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Author's Affiliation:
1. M. Kozybayev North Kazakhstan University – Kazakhstan
2. North Kazakhstan Research Institute of Agriculture – Kazakhstan
3. Innovative Eurasian University – Kazakhstan
4. S. Seifullin Kazakh Agro Technical Research University – Kazakhstan
5. Omsk State Agrarian University Named by P.A. Stolypin, Omsk – Russian Federation

***Corresponding Author:**
R.A. Zhaksalykov
Email: r.zhaksalykov@mail.ru

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Veterinary and sanitary assessment of milk quality in black-and-white cows fed with extruded compound feeds in North Kazakhstan

R.A. Zhaksalykov[1], K.N. Bayazitova[1], A.I. Polyak[2], L.N. Kassymbekova[3], R. Mustafina[4], M.V. Zabolotnykh[5]

Abstract

Background: Today, one of the most effective ways to increase the digestibility of nutrients is extrusion processing. Raw materials are exposed to high temperatures and pressure, which leads to qualitative and nutritional transformations. The study aims to identify the effect of extruded compound feeds on cow productivity and the qualitative composition of milk.

Methods: Based on the chemical analysis of milk, the following indicators were studied: fat mass fraction, protein mass fraction, casein, lactose, dry matter, skimmed milk residue, urea, density, titrated acidity, active acidity, and somatic cells. An organoleptic evaluation of milk was carried out according to the following indicators: color, smell, taste, appearance, and consistency. Once a month, a control milking was carried out to account for productivity.

Results: The EG's raw milk had higher casein and lactose content compared to the CG, with EG II showing the highest levels. Additionally, milk from the EG contained more solids, indicating better nutritional and technological properties, with solid content being 3.8-5.7% higher than in the CG.

Conclusion: Based on the obtained results, it was found that milk productivity had increased by 10-20%, the fat mass fraction by 7-10%, the protein mass fraction by 5.1-6.5%, the amount of dry matter by 3.8-5.7%, and lactose by 1.1-4.3%.

Introduction

Milk and dairy products have an important role in the human diet, providing essential nutrients such as proteins, fats, vitamins, and minerals. Despite their importance, the global demand for these products is often unmet, necessitating increased production and enhanced productivity of dairy animals [1-2]. Several factors influence the productivity and quality of milk, including genetic factors, environmental conditions, herd management practices, and notably, the nutritional composition of the feed provided to dairy cows. But the most important factor, in our opinion is feeding [3-5].

In dairy farming, grain is used as a source of energy and protein. The grain of cereals and legumes has high digestibility and taste qualities. Grain can contain anti-nutritional substances that reduce the availability of nutrients, thereby hurting cow productivity [6, 7]. Many authors argue that to completely or partially eliminate the anti-nutritional substances of grain, it is necessary to process it [8, 9]. One of the most effective methods of grain processing today is extrusion. As a result of grain exposure to high pressure and temperature, changes occur in the protein matrix of the endosperm and the starch structure, contributing to more efficient microbial enzymatic digestion [10, 15].

Including extruded feed in the diets of dairy cows contributes to an increase in productivity by 20-25% [2]. Grain extrusion impacts the productivity, quality, and digestion of dairy cows. Extruded feed helps to increase the concentration of lactose and dry matter; however, the mass fraction of fat and protein decreases. The digestibility of crude protein increases [14].

The milk productivity of cows is positively influenced by the inclusion of extruded lupin grain in the compound feed. For instance, extrusion processing can alter the protein matrix and starch structure in grains, making them more accessible to microbial enzymatic digestion in the cow's rumen. This increased digestibility translates to higher nutrient uptake, promoting better milk production and quality. Thus, 112 kg of milk was additionally obtained, the mass fraction of fat increased to 4.13%, and the mass fraction of protein equaled 3.38% [11]. The use of extruded soy in dairy cow feed contributed to an increase in milk productivity of 226 kg; however, a decrease in the mass fraction of fat by 0.16% was observed. An increase of 2.68 kg was found after the recalculation to butter fat [12].

