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Disease structure of milk cows and the effect of the mass fractions ratio of fat and protein in milk on the level of the metabolites

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Abstract. The analysis of diseases occurring is given in animals in the first 100 DIM. Determined milk content: MF, MP, pH, Ur, BHBA, Ac, calculated FPR. INCD in milk cows in the first 100 DIM is the second most widespread – 30.72 %. Among INCD, DSD and RSD predominate in the former – 38.8 % each, DMEO accounts for 20.4 % of disease cases. In 17.05 % of the examined animals, the FPR corresponded to optimal values, and in 82.95 % it was 1.10 or less, which may indicate the spread of subacute subclinical rumen acidosis in the animals of the studied population. Exceeding the upper limit of FPR, indicating the presence of ketosis in animals, has not been established. Studies revealed a double excess of Ur content in milk, and in animals with normal FPR values, the Ur content was 11.15 % ($p < 0.001$) higher than in animals with reduced FPR. The pH of milk generally corresponded to the values of the physiological norm. The level of BHBA in milk was below the threshold values, but in the animal's group with FPR 1.10 or less, the BHBA content in milk significantly (by 80.0 %, $p < 0.01$) exceeded the BHBA content in animals with normal FPR values. Cows with a normal FPR value, the Ac level in milk was found to exceed the threshold value by 28.57 %, and in animals with low FPR values, the established excess was 141.43 % ($p < 0.05$).

1 Introduction

At the beginning of lactation, most milk cows are in a state of negative energy balance (NEB), caused by the animal's increased need for energy needed to maintain life and milk production [1]. Very often during this period, cows receive immediately and in large quantities concentrated feeds. Numerous studies have shown that feeding cows a diet with a high- concentrated ration leads to an increase in the number of diseases that one way or another has to be called metabolic or their consequences. These are diseases such as rumen acidosis and ketosis, laminitis, fatty dystrophy, and hepatic abscess, abomasum displacement, etc. [2–5].

For example, diseases such as ketosis and fatty change of liver affect up to 50 % of cows, which is accompanied by a decrease in their productivity, milk quality, deterioration of reproductive qualities, etc. [6–7]. A serious threat is subacute rumen acidosis when the pH in the rumen becomes below 5.6 units. In this case, the digestion of fiber worsens, diarrhea may occur, and in general, the rumen microbiota undergoes serious changes. [8–9].

It was found that in cows with clinical features of ketosis, there is a significant increase in the concentration of non-esterified fatty acids and β-hydroxybutyrate (BHBA) in the blood, the activity of aspartate and alanine transaminase, alkaline phosphatase increases, and there is a noticeable decrease in glucose levels.

These data show that cows with clinical ketosis have severe liver damage. BHBA levels are considered to be an excellent biomarker for the ketosis diagnosis, including subclinical and clinical forms [10]. However, blood chemistry values can only provide limited information, since various metabolic disorders can progress, for example, during ketosis [11–12]. Therefore, it is important to take into account the clinical animal state, the composition, and quality of milk (including the content of ketone bodies in it, pH), and to find relationships between the indicated studied indicators.

A comprehensive assessment of the energy balance on large livestock farms is a costly undertaking. Determination of the mass fraction of fat (MF) and protein (MP) in milk, their ratio to each other (FPR) are indicators that give quite useful information, including

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about feeding in general, about energy supply in particular. [13].

Research on Holstein cows has shown that the optimal FPR is from 1.2 to 1.4. If FPR is greater than 1.5, then this is considered a risk factor for metabolic problems such as ketosis. When lactic acid inversion occurs (FPR less than 1.0), the herd is considered at risk of subacute rumen acidosis. [14–15].

Thus, the purpose of this research was to study the prevalence proportions in animals during the days in milk, especially metabolic and related diseases, and to assess the content of metabolites in cow milk with different FPR values.

2 Materials and methods

During the research, the treatment of experimental animals was carried out by AUSS (All-Union state standard) 33215-2014 and did not contradict the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (European Treaty Series – No. 123).

