The influence of cavitation processing on biotechnological aspects of feed application

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Abstract. The problem using production waste rationally is a fundamental one for our country. Waste agro-industrial complex is characterized by a high content of carbohydrates, proteins and fat, which makes them indispensable when balancing rations. In this regard, the method is about obtaining fodder product on the basis of cellulose-containing wastes enriched with zeolite powder. The method is based on ultrasonic treatment of joint products (bran) and the mineral zeolite. The efficiency of the use of the product lies in poultry feeding.

1. Introduction
At present, the priority areas for the development of agricultural science and scientific support of the Russian agro-industrial complex are related to the development of high-tech technologies until 2025, which are aimed at finding fundamentally new, environmentally friendly and effective methods of intensifying technological processes and improving them. They are also aimed at creating a system of resource-saving technological processes and machines, stabilizing indicators of technological adequacy and ensuring safety of food raw materials and finished products [1–3]. Modern scientific directions in the development of modern, safe and highly effective technologies should be aimed at developing competitive new-generation food and feed products from the perspective of the implementation of anti-crisis measures in the agricultural sector of Russia [4–6].

The basis for the creation of highly efficient technological processes for the production and processing of agricultural waste, taking into account the requirements for modern equipment, should be safe cavitation, physico-chemical, electrophysical and mechanical methods of processing agricultural raw materials. This also includes using modern processing methods, allowing to obtain products with predefined properties [7].

One of the most promising and modern methods of technological processes intensification for the production of feed products is the use of cavitation in the processing of agricultural waste in combination with rational hydromechanical influences [8–10].

The problem of rational use of production waste is one of the fundamental in our country. In addition to the pan-European standard, it is necessary to take into account the fact that an effective economy can be created only on the basis of non-waste production [11–12].

It makes sense to investigate the effect of cavitation treatment on cellulose-containing agricultural waste.

2. Materials and methods
The development of the technology for the production of feed additives by the method of cavitation destruction of indigestible carbohydrates included the production of laboratory samples of cavitation
hydrolyzed products, and invivo digestibility of the obtained feed product. The chemical composition
was determined by standard methods.

A magnetostrictive emitter with a power of 100 W, oscillation amplitude of 50 μm, a frequency of
27 kHz was used as basic equipment for obtaining cavitation products. In order to have a deeper effect
of ultrasound on this type of waste, we used zeolitized tuff powder (clinoptilolite) with a particle size
of 0.1 to 1 mm.

To determine the effectiveness of using the obtained product in animal feeding, we conducted
experiments on broiler chickens of the cross "Smena-7". Four groups (n = 30) were formed by the
pair-analog method, which were in the same feeding and keeping conditions [8, 9].

Experimental poultry was fed with compound feed developed according to the recommendations of
the All-Russian Scientific Research and Technological Institute of Poultry (2004). During the
experiment, broiler chickens up to 4 weeks of age received a starting composition, and then a growth
composition (table 1).

1 kg of the starting feed of the control group contained: exchange energy – 12.79 MJ; crude
protein – 234 g.

The amount of exchange energy and crude protein in the starting feed of the experimental groups
was 13.16–13.96 MJ/kg and 225–229 g/kg.

### Table 1. Composition and nutritional value of the starting ration, g/kg

| Index                                | control | 1st experimental group | 2d experimental group | 3d experimental group | 4th experimental group |
|--------------------------------------|---------|------------------------|-----------------------|-----------------------|------------------------|
| The composition of the diet:         |         |                        |                       |                       |                        |
| full wheat                           | 320     | 220                    | 220                   | 220                   | 220                    |
| unshelled barley                     | 10      | 10                     | 10                    | 10                    | 10                     |
| sunflower meal 35%                   | 184     | 184                    | 184                   | 184                   | 184                    |
| soybean meal 40%                     | 200     | 200                    | 200                   | 200                   | 200                    |
| fish meal 58%                        | 40      | 40                     | 40                    | 40                    | 40                     |
| vegetable oil                        | 60      | 60                     | 60                    | 60                    | 60                     |
| corn                                 | 163     | 163                    | 163                   | 163                   | 163                    |
| lime stone                           | 10      | 10                     | 10                    | 10                    | 10                     |
| table salt                           | 3       | 3                      | 3                     | 3                     | 3                      |
| premix                               | 10      | 10                     | 10                    | 10                    | 10                     |
| Cavitationally crafted products      | –       | 100                    | 100                   | 100                   | 100                    |
| Zeolite                              | –       | 3.2 (size 0.1 mm)      | 3.2 (size 0.5 mm)     | 3.2 (size 1 mm)       |                        |
| The diet contains:                   |         |                        |                       |                       |                        |
| exchange energy, MJ                  | 12.79   | 13.16                  | 13.40                 | 13.54                 | 13.96                  |
| dry matter                           | 913     | 911                    | 904                   | 921                   | 923                    |
| crude protein                        | 234     | 228                    | 225                   | 229                   | 228                    |
| raw fat                              | 82.2    | 73.7                   | 72.9                  | 74.5                  | 74.3                   |
| crude fiber                          | 36.8    | 32.2                   | 31.7                  | 32.4                  | 32.3                   |
| calcium                              | 10.09   | 10.07                  | 9.99                  | 10.11                 | 10.18                  |
| phosphorus                           | 6.98    | 6.91                   | 6.88                  | 7.01                  | 7.12                   |
| Energy Protein Ratio                 | 0.28    | 0.26                   | 0.25                  | 0.25                  | 0.26                   |