Using extruded compound feed (ECF) concentrate consisting of barley and corn in feeding dairy cows allowed increasing the average daily yield by 6.5% and had a positive effect on the qualitative composition of milk, since the mass fraction of fat increased by 0.10% and the mass fraction of protein by 0.12% [13]. This increased digestibility translates to higher nutrient uptake, promoting better milk production and quality.

Thus, our study aimed to determine the effect of ECF on cow productivity and the qualitative composition of milk.

By examining a range of physicochemical and organoleptic parameters, this research seeks to provide a detailed understanding of how ECF influences dairy production, offering valuable insights for dairy farmers and industry stakeholders aiming to optimize milk production and quality.

Methods

The study was conducted in the autumn/winter period in North Kazakhstan of 2023-2024. The research aimed to assess the impact of extruded compound feeds (ECF) on the productivity and quality of milk from highly productive black-and-white cows.

Three experimental groups (EG) and a control group (CG) were formed for the experiment. Each group consisted of 10 cows, which were taken from farms located in northern Kazakhstan. These cows were selected to be analogous in terms of live weight, productivity, age, and calving date. The CG cows were fed the basic diet (BD), and the EG, in addition to the BD, received 1.0, 1.5, and 2.0 kg of ECF, which consisted of barley and corn in equal proportions. Once a month, control milking was carried out to account for milk productivity, and milk was selected for chemical analysis.

The chemical analysis of milk was carried out using a CombiFoss FT+ infrared spectrometer to control the following indicators: mass fraction of fat, mass fraction of protein, casein, lactose, dry matter, urea, and somatic cells (according to the State Standard (GOST) 32255-2013 "Milk and dairy products. An instrumental express method for determining the physicochemical identification parameters using an infrared analyzer") [16].

Milk density and non-fat milk solids (NFMS) were determined according to Kazakh standards (ST RK) 1483-2005 "Cow milk. Test methods for determining the composition and density of milk". The analysis was performed using a Lactane 1-4 ultrasonic milk analyzer. The ultrasonic method was based on measuring the ultrasound velocity in milk [17].

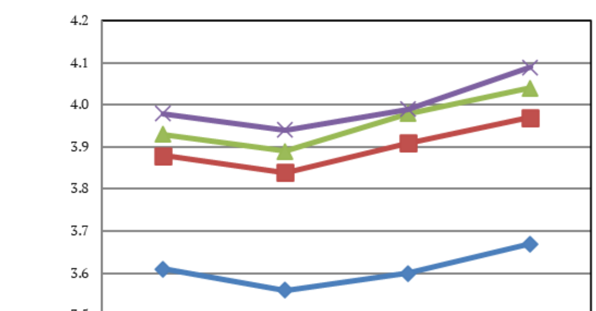
The titrated acidity of milk was determined according to GOST 3624-92 "Milk and dairy products. Titrimetric methods for determining acidity". The essence of the method is the titration of milk with potassium or sodium hydroxide in the presence of a phenolphthalein indicator.

The active acidity was determined according to GOST 32892-2014 "Milk and dairy products. The method of measuring active acidity". It is a potentiometric method based on measuring the potential difference between two electrodes immersed in milk [18].

Results

The milk productivity of cows is the quantity and quality of milk received over a certain period. Milk productivity is a complex feature conditioned by the morphological structure of the udder and its functional features, which are associated with metabolism and nervous and humoral regulation. The control milking of highly productive dairy cows during the experiment is presented in Table 1. Adding the ECF increased daily milk yields by 1.96-4.24 kg. A significant increase was observed in EG II. In September, the average daily milk yield in EG II exceeded the CG by 12.9% at P<0.05 and by the end of the experiment, by 23.9% at P<0.001. Compared with the CG, milk productivity in EG I increased by 15.4%, in EG II, by 19.4%, and in EG III, by 10.0%. The lactation curves of the groups are shown in Figure 1.