The prevalence of diseases in animals in the first 100 days of lactation (100 DIM) was calculated based on the analysis of veterinary registration forms and databases of the "SELEX. Milk cattle" program. The analysis of sickness cases in 1006 milk cows in livestock enterprises of the Republic of Tatarstan in the period from 2013 to 2019 was carried out.

The analyzed diseases were divided into 4 groups: obstetric-gynecologic diseases (OGD), internal non-infectious diseases (INCD), surgical diseases (SD), infectious and invasive diseases (IID). Also, INCD was divided into digestive system diseases (DSD), respiratory system diseases (RSD), metabolic and endocrine organ diseases (DMEO), heart system diseases (DCS).

Determination of the content of MF (%) and MP (%) in milk, active acidity (pH), urea (Ur, mg/100 ml), BHBA (mmol/L) and acetone (Ac, mmol/L) was carried out based on intensity measuring of infrared radiation passed through the milk sample and calculating the content of the components to be determined, based on the obtained spectral data using the milk analyzer MilcoScan 7RM ("FOSS Analytical A/S", Denmark) by the manufacturer's instructions.

The study was subjected to an average sample of milk from animals selected and prepared according to AUSS 26809-86 by the methods defined for each of the studied parameters: MF ISO 1211:2010 [IDF 1:2010]; MP ISO 8968-1:2001 [IDF 20-1: 2001]; pH ISO 26323:2009 [IDF 213:2009], Ur ISO 14637:2004 [IDF 195:2004]; BHBA and Ac – on A.P.de Roos (2007) [16]. The milk research by the studied indicators in 440 cows was completed in 2019. FPR was determined using the following formula:

$$FPR = \mathrm{MF} : \mathrm{MP} \quad (1)$$

FPR was considered optimal from 1.1 to 1.5 W. Richardt (2004) [17].

3 Results and Discussion

In recent decades, breed selection for disease resistance has become increasingly popular [18]. However, despite this, due to feeding that does not meet the real needs of the animal, it is not uncommon for cows to have NEB in the first months of lactation, which leads to a decrease in productivity due to the metabolic disease's development, and then infertility. In NEB conditions, fat from fatty tissue is mobilized due to low blood glucose levels to meet the animal's energy needs. This leads to an increase in the content of non-esterified fatty acids, BHBA, and other metabolites in the body fluids [19].

The data presented in Fig. 1 show that in the first 100 DIM in animals, OGD diseases are most often recorded – 42.05 %, INCD diseases (30.72 %) are slightly less common. In third place in terms of SD distribution is 26.64 %; in rare cases, IID is recorded. Thus, almost 1/3 of all animals in the first 100 DIM have INCD, which in general is a noticeably high number of animals. The presented results agree with the regularities of the distribution of disease groups among the cow population, given by P. T. Thomsen и H. Houe (2006), however, in our study, the number of OGD cases was 3.0 % higher, and the number of INCD and SD cases was 10.0 and 6.0 % higher, respectively [20].

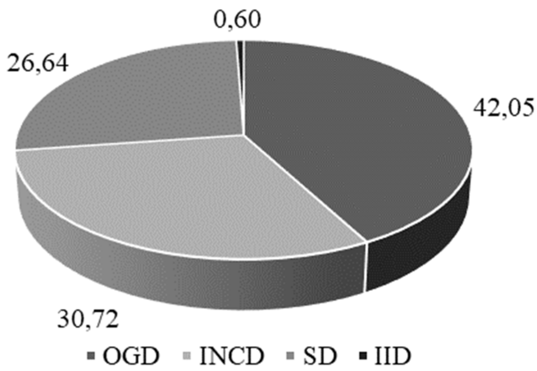

Fig. 1. Structure of cow diseases in the first 100 DIM

We have analyzed the INCD structure, which in Fig.2 is presented. It was found that in equal numbers in the studied animal population were noted DSD and RSD in the first 100 DIM of 38.8 % each. DMEO is 18.4 % less common, and DCS accounts for no more than 2.0 % of cases all sickness.