One kilogram of mixed feed contained: exchange energy – 12.34 MJ; crude protein – 217 g. The
amount of exchange energy and crude protein in the growth feed of the experimental groups was
12.70–12.93 MJ/kg and 197–211 g/kg. The composition and nutritional value of the growth diet are
presented in table 2.

The crude fiber content in the starting and growth diets of the control group was 36.8 and
42.5 g/kg. A similar indicator in the experimental groups was 31.7–32.4 and 34.7–38.0 g/kg.
Table 2. Composition and nutritional value of the growth ration, g/kg

| Index                      | control | 1st experimental group | 2nd experimental group | 3rd experimental group | 4th experimental group |
|----------------------------|---------|------------------------|------------------------|------------------------|------------------------|
| The composition of the diet:|         |                        |                        |                        |                        |
| full wheat                 | 182     | 82                     | 82                     | 82                     | 82                     |
| unshelled barley           | 50      | 50                     | 50                     | 50                     | 50                     |
| sunflower meal 35 %        | 180     | 180                    | 180                    | 180                    | 180                    |
| soybean meal 40 %          | 75      | 75                     | 75                     | 75                     | 75                     |
| fish meal 58 %             | 45      | 45                     | 45                     | 45                     | 45                     |
| vegetable oil              | 45      | 45                     | 45                     | 45                     | 45                     |
| corn                       | 400     | 400                    | 400                    | 400                    | 400                    |
| limestone                  | 10      | 10                     | 10                     | 10                     | 10                     |
| table salt                 | 3       | 3                      | 3                      | 3                      | 3                      |
| premix                     | 10      | 10                     | 10                     | 10                     | 10                     |
| cavitation products        | –       | 100                    | 100                    | 100                    | 100                    |
| Zeolite –                  | –       | –                      | 1.8 (size 0.1 mm)      | 1.8 (size 0.5mm)       | 1.8 (size 1 mm)        |
| The diet contains:         |         |                        |                        |                        |                        |
| exchange energy, MJ        | 12.34   | 12.93                  | 12.71                  | 12.70                  | 12.71                  |
| dry matter                 | 907     | 882                    | 875                    | 880                    | 887                    |
| crude protein              | 217     | 211                    | 201                    | 197                    | 205                    |
| raw fat                    | 77.9    | 73.3                   | 72.5                   | 73.2                   | 70.8                   |
| crude fiber                | 42.5    | 38.0                   | 37.7                   | 34.8                   | 34.7                   |
| calcium                    | 11.70   | 11.53                  | 11.24                  | 11.38                  | 11.62                  |
| phosphorus                 | 7.65    | 6.98                   | 7.16                   | 7.27                   | 7.02                   |
| Energy Protein Ratio       | 0.26    | 0.26                   | 0.25                   | 0.24                   | 0.25                   |

3. Results and its discussion

In order to establish changes in the assimilation of nutrients during the studies, we calculated the consumption of food by the experimental bird daily. As the results of the study showed, in the first two weeks of the experiment, the feed intake in the experimental groups was less than in the control by 76, 23, 115, 45 g/goal, respectively.

Over the second two weeks, a similar indicator in the experimental groups was greater than in the control at 18, 6, 25, 24 g/goal, respectively.

Feed intake for the entire experiment in the experimental groups was less than in the control. The difference in group 1 was 58 g/goal, in group 2 – 17, in group 3 – 90 and in group 4 – 21 g/goal, which is lower than in the control by 2.42; 0.71; 3.76 and 0.87 %, respectively.

Thus, in general, a change in the composition of the diet did not significantly affect the food intake of experimental broiler chickens.

Feeding the test food to the experimental bird led to a change in the digestibility of the substances (table 3).

The digestibility of the organic matter of the starting feed in the experimental groups exceeded the control value by 2.6–6.1 %, but the difference was not statistically significant.

The degree of use of raw protein by the experimental bird was the highest in the 4th experimental group (88.0 %) and exceeded this indicator in the control group by 3.0 %, in the 1st experimental group – by 4.1 %, 2d – by 4.0 % and 3d – by 6.0 %. However, these differences are not statistically significant.

