Experimental studies on the evaluation of ultrasonic effects on the structure, composition and nutrition of sunflower husks

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Abstract. Today, the bulk of the sun generated in the food and processing industry (about 70%) is supplied to agriculture unchanged, and more than 10% is not used at all. The volume of aircraft waste annually in Russia is about 3.0 million tons and the problem of their use requires serious attention, since the content of dry substances in them is about 5-10%, they are very unstable during storage, quickly sour, ferment, losing valuable components and polluting the environment. Storing them in this state is possible only for 2-3 days. Therefore, it is undoubtedly relevant and necessary to increase the degree and depth of processing of raw materials, the complexity of its use, more complete extraction of valuable components from it with the use of progressive environmentally friendly technologies. The studies were carried out at the Federal State Budgetary Scientific Institution "Federal Scientific Center for Biological Systems and Agricultural Technologies of the Russian Academy of Sciences" and the Federal State Budgetary Educational Institution of Higher Education "Orenburg State University". In the course of the work, laboratory studies were carried out to assess the effect of cavitation treatment of sunflower husks on the chemical properties. Based on the studies carried out, it can be noted that the most pronounced changes in the chemical composition of sunflower husks are observed at pH3. So after processing in an acidic environment, the content of crude fiber is 35-40%, while the digestibility increases to 53.6%. In an alkaline medium, these values were on average 5-10% lower than in an acidic medium. The depth of interaction of cavitation treatment of sunflower husks depends on the exposure time, temperature and ultrasound intensity. It is technologically expedient to carry out cavitation treatment with the following parameters: hydromolule 1:3, medium temperature from 40 to 60 °C, time 15-20 minutes, ultrasound intensity 0.3-0.35 kW.

1. Introduction
A systematic approach to solving production problems is the most striking difference between the modern algorithm for planning technological processes from similar schemes of an industrial society. This fully applies to modern technological solutions for building production lines in industry. A significant mass of the substance remaining after the production of food is nothing more than a secondary resource and requires disposal or deeper processing for further use in animal feeding [1].

Numerous wastes from food production processes are potential sun exposure. Today, the bulk of the sun generated in the food and processing industry (about 70%) is supplied to agriculture unchanged, and more than 10% is not used at all. The volume of aircraft waste annually in Russia is about 3.0 million tons, and the problem of their use requires serious attention, since the content of dry substances in them is about 5-10%, they are very unstable during storage, quickly acidify, ferment losing valuable components and polluting the environment. Storing them in this state is possible only for 2-3 days. Therefore, it is undoubtedly relevant and necessary to increase the degree and depth of processing of...
raw materials, the complexity of its use, a more complete extraction of valuable components from it with the use of progressive environmentally friendly technologies [2-3].

The accumulated domestic and foreign experience in waste disposal is poorly used, and the small volume of capital investments in the development of waste processing facilities [4-5] also affects, therefore, it is relevant and necessary to increase the degree and depth of processing of raw materials, the complexity of its use, more complete extraction from its valuable components [7].

Sunflower husk is of particular interest for domestic livestock raising. This waste is a good source of valuable protein, second only in lysine to animal protein. The only drawback of this waste is the significant content of crude fiber from the husk.

Based on the literature data, it can be concluded that the most effective transformation of coarse raw materials, in particular cellulose, occurs with the simultaneous effect of pressure and temperature, that is, when using cavitation treatment, such an effect can be achieved using cavitation treatment [8-10]. The resulting products are fine mixtures that have the best characteristics in appearance and are unpretentious in storage. Receipt processing increases the digestibility of nutrients, improves the taste of the product, and suppresses the negative properties of raw materials.

Cavitation treatment of plant raw materials reduces the activity of hydrolyzing and redox enzymes. During the process of cavitation of inhomogeneous mixtures, the volume of the mixture increases, which is a consequence of the rupture of the cell walls and the destruction of the granule structure and the rupture of the molecular chain of cellulose, starch, etc. This increases the energy and feed value of the product [11-12]. During cavitation treatment of cellulose-containing components, denaturation of proteins is also observed, as a result of which the ratio of protein and non-protein nitrogen changes.

2. Materials and methods
The studies were carried out at the Federal State Budgetary Scientific Institution "Federal Scientific Center for Biological Systems and Agricultural Technologies of the Russian Academy of Sciences" and the Federal State Budgetary Educational Institution of Higher Education "Orenburg State University". In the course of the work, laboratory studies were carried out to assess the effect of cavitation treatment of sunflower husks on the chemical properties.

The following objects were selected for research: sunflower husk, which was selected at the grain processing enterprises of the city of Orenburg KHP-1, KHP-3 and a feed mill.