Thus, considering the number of cases of DSD and DMEO, realizing that their etiology is very often associated with the influence of dietary factors, we can assume that a total of 59.2 % of sickness cases in the first 100 DIM are associated with errors in animal feeding technologies and the feeding quality. Our results are significantly higher than those of P.T. Thomsen и H. Houe (2006) [20] relative to DSD and DMEO by 13.0 and 6.0 %, respectively, which in total equation gives a difference of 19.0 %.

It is known that the milk of different animal species differs from each other in organoleptic (color, smell, taste, etc.) and physical and chemical (density, MF, MP, etc.) and other properties. Also, the influence may be due to the breed, feeding quality, milking technology, storage, etc. [21].

As mentioned earlier, FPR can be used as one of the assessment criteria of animal energy availability, as well as for assessing the risks of ketosis and acidosis. For example, it is believed that the butterfat percentage usually increases with ketosis (more than 4.5), and milk protein decreases (less than 3.2) [22–23]. There is no single understanding of optimal FPR. So some scientists point out that the optimal FPR for cows varies between 1.00–1.25, others consider the optimal range of FPR 1.10–1.50, and others-1.33 [24–26]. The data obtained by us, presented in Fig. 3. indicate that in 17.05 % of animals FPR corresponded to optimal values, and in 82.95 % it was 1.10 or less, which may indicate the spread of subacute subclinical rumen acidosis in the animals of the studied population [14–15].

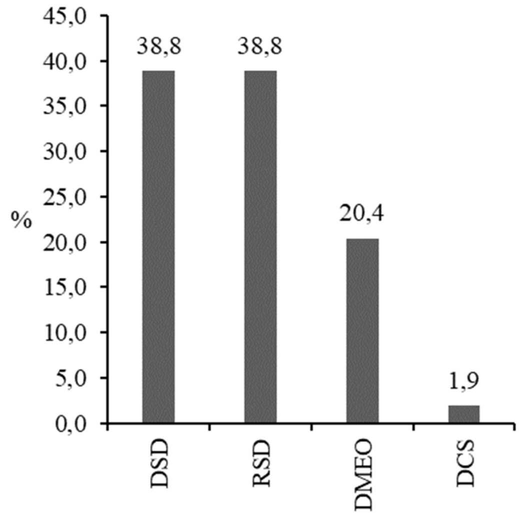

Fig. 2. INCD structure in cows in the first 100 DIM

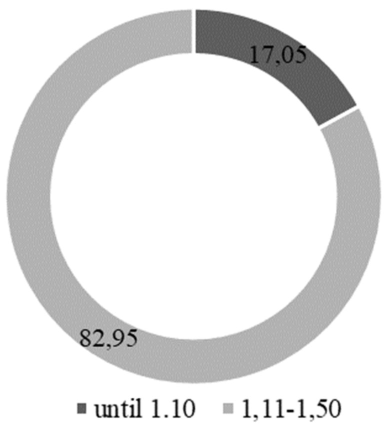

Fig. 3. FPR in cows in the first 100 DIM

C. Weber et al. (2015) found that changes in Ur content in milk depend mainly on the lactation phase, rather than on the level of milk productivity, and in the first 100 DIM maybe 21–26 mg/100 ml. [27]. The results obtained in our studies, in Fig. 4. presented, indicate on average a double excess of Ur content in milk, relative to those observed in the authors mentioned above [27]. Moreover, in animals with normal FPR values, the Ur content was 11.15 % higher than in animals with reduced FPR ($p < 0.001$).

Helmenstine A.M. (2020) reported that the pH of cow milk ranges from 6.4 to 6.8. Fresh milk from a cow usually has a pH between 6.5 and 6.7 [28]. In our study, the obtained values generally fell within the range of normal pH values, however, in animals with FPR less than 1.10, this indicator was significantly biased towards more acidic values by 0.12 ($p < 0.001$).