In the four months of lactation, the milk yields changed significantly. By the 2nd month, cows had a peak, and then a gradual decrease in milk yields was observed. The highest milk yields by the 2nd month indicate that the cows were highly productive since this is their characteristic feature. Starting from the 2nd month, there is a gradual decrease of 4-5% for each subsequent month.



	September	October	November	December
CG	3.61	3.56	3.60	3.67
EG I	3.88	3.84	3.91	3.97
EG II	3.93	3.89	3.98	4.04
EG III	3.98	3.94	3.99	4.09

Figure 1: Lactation curves in the groups (kg).

By the nature of lactation curves, highly productive black-and-white dairy cows have a high and stable lactation activity. After calving, the peak of lactation was observed at 2 months of lactation. High milk productivity persisted for a long time, that is, the lactation curve is smooth.

The mass fraction of milk fat in all groups was minimal in the 2nd month of lactation but then increased. There is a relationship between milk yield and the mass fraction of fat in milk, so if milk yield decreases, the mass fraction of fat in milk increases and vice versa. In this regard, a decrease in butter fat yielding capacity is considered acceptable, since an increase in the average daily milk yield was observed.

EG III had the highest milk fat content throughout the study, but when converted to butter fat, this group was inferior to other groups. When comparing the EG with the CG in terms of butter fat yielding capacity, it can be concluded that they exceeded the CG by 7-10% throughout the experiment.

Table 2 shows cow productivity over the entire period of the experiment. All groups had a high level of milk productivity. The maximum average daily milk yield was obtained from the EG II cows. The EG outperformed the CG by 10.0-19.4% in terms of average daily milk yield. EG III had the highest indicators of fat mass fraction and protein mass fraction. However, after the recalculation of butter fat and milk protein, this group showed lower results than EG I and EG II. In terms of milk fat, EG II exceeded the CG by 25.9% at P<0.01. As for milk protein, EG II exceeded the CG by 23.7% and EG I and EG III by 3.9 and 9.2%, respectively. In terms of milk with basic fat content, EG II had the highest indicator, surpassing the CG by 25.6% and EG I and EG III by 5.1 and 8.4%, respectively. In the Republic of Kazakhstan, a differentiated norm of basic fat content in cow milk has been established for each region, according to Resolution No. 785 of the Cabinet of Ministers of the Republic of Kazakhstan dated September 21, 1992. For the North Kazakhstan region, the basic fat content is 3.5%. During the experiment, we studied the organoleptic parameters of milk. The following indicators were determined:

- color;
- appearance and consistency;
- smell and taste.

After the organoleptic assessment carried out by a commission, we compared the data obtained with the requirements set out in TR TS 033/2013 [21].

During the organoleptic evaluation, we found that the milk samples had a clean smell and taste, without extraneous tastes and odors, a homogeneous non-viscous consistency without protein flakes and fat lumps, and a white color. The EG III milk had a light cream color. Adding the ECF to the BD contributed to a significant improvement in milk quality. The indicators of the physicochemical composition of milk are presented in Table 3. The casein and lactose content in the raw milk in the EG was higher than in the CG. The maximum content of casein and lactose was noted in EG II. The CG II casein content was higher than that of the CG by 6.4%, EG I by 1.1%, and EG III by 0.3%. The milk from the EG contained a higher number of solids.

Lactation month	groups			
	CG	EG I	EG II	EG III
1	2	3	4	5
Before the experiment	16.78±0.50	16.85±0.58	16.76±0.63	16.85±0.51
September	17.08±0.75	19.23±0.84	19.62±0.73**	18.74±0.93
October	19.61±0.97	22.24±0.98	23.15±0.90	21.68±0.97
November	17.44±1.12	21.44±0.92**	22.12±0.92	19.81±1.08
December	16.36±0.86	20.41±0.90	21.51±0.87*	18.10±1.01
Total	17.62±1.52	20.83±1.44	21.86±1.69	19.58±1.68
Increase	-	+3.21	+4.24	+1.96

*P≤0.001; **P≤0.05

Table 1: Control milking over the experimental period, kg (x±Sx).

