaluating RADG as it is dependent on body size and may not accurately reflect mature cow size. RFI and ADG Distribution in Pavlodar Farm shown in Figure 3.

The distribution of RFI and ADG in the Pavlodar Farm is depicted in Figure 3. From the diagram, 18 of the 55 bulls were found to be in the Favorable RFI - Above ADG segment, and these animals will be retained to improve the herd. Nine bulls were in the Favorable RFI - Below ADG segment, with one of them being in a borderline state near the Favorable RFI - Above ADG segment. The remaining 28 bulls were in lower segments and will be used for fattening purposes.

Numerous studies have been conducted by various scientists in different time frames and locations. According to the research of scientists Arthur P.F., Crews D.H., and Schenkel F. S., Residual Feed Intake (RFI) has been found to possess moderate heritability, with a range from 26% to 58% (Schenkel et al., 2004; Fox et al., 2001; Mao et al., 2013). Utilizing RFI as a genetic selection tool can result in offspring that consume less feed at the same level of production. Additionally, since RFI is independent of height, body size, and other traits (Kelly, 2015; Kenny et al., 2018; Foroutan et al., 2021), the selection of animals with low RFI will result in reduced feed intake without affecting body size, skeletal quality, or growth. The study (Culbertson et al., 2015) found no interaction between RFI and sex for growth characteristics and carcass traits, indicating that sex may not significantly impact these phenotypes in beef cattle with high RFI. However, it is important to acknowledge that this result should not be relied upon as a definitive biomarker of efficient beef cattle.

As feed efficiency is a complex multifactorial characteristic of beef cattle, RFI has become a commonly preferred metric for measuring this trait. Defined as the

difference between an animal's actual and predicted feed intake (based on weight and height), RFI is independent of height and body size. Furthermore, incorporating other energy expenditure-related characteristics, such as carcass composition estimates, into the RFI calculation further ensures independence from these traits.

The differences in feed efficiency between animals are due to the interaction of several biological processes that are influenced by the physiological status and mode of management. Approximately 70% of the cost of beef production is associated with diet. Hence, maximizing production efficiency requires not only genetic selection for maximum feed efficiency but also optimal nutrition at all stages of growth and development, including pregnancy, to ensure maximum growth efficiency and reproductive performance.

At present, the growing interest in the RFI methodology, particularly regarding measurement periods and the capability to assess the significance of various biological components of overall feed efficiency, is likely to drive the adoption of the RFI method in precision animal husbandry, including beef cattle, in Kazakhstan. This will allow for short- and long-term performance assessments in terms of sustainable performance objectives, which can be incorporated into future selection and management strategies in the livestock industry in Kazakhstan.

#### 4. Conclusions

In this study, the Vytelle digital technology system for individual evaluation of feed intake and stress-free weighing was introduced for the first time in two basic farms in Kazakhstan. The RFI index was also introduced for the first time. The Vytelle system allowed for a more accurate and faster determination of RFI values than traditional methods, as it generated weight gain charts based on continuous weight monitoring and feeding technology. The results of the study showed that the weight of 11-12-month-old bulls in the Akmol farm increased from  $358.27 \pm 9.54$  kg to  $406.59 \pm 11.38$  kg, with an average daily gain of  $0.93 \pm 0.07$  kg. It was determined that 1 kg of weight was gained using  $9.39 \pm 0.30$  kg of DM feed. RFI values ranged from -2.08 to +2.88. Out of the 26 evaluated bulls, 7 were selected for breeding use. The weight of 8-9 month-old bulls in the Pavlodar farm increased from  $283.76 \pm 4.85$  kg to  $320.22 \pm 5.22$  kg, with an average daily gain of  $0.61 \pm 0.03$  kg. It was determined that 1 kg of weight was gained using  $7.36 \pm 0.12$  kg of DM feed. RFI values ranged from -1.89 to +2.06. Out of the 55 evaluated bulls, 18 were selected for breeding use. The Vytelle system allows for timely adjustment of rations and full utilization of animal genetic potential. It also eliminates errors associated with the human factor by providing reliable data 24/7, thus improving the quality of animal growth and development.