Before starting the research, a chemical analysis of sunflower husks was carried out according to generally accepted methods. The husk was ground in a laboratory mill to an equivalent particle diameter of 2.0-3.0 mm. Then the hydromodule of the product with water was prepared in the following ratio - (husk: water) 1: 3. The study of the effect of the pH-medium on the efficiency of ultrasonic hydrolysis was carried out by acidification with hydrochloric acid to pH from 3 to 1 unit, alkalinization with sodium hydroxide to pH 9-11 units.

The ultrasound parameters were selected in the range from 0.1 kW to 0.45 kW. Processing time from 5 to 20 minutes in 5 minute increments. The temperature of cavitation treatment of cellulose-containing mixtures was 20, 40, 60, 90 °C.

The obtained samples of fodder products after processing were dried in a thermostat at a temperature of 103-110 °C and subjected to mechanical grinding in a laboratory mill.

In the study of the chemical composition of the obtained products, the following methods were used: sampling was carried out according to GOST 13586.3-83, the content of the mass fraction of moisture in processed products and waste is determined according to GOST 13586.5-85, crude protein by the Kjeldahl method according to GOST 13496.4-84, the ash content is determined according to GOST 13496.16-75, the crude fat content is determined according to the classical method on a Soxhlet device according to GOST 13496.15-75, the crude fiber content is determined according to the method described in GOST 13496.2-84.

In the course of the research and study of the influence of technical characteristics, a device for cavitation processing of cellulose-containing raw materials was developed [13]. The device diagram is shown in figure 1.
1- body, 2- frame, 3- shock absorbers, 4- vibration exciter, 5,6- loading and unloading fittings, 7- working body, 8- power source.

Figure 1. General diagram of a device for processing cellulose-containing products.

The device works as follows. The crushed components of sunflower husk for the formation of a hydromodular mixture are fed through the nozzle 5 into the working body 1 mounted on the frame 2, through the shock absorbers 3, the vibration exciter 4, fixed coaxially under the cylindrical body 1. As a result of vibrations created by the vibration exciter 4 and the internal working body 7 made in the form of a pentagonal regular star-shaped pyramid made of piezoceramic material - a converter of electrical energy into ultrasonic waves, the components, the mixing process takes place. During the mixing process, an electric current is supplied to the working body 7 through the power source 8. Electricity, passing through a layer of piezoelectric material, is converted into mechanical energy, creating ultrasonic vibrations. Ultrasonic waves are generated using an electro-acoustic transducer, a piezoceramic material that converts the supplied electrical energy into mechanical vibrations by means of piezoelectricity or magnetostriction. When ultrasonic waves pass through the layer of inhomogeneities of the mixing mixture, cavitation bubbles are formed, the collapse of which causes the disintegration of large inclusions of the mixture. When colliding with the mirror surface of the cylindrical body 1, ultrasonic waves are reflected and also affect the mixture components. Moreover, the presence of a cylindrical mirror surface at the body eliminates the effect of loss, quenching, scattering of ultrasonic waves, and also leads to the appearance of a resonance effect. The finished mixture is discharged through the unloading fittings 6.

Thus, the installation contributes to the intensification of the mixing process both at the macro and micro levels, and, consequently, to a decrease in the duration of its cycle, by increasing the efficiency of ultrasonic waves, as well as increasing the efficiency of the process by increasing the degree of homogeneity of the mixture, which is achieved due to using an ultrasonic emitter.

The results obtained were statistically processed using generally accepted methods using the Excel application from the Microsoft Office XP and Statistica 6 software package, with the determination of the arithmetic mean, standard mean error and standard deviation. To identify statistically significant (significant) differences, the Student's test was used [14].

3. Results and discussions
Of practical importance is the development of a method that makes it possible to increase the nutritional value of cellulose-containing wastes in order to meet the needs of farm animals for essential nutrients in the form of simple carbohydrates [15].

When using waste from oil extraction plants for feed for farm animals in fodder production, a number of problems arise, the main of which is the low nutritional value of cellulose-containing waste. They contain mainly fiber, lignin and a small amount of protein. Sunflower husk is such a raw material.