Indicator	Cow group			
	CG	EG I	EG II	EG III
1	2	3	4	5
Average daily milk yield, kg	17.62±1.52	20.83±1.44	21.86±1.69	19.58±1.68
Mass fraction of fat, %	3.61±0.09	3.90±0.11	3.96±0.10	4.00±0.11
Mass fraction of protein, %	3.32±0.09	3.50±0.10	3.54±0.08	3.55±0.10
Butter fat, kg	0.63±0.04	0.81±0.04	0.85±0.05**	0.78±0.05
Milk protein, kg	0.58±0.04	0.73±0.04	0.76±0.05	0.69±0.05
Amount of milk with basic fat content*, kg	18.14±1.26	23.16±1.31	24.40±1.59	22.34±1.48

*3.5: The basic norm of the mass fraction of fat in milk adopted in the Republic of Kazakhstan for the North Kazakhstan region; **P≤0.01

Table 2: Productivity of dairy cows (x±Sx).

Indicators	Group			
	CG	EG I	EG II	EG III
1	2	3	4	5
Casein, %	2.65±0.07	2.80±0.08	2.83±0.07	2.82±0.08
Lactose, %	4.67±0.15	4.78±0.15	4.88±0.11	4.72±0.13
Dry matter, %	12.10±0.29	12.60±0.29	12.83±0.23	12.58±0.27
NFMS, %	8.50±0.27	8.70±0.26	8.87±0.20	8.58±0.24
Urea, mg	20.92±1.71	22.34±1.72	22.52±1.35	25.79±2.70
Density, kg/m³	1,028.75±1.08	1,029.30±1.07	1,029.85±0.77	1,028.75±0.93
Titrated acidity, °T	17.29±0.36	17.37±0.32	17.19±0.32	17.82±0.35
Active acidity, pH	6.70±0.02	6.69±0.01	6.70±0.01	6.67±0.02

Table 3: Indicators of the physicochemical composition of milk (X±Sx).

Indicator	Cow group			
	CG	EG I	EG II	EG III
1	2	3	4	5
Background				
Somatic cells, thousand/cm³	204.45±92.72	209.50±85.22	211.07±75.10	213.95±93.80
1st month of lactation				
Somatic cells, thousand/cm³	203.50±95.27	210.40±88.54	212.80±79.64	215.00±96.97
2nd month of lactation				
Somatic cells, thousand/cm³	205.00±96.88	210.40±88.51	210.30±76.59	215.90±99.86
3rd month of lactation				
Somatic cells, thousand/cm³	205.90±97.99	210.60±86.80	214.10±78.63	213.50±96.56
4th month of lactation				
Somatic cells, thousand/cm³	203.40±95.33	206.60±90.85	207.10±77.59	211.40±97.02

Table 4: The content of somatic cells in milk (X±Sx).

This indicates that milk has more nutritious and technological properties. Thus, in the EG, the number of solids in milk was 3.8-5.7% higher than in the CG.

The NFMS is what remains of milk if all water and fat are removed. The NFMS content in the EG was higher than in the CG by 0.93-4.2%. EG II had the highest NFMS index of 8.87±0.20%.

The titrated and active acidity in the milk from the groups was within acceptable limits, which indicates the good quality of the obtained raw materials. The urea content should be given special attention, since in EG III, by the end of the experiment, the urea content in milk was 27.96 mg, which indicates an excess of metabolic energy and crude protein. In the other groups, this indicator was within the normal range. The content of somatic cells during the experiment is shown in Table 4.

