Evaluation of the method of reducing the bioavailability of starch in the rumen of ruminants

B S Nurzhanov¹, G K Duskaev¹, I I Kochish², Yu A Yuldashbaev³, Sh G Rakhmatullin¹, I S Miroshnikov¹

¹ Federal Scientific Center of Biological Systems and Agrotechnologies of the Russian Academy of Sciences, 29, January 9 str., Orenburg, 460000, Russia
² Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin, Moscow, Russia
³ Russian State Agrarian University-Moscow Agricultural Academy named after K.A. Timiryazev, 49, Timiryazev str., Moscow, 127550, Russia

E-mail: baer.nurzhanov@mail.ru

Abstract. Prevention of metabolic acidosis, tympania of the rumen during the fattening of cattle is an important issue in the production of beef. Researchers are actively searching for available substances and evaluating their effect on fermentation of the ruminant cicatrix. Perspective in this regard may be the use of organic acids in animal nutrition. The following samples were prepared for the study: crushed barley + distilled water (control); crushed barley + 0.5% solution of lactic acid; crushed barley + 1.0% solution of lactic acid; crushed barley + 2% solution of lactic acid. The digestibility of dry matter and starch in the artificial scar (in vitro), depending on the concentration of lactic acid and 30 min exposure, was studied by exposure for 3 and 6 hours. The experiment found that the processing of ground barley with 0.5%, 1% and 2% lactic acid contributed to the decrease in digestibility of dry matter by 26.7-32.2% and starch by 16.1-21.1% 3 hours after incubation. A 0.5-1.0% solution of lactic acid is optimal for use, as it effectively reduces the availability of starch for the cicatrical microflora of ruminants.

1. Introduction
To maintain a high productivity of animals, including the cultivation and fattening of beef cattle, requires a large amount of energy for the body. Replenishment of the latter is carried out through the inclusion in the rations of a significant amount of readily available carbohydrates, which are the source of energy for the rumen microorganisms. The peculiarities of the formation of acid-base relationships in ruminants are more dependent on the physiological state, conditions of detention and feeding, than in other types of farm animals [1-4]. The most common cereal products used in feeding ruminants are barley, maize, wheat, etc. Unlike maize, barley starch grain is subjected to more fermentation in the rumen fluid, which leads to more rapid accumulation of volatile fatty acids. With an increase in the proportion of concentrated feed in the diet, the physicochemical parameters of the scar content change and metabolic acidosis, atony, and tympania are observed [5, 6].
It is known that lactic acid is actively used in veterinary medicine as an anti-fermenting agent, for the treatment of enteritis, gastritis, tympania, flatulence, with acute expansion of the stomach, with trichomoniasis of cattle, skin diseases in the form of 40 and 80% solutions, and also for disinfection of livestock, poultry and production facilities, equipment and inventory. It is a metabolite of metabolism in the body of ruminants, non-toxic, and has no contraindications when using products of slaughter after use [7, 8].

There is evidence that lactic acid can slow down the enzymatic action of grain amylase, which led to a decrease in the breakdown of starch in laboratory studies [9, 10]. Another explanation could be that the interaction between gluten and an organic acid can provide a barrier to enzymatic decomposition [11–13].

In connection with the above, the need arises to develop effective feeding strategies for ruminants in order to maintain optimal rumen metabolism. Since the amount of fiber in the diet of highly productive ruminants is limited, slowing down the rate of cicatricial degradation of starch in cereal feeds would be the necessary condition for reducing the risk of disease [14–16]. In this connection, the question of the influence of lactic acid on the disintegration of starch in the rumen of ruminants is interesting.

The aim of the research was to develop a method for regulating the breakdown of starch in the rumen by reducing its availability to microflora.

2. Materials and methods
Cicatricial bulls of red steppe breed bulls with chronic scar fistula.

Animal care and experimental studies were performed in accordance with the instructions and recommendations of the Russian Regulations, 1987 (Order No.755 on 08/12/1977 by the USSR Ministry of Health) and "The National Academy Press Washington, DC 1996). In doing research, efforts were made to minimize animal suffering and reduce the number of samples used.

The following samples were prepared for the study: crushed barley + distilled water (control); crushed barley + 0.5% solution of lactic acid; crushed barley + 1.0% solution of lactic acid; crushed barley + 2% solution of lactic acid. The method included mixing 35–45% of crushed grain feed from the daily ration of the diet with a solution of lactic acid in a ratio of 75:25, wt. % and holding the resulting mixture with an exposure of 30 min at a temperature of 18–22 °C, followed by stirring with the rest of the concentrated feed.

The digestibility of dry matter and starch in the artificial scar KPL 01 (in vitro), depending on the concentration of lactic acid and 30 min. Aging in nylon bags, was studied by exposing for 3 and 6 hours after feeding according to the method of Professor V. Lampeter. In vitro digestibility of the dry matter of the feed was determined based on the difference in the mass of the feed sample together with the bag and after two-stage incubation and drying to constant weight at a temperature of 60 °C.

Laboratory studies were carried out using the material and technical base of the Testing Center of the TsKP FGBNU FNTS BST RAS (accreditation certificate No. RA.RU.21PF59 from 12.10.2015), including the GP-20 dry heat ovens (drying the samples for 45 min at a temperature of 60 °C to a constant weight), subsequent weighing (laboratory scales VM 510D).