The highest degree of raw fat digestion in the starting period was observed in the control group – 76.9 %, which exceeded the same indicator in the experimental group 1st by 4.8 % (P<0.05), in 2d – by 0.5, in 3d – by 8.8 and in 4th – by 1.3 %. When comparing this indicator in the experimental groups, the following significant differences were revealed: fat digestibility in the 2d experimental...
group was 4.3 % higher than in the 1st experimental group and 8.3 % higher than in the 3d group; the digestibility of fat in the 4th experimental group is 7.5 % higher than in the 3d group.

Table 3. Digestibility of the nutrients of the starting feed, %

| Index               | control   | 1st experimental group | 2d experimental group | 3d experimental group | 4th experimental group |
|---------------------|-----------|------------------------|-----------------------|-----------------------|------------------------|
| Organic matter      | 75.1±2.08 | 77.7±1.26              | 79.5±1.24             | 79.3±1.99             | 81.2±1.90              |
| Crude protein       | 85.0±1.63 | 83.9±1.12              | 84.0±1.17             | 82.0±2.01             | 88.0±1.62              |
| Crude fat           | 76.9±1.27 | 72.1±0.98              | 76.4±0.84             | 68.1±1.93             | 75.6±1.43              |
| Carbohydrates on average | 71.5±2.52 | 78.5±1.35              | 80.7±1.31             | 82.3±1.99             | 81.9±2.07              |

Note: a – P≤0,05 when compared with control; b – P≤0,05 when comparing with 1st group; c – P≤0,05 when comparing with 2d group; d – P≤0,05 when comparing with 3d group.

The digestibility of carbohydrates in the starting feed in all experimental groups exceeded this indicator of the control group. The difference with group 1 was 7.0 %, with 2 – 9.2 (P≤0.05), with 3 – 10.8 (P≤0.05) and with 4 – 10.4 % (P≤0.05).

A similar picture was noted by the degree of nutrients digestion of growth compound feed (table 4).

Table 4. Digestibility ratios of nutrients of growth feed, %

| Index               | control   | 1st experimental group | 2d experimental group | 3d experimental group | 4th experimental group |
|---------------------|-----------|------------------------|-----------------------|-----------------------|------------------------|
| Organic matter      | 77.2±1.48 | 80.6±2.11              | 79.8±2.17             | 76.8±1.89             | 78.9±1.93              |
| Crude protein       | 86.0±1.31 | 90.8±1.73              | 87.9±1.94             | 84.8±1.66             | 88.8±1.57              |
| Crude fat           | 72.8±1.15 | 73.1±1.26              | 72.0±1.34             | 71.2±1.07             | 71.8±1.13              |
| Carbohydrates on average | 73.4±1.72 | 78.0±2.40              | 78.3±2.36             | 75.0±2.13             | 76.6±2.20              |

It is possible to note an insignificant excess of digestibility in the experimental group 1 in comparison with the control and experimental groups 2, 3, 4 in organic matter by 3.4 and 0.8–3.8 %; crude protein by 4.8 and 2.0–6.0 %; for raw fat by 0.3 and 1.1–1.9 %. Digestibility of carbohydrates was the largest in the 2 experimental group and exceeded this indicator of the control group by 4.9 % and the indicator of 1, 3, 4 experimental groups by 0.3–3.0%. No significant differences were found.

Thus, based on the foregoing, we can conclude that the introduction into the diet of broiler chickens of processed products of wheat bran positively affects the degree of digestibility of carbohydrates in the starting period.

The live weight of broiler chickens is one of the main indicators of balanced feeding. In the process of the study, we evaluated the change in live weight of the bird during the reference period by groups depending on the diet received. For this, individual weighing of the bird was carried out daily, starting from 15 days of age. Data on live weight are shown in table 5.

It is clear from the data above that during the entire reference period, the live weight of broiler chickens in the experimental groups exceeded the same indicator in the control group. So at the end of the first week of experimental feeding, the difference with group 1 was 48.3 g, from group 2 – 64.7 g (P≤0.05), from group 3 – 28.0 g and from group 4 – 34.7 g or 12, 4; 16.5; 7.2 and 8.9%, respectively.