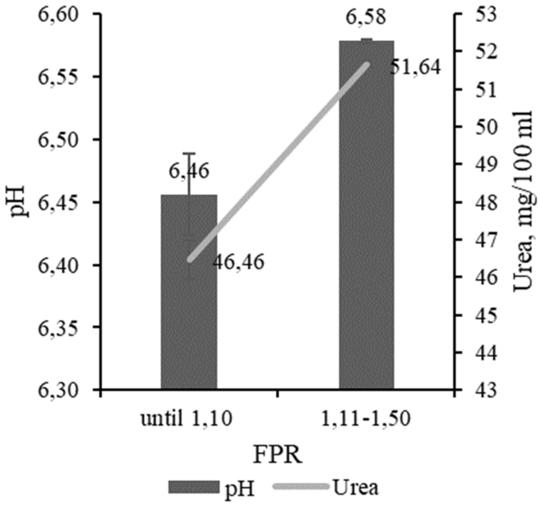

Fig. 4. pH and urea content in cow milk in the first 100 DIM depending on FPR

O.M. Radostits, C.C .Gay, K.W. Hinchcliff (2008) и B.P. Smith (2009) note that since ketosis (the main metabolic disorders of which are hyperketonemia and hypoglycemia) does not always have pathognomonic symptoms, ketone bodies in the blood, urine, and milk (BHBA, Ac, acetoacetic acid) should be determined for its early diagnosis [29–30]. A.T.M. van Knegsel et al. (2010) indicates that the optimal threshold value for BHBA content in milk for animals up to 10 weeks of lactation is 23 mmol/L. [31].

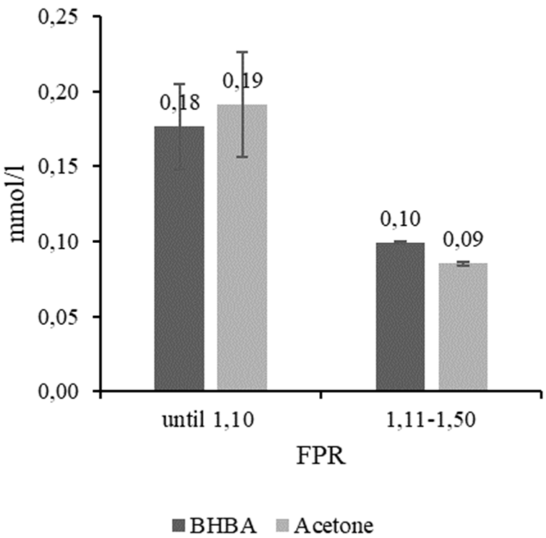

Fig. 5. The content of BHBA and Ac in cow milk in the first 100 DIM depending on the FPR

Our results (Fig. 5) significantly lower than the indicated values, but in the group of animals with FPR 1.10 or less, the BHBA content in milk was significantly (by 80.0 %, $p < 0.01$) higher than the BHBA content in animals with normal FPR values.

The same authors [31] consider the optimal threshold value of the Ac content in milk to be 0.07 mmol/L. In our study, cows with a normal FPR value had an Ac level in milk that was 28.57 % higher than the threshold, and animals with low FPR values had a significant excess of 141.43 % ($p < 0.05$).

4 Conclusion

INCD in milk cows in the first 100 DIM is the second most widespread – 30.72 % of the total number of diseases. Among INCD, DSD and RSD predominate in the former – 38.8 % each, DMEO accounts for 20.4 % of disease cases. In 17.05 % of the examined animals, the FPR corresponded to optimal values, and in 82.95 % it was 1.10 or less, which may indicate the spread of subacute subclinical rumen acidosis in the animals of the studied population.

Exceeding the upper limit of FPR, indicating the presence of ketosis in animals, has not been established. Studies revealed a double excess of Ur content in milk, and in animals with normal FPR values, the Ur content was 11.15 % ($p < 0.001$) higher than in animals with reduced FPR.

The pH of milk in our study generally corresponded to the values of the physiological norm. The level of BHBA in milk was below the threshold values, but in the animal's group with FPR 1.10 or less, the BHBA content in milk significantly (by 80.0 %, $p < 0.01$) exceeded the BHBA content in animals with normal FPR values. Cows with a normal FPR value, the Ac level in milk was found to exceed the threshold value by 28.57 %, and in animals with low FPR values, the established excess was 141.43 % ($p <0.05$).

5 Acknowledgments

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