Statistical processing was performed using the program "Statistica 10 RU", calculating the average value (M), standard deviation (σ), standard deviation error (m). The significance level was considered significant at p <0.05.

3. Research results and discussion
In the first series of laboratory studies assessing the effect of the dose of the solution on the structure of the crushed grain feed, it was established that at a dosage of 0.25-0.3 liters per 1 kg of the crushed grain feed, optimum mixing and formation of a crumbly, wetted feed mixture occur. Subsequently, this leads to more uniform mixing and distribution with the untreated part of the concentrated feed. The complete absence of exposure leads to the loss of small particles of feed and not enough complete "absorption" of the solution.
In the second series of laboratory studies (Table 1) on an artificial scar according to the assessment of different exposure periods of ground barley in distilled water (control) and 0.5% lactic acid solution, it was established that a 30-minute period reduces digestibility of dry matter of feed by 26.7%.

| Sample name                                           | Without exposure | 30 min. | 60 min. | 90 min. | 120 min. |
|--------------------------------------------------------|------------------|---------|---------|---------|----------|
| crushed barley + distilled water (control)            | 45.7±1.09        | 43.4±2.05 | 45.1±0.95 | 45.1±1.56 | 46.9±0.79 |
| crushed barley + 0.5% solution of lactic acid          | 31.2±1.21        | 16.7±2.54* | 17.1±1.05* | 17.5±1.22* | 16.9±2.01* |

* - hereinafter, P≤0.05 compared to control.

A further increase in the exposure time or its complete absence practically does not change this value or leads to a slight increase in digestibility.

In the third series of laboratory studies on the in vitro model of the rumen (Table 2), the effect of solution concentration on the degree of digestion of dry matter and starch of crushed grain feed was studied. Processing the ground barley with a solution of lactic acid helped reduce the digestibility of dry matter by 26.7-32.2% 3 hours after incubation. It was the lowest at 1.0% concentration of the lactic acid solution; at the same time, the starch digestibility after 3-hour incubation of the sacs in the rumen decreased by 21% compared with the control. A similar difference in the treatment with 0.5% solution was 16.1%, with 2.0% solution - 18.0%.

| Sample name                                           | Dry matter after 3 hours | Starch after 3 hours |
|--------------------------------------------------------|--------------------------|----------------------|
| crushed barley (control)                              | 43.67±2.05               | 38.2±1.23            |
| crushed barley + 0.5% milk solution. acids            | 16.99±2.54*              | 22.1±1.14            |
| crushed barley + 1.0% milk solution. acids            | 11.43±0.7*               | 17.13±0.81*          |
| crushed barley + 2.0% milky solution. acids           | 15.4±0.55*               | 20.2±0.78*           |

| Sample name                                           | Dry matter after 6 hours | Starch after 6 hours |
|--------------------------------------------------------|--------------------------|----------------------|
| crushed barley (control)                              | 17.26±0.70               | 91.5±1.97            |
| crushed barley + 0.5% milk solution. acids            | 15.21±2.36               | 85.7±1.02            |
| crushed barley + 1.0% milk solution. acids            | 14.69±1.78               | 79.8±0.88*           |
| crushed barley + 2.0% dairy solution. acids           | 16.18±1.83               | 89.4±0.95            |

Further incubation of nylon bags with samples (6 hours) showed that the breakdown of starch in the control group increased significantly (more than 90%), while processing it with a 0.5% solution of lactic acid reduced its hydrolysis by 5.8%, 1.0% solution - by 11.7% (P≤0.05), 2.0% - by 2.1%.

In vitro starch digestibility results are shown in Figure 1.
Figure 1. The rate of digestion of crushed barley starch in vitro over a 3-hour period, % (a - the native form of crushed barley; b - crushed barley treated with 0.5% lactic acid solution; c - crushed barley treated with 1.0% lactic acid solution; d - crushed barley processed 2.0% solution of lactic acid)

The speed of digestion of starch of crushed barley grain after treatment with 1.0% lactic acid solution was lower compared to the control by 3.3%. Developing effective feeding strategies for ruminants requires maintaining optimal rumen metabolism. During the experiment, it was established that the treatment of chopped barley with 0.5%, 1% and 2% lactic acid solution contributed to the reduction of dry matter digestibility by 26.7-32.2% and starch by 16.1-21.1% 3 hours after incubation. This effect is most likely since lactic acid has the ability to slow down the enzymatic action of grain amylase, which leads to a decrease in the breakdown of starch. The exact mechanism of action of this acid on the structure of starch is currently not fully understood. The experimental data obtained by us on the digestibility of dry matter and starch in vitro, depending on the exposure time and on the concentration of lactic acid, are consistent with the previously obtained data [12, 17, 18].

Starch digestibility after treatment with 1.0% lactic acid solution and 3-hour incubation of sacs in the rumen decreased by 21%. Earlier, similar results were obtained in other studies [19].

Despite the available experimental data on the degradation of starch in feed grain in the rumen, additional research is still needed to improve these techniques.

4. Conclusions

Thus, in the course of research, we developed a method for regulating the breakdown of starch in the artificial rumen of ruminants by reducing its availability for microflora. During the experiment, it was established that the processing of crushed grain feed with 0.5-1.0% solution of lactic acid contributes to reducing the availability of starch for cicatricial ruminant microflora.

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