#### Acknowledgements

The authors of this study would like to thank the owners and employees of the two farms in Kazakhstan,

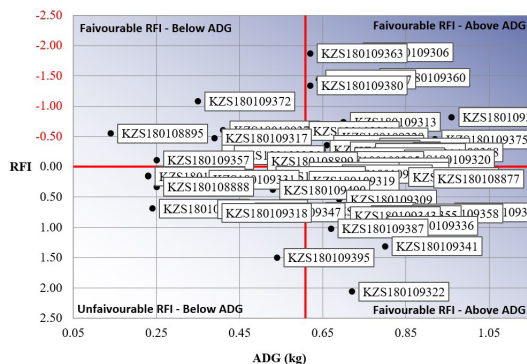


Figure 3. RFI and ADG Distribution in Pavlodar Farm.

where these studies were conducted. The research results presented in this paper were conducted under the program funded by the Ministry of Agriculture of the Kazakhstan Republic. Program Number: BR10865103.

## References

- AALHUS, J.L., LÓPEZ-CAMPOS, Ó., PRIETO, N., RODAS-GONZÁLEZ, A., DUGAN, M.E., UTTARO, B. and JUÁREZ, M., 2014. Review: canadian beef grading-opportunities to identify carcass and meat quality traits valued by consumers. *Canadian Journal of Animal Science*, vol. 94, no. 4, pp. 545-556. <http://dx.doi.org/10.4141/cjas-2014-038>.
- AHOLA, J., SKOW, T., HUNT, C. and HILL, R., 2011. Relationship between RFI and end product palatability in longissimus steaks from steers sired by angus bulls divergent for intramuscular fat expected progeny difference. *The Professional Animal Scientist*, vol. 27, no. 2, pp. 109-115. [http://dx.doi.org/10.15232/S1080-7446\(15\)30456-3](http://dx.doi.org/10.15232/S1080-7446(15)30456-3).
- ALBERTA, 2018 [viewed 9 October 2018]. *Agri-facts, and the practical information for Alberta's agriculture industry* [online]. Available from: <https://open.alberta.ca/dataset/91a77dec-f0a4-49c2-8c54-f172fe568e2c/resource/721e982c-b90f-4605-9de0-a3b8bb312b1f/download/2006-420-11-1.pdf>
- ARTHUR, P.F., ARCHER, J.A., JOHNSTON, D.J., HERD, R.M., RICHARDSON, E.C. and PARNELL, P.F., 2001. Genetic and phenotypic variance and covariance components for feed intake, feed efficiency, and other postweaning traits in Angus cattle. *Journal of Animal Science*, vol. 79, no. 11, pp. 2805-2811. <http://dx.doi.org/10.2527/2001.79112805x>. PMID:11768108.
- BAKER, S.D., SZASZ, J., KLEIN, T., KUBER, P., HUNT, C., GLAZE JUNIOR, J., FALK, D., RICHARD, R., MILLER, J., BATTAGLIA, R. and HILL, R.A., 2006. RFI of purebred angus steers: effects on meat quality and palatability. *Journal of Animal Science*, vol. 84, no. 4, pp. 938-945. <http://dx.doi.org/10.2527/2006.844938x>. PMID:16543572.
- BERRY, D.P. and CROWLEY, J., 2012. Residual intake and RFI weight gain: a new measure of efficiency in growing cattle. *Journal of Animal Science*, vol. 90, no. 1, pp. 109-115. <http://dx.doi.org/10.2527/jas.2011-4245>. PMID:21890504.
- CREWS JUNIOR, D.H., SHANNON, N.H., GENSWEIN, B.M.A., CREWS, R.E., JOHNSON, C.M. and KENDRICK, B.A., 2003. Genetic parameters for net feed efficiency of beef cattle measured during postweaning growing versus finishing periods. *Proceedings, Western Section, American Society of Animal Science*, vol. 54, pp. 125-128.