At the end of the second week, the live weight of chickens in the control group was lower than the corresponding indicator of the experimental group by 35.6 g or 5.2 %, 2 – by 80.0 g (P≤0.05) or 11.7 %, 3 – by 18.6 g or 2.7 %; and 4 – by 24.6 g or 3.6 %.
Table 5. Dynamics of live weight of broiler chickens, g

| Accounting week | control       | 1st experimental group | 2nd experimental group | 3rd experimental group | 4th experimental group |
|-----------------|---------------|------------------------|------------------------|------------------------|------------------------|
| Beginning of the period | 257.3±13.43  | 256.3±20.68            | 265.3±13.52            | 254.3±24.88            | 259.0±8.24             |
| 1               | 391.0±18.11  | 439.3±23.35            | 455.7±20.15            | 419.0±12.38            | 425.7±12.63            |
| 2               | 684.7±23.77  | 720.3±21.59            | 764.7±32.33            | 703.3±20.71            | 709.3±23.43            |
| 3               | 1026.3±36.28 | 1094.7±29.15           | 1183.7±49.43           | 1049.7±33.24           | 1091.0±38.62           |
| 4               | 1474.0±47.11 | 1541.0±43.22           | 1612.3±58.77           | 1495.3±34.01           | 1536.7±59.43           |

Note: *– P≤0.05 when compared with the control group;  
**– P≤0.05 when compared with the 2d group.

After three weeks of experimental feeding, the live weight in the 1st, 2d, 3d, and 4th experimental groups exceeded the live weight of the control group by 68.4; 157.4 (P≤0.05); 23.4 and 64.7 g or 6.7; 15.3; 2.3 and 6.3 %. At the end of the fourth week, the live weight in the 1st, 2d, 3d, and 4th experimental groups exceeded the control group by 67.0; 138.3; 21.3 and 62.7 g or 4.5; 9.4; 1.4 and 4.3 %.

As follows from the data obtained, the introduction of the obtained grain processing products into the poultry diet in the first week of experimental feeding contributed to an increase in the poultry growth rate compared to the control. In the following days of feeding, we observed a decrease in the relative growth rate of experimental broilers. It should be noted that the highest growth rate of poultry was observed in the 2 experimental group, which received wheat bran with zeolite particles treated with cavitation as part of feed.

For a more complete description of broiler growth, the average daily gain in live weight was calculated (table 6).

Table 6. Average daily gain in live weight of broiler chickens for the reference period, g

| Accounting week | control       | 1st experimental group | 2nd experimental group | 3rd experimental group | 4th experimental group |
|-----------------|---------------|------------------------|------------------------|------------------------|------------------------|
| 1               | 22.3±1.72    | 30.5±4.81              | 31.7±1.18              | 27.4±3.53              | 27.8±1.08              |
| 2               | 42.0±1.63    | 40.1±1.78              | 44.1±1.70              | 40.7±1.29              | 40.5±1.82              |
| 3               | 48.8±2.39    | 53.5±2.30              | 59.9±3.28              | 49.4±2.13              | 54.5±2.69              |
| 4               | 63.9±2.00    | 63.8±3.24              | 61.2±2.94              | 63.7±1.04              | 63.7±3.75              |
| 1–4             | 45.1±1.46    | 47.6±1.32              | 49.9±1.78              | 46.0±1.08              | 47.3±2.13              |

Note: *– P≤0.05 when compared with the control group;  
**– P≤0.05 when compared with the 2d group.

It can be seen from the data above that the average daily gain in live weight of broiler chickens in the experimental groups in the first and third weeks of experimental feeding was higher compared to the control group. So, for the first week of the accounting period, the significant difference with the 2d experimental group was 9.4 g or 42.0% (P≤0.05), with the 4th experimental group – 5.5 g or 24.6% (P≤0.05). For the third week, the average daily gain in the 2d experimental group exceeded the similar control indicator by 11.1 g or 22.7% (P≤0.05). No significant differences were found in the second and fourth weeks.

In general, over the entire growing period, the average daily weight gain in the 1st, 2d, 3d, and 4th experimental groups exceeded this indicator of the control group by 2.5; 4.8 (P≤0.05); 0.9 and 2.2 g or 5.5; 10.6; 2.0 and 4.9%.

Analysis of data on the absolute increase in live weight showed that the value of this indicator in the 1st experimental group exceeded the value in the control by 5.59%, in the 2d experimental group by 10.71% (P≤0.05), in 3d – by 2.0% and in 4th – by 5.01%.

The mechanism of action of cavitation on various types of surfaces is actively discussed by researchers [13,14]. In particular, ultrasound caused structural changes on the starch granules, mainly
in morphological changes in the granules and a decrease in crystallinity. A longer treatment significantly reduced the change in gelatinization enthalpy, bonding viscosity, gelability while increasing in vitro starch digestibility [15]. The use of hydrodynamic cavitation does not impair the fibrillar structure of cellulose but causes a displacement and partial removal of lignin during straw processing [16]. Cavitation [17], as well as extraction, [18] contributes to the release of biologically active substances from plants, which positively affects the productivity of birds when feeding these feeds.

4. Conclusion
Thus, we can conclude that the introduction into the diet of broiler chickens of the products of cavitation treatment of wheat bran, together with the zeolite, has a positive effect on the degree of digestibility of carbohydrates in the starting period.

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