The content of somatic cells in cow milk indicates under health [19]. According to GOST 31449-2013, "Raw cow's milk. Technical specifications", the number of somatic cells should not exceed 400 thousand/cm³ [20]. In our studies, the number of somatic cells in the tested milk ranged from 203.40 to 215.90 thousand/cm³, which meets the requirements. The CG throughout the experiment had the smallest number of somatic cells in milk (203.40-205.9 thousand/cm³).

During the experiment, the number of somatic cells increased in all groups by the 2nd month of lactation and decreased by the end of the experiment. It can be concluded that adding the ECF to the main diet did not affect the number of somatic cells in milk. The values were within acceptable norms, which indicates that the farm complied with the technology of keeping and milking cows.

Discussion

It was concluded that the optimal amount of the ECF is 1.5 kg. Milk productivity in the EG increased by 10-20% compared to the CG. The introduction of the ECF into the diet had a positive effect on the physicochemical parameters of milk, since the mass fraction of fat in the milk from the EG was higher than in the CG by 7-10%, the mass fraction of protein by 5.1-6.5%, solids by 3.8-5.7%, and lactose by 1.1-4.3%. The studied milk samples had a clean smell and taste, without extraneous tastes and odors, a homogeneous non-viscous consistency without protein flakes and fat lumps, and a white or light cream color. In cows overfed with the ECF, urea levels in milk increased. This indicates an excessive amount of crude protein and metabolizable energy in the diet.

Using the ECF in the feeding of dairy cows does not affect the content of somatic cells in milk. The titrated and active acidity in the milk of all experimental groups was within acceptable limits, which indicates the good quality of the raw materials obtained.

Since ECF formulations have to combine several parameters including component kind and shape, extrusion temperature, ECF concentration, and dairy cow characteristics, the conclusions of previous research are highly heterogeneous.

Risyahadi et al., reviewed existing data on the effects of extrusion and found that, compared to non-extruded feed, such heat processing increased milk yield, dry matter, and lactose content in milk, which is consistent with our findings [22]. However, milk fat and/or protein content was reduced or remained unchanged in most studies [22-26]

The most significant gain after feed extrusion occurs in milk productivity [26, 27]. Increased milk productivity correlates with acetate/propionate molar ratio in faba bean and lupin fed experiments, therefore, it was suggested that a higher proportion of acetate compared to propionate results in enhanced milk productivity because acetate serves as a precursor to milk yield [23].

High-temperature processing of grain changes the molecular structure of the proteins it contains, which in turn changed the digestibility of the protein. The proteins were broken down into peptides, and this form was more accessible to hydrolyzing digestive enzymes. Furthermore, extrusion reduced the levels of anti-nutritional factors in the grain, such as protease inhibitors, so protein biodegradability was intensified. [28]. The increase in milk protein in our case can be associated with the above-mentioned processes. Studies that obtain opposite results claim that excessive processing leads to protein denaturation and most likely converts proteins into a more stable indigestible form. Also, despite the increase in the digestibility of crude protein, this does not lead to an increase in the concentration of milk protein, which suggests that greater digestibility of crude protein does not necessarily lead to increased flow of amino acids into the mammary gland and the production of casein [29].

According to other studies, the greatest difference between extruded and non-extruded samples is in the total levels of butyrate, iso-butyrate and valerate. Untreated samples have higher levels of these fatty acids, and they accelerate blood flow in the cow's rumen, which improves the absorption of other fatty acids [30].

The sensory properties of milk were also assessed by other authors: ECF containing faba beans does not lead to a specific aroma, taste or texture of milk, which corresponds to our data [27].

Authors note that by demonstrating the positive impact of ECF on milk yield and quality, the findings provide a practical solution for enhancing dairy productivity in regions similar to North Kazakhstan. This can help meet the increasing demand for milk and dairy products, contributing to better food security and economic stability for dairy farmers.

Author Contributions

All authors developed the concept, designed the methodology, collected and analyzed the data, and prepared the original draft of the manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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