- CULBERTSON, M.M., SPEIDEL, S.E., PEEL, R.K., COCKRUM, R.R., THOMAS, M.G. and ENNS, R.M., 2015. Optimum measurement period for evaluating feed intake traits in beef cattle. *Journal of Animal Science*, vol. 93, no. 5, pp. 2482-2487. <http://dx.doi.org/10.2527/jas.2014-8364>. PMID:26020343.
- FOROUTAN, A., WISHART, D.S. and FITZSIMMONS, C., 2021. Exploring biological impacts of prenatal nutrition and selection for RFI on beef cattle using omics technologies: a review. *Frontiers in Genetics*, vol. 12, pp. 720268. <http://dx.doi.org/10.3389/fgene.2021.720268>. PMID:34790219.
- FOX, D.G., TEDESCHI, L.O. and GUIROY, P.J., 2001. Determining feed intake and feed efficiency of individual cattle fed in groups. In: *Beef Improvement Federation Meet Proceedings*, 2001, San Antonio, Texas. Manhattan: BIF, pp. 80-98.
- KELLY, J.E., 2015. *Impact of RFI classification and management regimen on feedlot growth performance, carcass traits, and meat quality in beef cattle*. Guelph: University of Guelph, 169 p. Master's thesis in Animal and Poultry Science.
- KENNY, D.A., FITZSIMONS, C., WATERS, S.M. and MCGEE, M., 2018. Invited review: Improving feed efficiency of beef cattle: the current state of the art and future challenges. *Animal*, vol. 12, no. 9, pp. 1815-1826. <http://dx.doi.org/10.1017/S1751731118000976>.
- KOCH, R.M., SWIGER, L.A., CHAMBERS, D. and GREGORY, K.E., 1963. Efficiency of feed use in beef cattle. *Journal of Animal Science*, vol. 22, no. 2, pp. 484-494. <http://dx.doi.org/10.2527/jas1963.222486x>.
- MAO, F., CHEN, L., VINSKY, M., OKINE, E., WANG, Z., BASARAB, J., CREWS, D. Jr. and LI, C., 2013. Phenotypic and genetic relationships of feed efficiency with growth performance, ultrasound, and carcass merit traits in angus and charolais steers. *Journal of Animal Science*, vol. 91, no. 5, pp. 2067-2076. <http://dx.doi.org/10.2527/jas.2012-5470>. PMID:23463551.
- SCHENKEL, F.S., MILLER, S.P. and WILTON, J.W., 2004. Genetic parameters and breed differences for feed efficiency, growth, and RFI composition traits of young beef bulls. *Canadian Journal of Animal Science*, vol. 84, no. 2, pp. 177-184. <http://dx.doi.org/10.4141/A03-085>.
- TOKYSHEVA, G., MAKANGALI, K., UZAKOV, Y., KAKIMOV, M., VOSTRIKOVA, N., BAIYSBAYEVA, M. and MASHANOVA, N., 2022. The potential of goat meat as a nutrition source for schoolchildren. *Potravinarstvo Slovak Journal of Food Sciences*, vol. 16, pp. 398-410. <http://dx.doi.org/10.5219/1763>.
- TULTABAYEVA, T., TOKYSHEVA, G., ZHAKUPOVA, G., KONYSBAYEVA, D., MUKHTARKHANOVA, R., MATIBAYEVA, A., MUKHAMETOV, A., ZAMARATSKAIA, G. and MAKANGALI, K., 2023. Enhancing nutrition and palatability: the development of cooked sausages with protein hydrolysate from secondary raw materials for the elderly. *Applied Sciences*, vol. 13, no. 18, pp. 10462. <http://dx.doi.org/10.3390/app131810462>.