Table 1 shows the chemical composition of sunflower husk obtained at the oil extraction plant in Orenburg.
Table 1. Chemical composition of sunflower husk.

| Name sample   | SV, % | SK, % | Lignin, % | Fat, % | Protein, % | Vit.E, mg/kg | Vit.A, mg/kg | Ash, % | K, % | P, % |
|---------------|-------|-------|-----------|--------|------------|--------------|--------------|--------|------|------|
| Sunflower husk| 85.74 | 55.93 | 23.12     | 4.32   | 9.41       | 26.52        | -            | 8.01   | 0.1  | 0.998|

Analysis of the data obtained showed that the content of crude fiber is 55.93%, fat - 4.32%, protein - 9.41%. Due to the high lignin content of 23.12%, it is possible to make an input that the availability of feed substances is at a low level. This is due to the fact that lignin is almost completely bound to fiber molecules and prevents the action of digestive enzymes of farm animals on the digestibility of cellulose. Based on the above, we can state the fact that the destruction of the bond between lignin and cellulose will increase the digestibility of nutrients in sunflower husks. This can be achieved by treating cellulose-containing waste with physical methods that are safe for the animal body.

The authors proposed a cavitation method for processing sunflower husks with the introduction of hydrochloric acid and sodium hydroxide. At the same time, a rupture of bonds between lignin and cellulose molecules is observed, physicochemical and rheological changes occur in the carbohydrate complex of the husk [16-17].

The physical effects of cavitation processes lead to the formation of simple monocarbohydrates, as well as to the partial dissolution of cellulose, hydrolysis of proteins and fats. All this makes it possible to increase the digestibility and nutritional value of substances that are part of the sunflower husk [18].

When carrying out cavitation treatment of sunflower husks at different pH and temperature conditions, the structure of the husk is destroyed, becomes loose, homogeneous, the initial chemical composition changes. With an increase in the intensity of ultrasound, the amount of water-soluble substances increases.

Figures 2 and 3 show graphical dependences of changes in the yield of water-soluble substances depending on temperature at pH 8 and 3.
Based on the data obtained, it can be stated that, regardless of the pH of the medium, an increase in the intensity of ultrasound above 0.35 kW does not lead to an increase in the amount of simple water-soluble substances. At the same time, a decrease in the efficiency of cavitation processes is observed with an increase in the temperature of the treated medium above 60 °C.

Table 2 presents the results of a study on the effect of ultrasonic cavitation on the content of crude fiber and lignin.

Table 2. Influence of ultrasound on the content of the main components in sunflower husk.

| Product content | Duration of cavitation treatment, min |
|-----------------|--------------------------------------|
|                 | 0 | 5 | 7.5 | 9 | 10.0 | 12.5 | 15.0 | 20 |
| Raw cellulose, %| 55.93 | 50.43 | 48.58 | 46.73 | 45.85 | 44.32 | 43.58 |
| Lignin, %       | 23.12 | 20.13 | 18.73 | 16.93 | 17.93 | 18.01 | 18.63 |

The experimental data given in table 2 indicate that in the first 10-12 minutes there is an intensive hydrolysis of cellulose and destruction of lignin. After 12 minutes, a reverse process is observed for lignin, which is most likely associated with the catalytic effect of the polymerization reaction of this substance. This is due to the formation of free radical groups H and OH, which are formed during cavitation hydrolysis of cellulose-containing polymers.

To study the effect of cavitation on the microbiological contamination of sunflower husk, we conducted a study to determine the content of mesophilic aerobic and facultative anaerobic microorganisms (CMAPAnM) of sunflower husk under various processing modes.

Table 3. The number of mesophilic aerobic and facultative anaerobic microorganisms (KMAFAAnM) in husk samples, CFU/g.

| Ultrasonic treatment mode | Duration of ultrasonic treatment, min |
|--------------------------|--------------------------------------|
|                          | 5 | 7.5 | 9 | 10.0 | 12.5 | 15.0 | 20 |
| Intensity - 0.2 kW, t = 20 °C | 8·10^7 | 7·10^7 | 6·10^8 | 6·10^8 | 8·10^7 | 7·10^7 |
| Intensity - 0.2 kW, t = 40 °C | 3·10^7 | 5·10^7 | 4·10^7 | 6·10^6 | 5·10^6 | 7·10^6 | 6·10^6 |
| Intensity - 0.2 kW, t = 60 °C | 2·10^7 | 2·10^7 | 8·10^6 | 6·10^6 | 8·10^6 | 7·10^6 | 9·10^6 |
| Intensity - 0.3 kW, t = 20 °C | 8·10^6 | 7·10^6 | 9·10^5 | 6·10^4 | 8·10^4 | 2·10^4 | 7·10^3 |
| Intensity - 0.3 kW, t = 40 °C | 7·10^6 | 9·10^5 | 6·10^5 | 5·10^4 | 3·10^4 | 8·10^3 | 7·10^3 |
In the course of the conducted microbiological studies, the number of microorganisms in 1 g of sunflower husk was counted. The number of mesophilic aerobic and facultatively anaerobic microorganisms in the samples not treated with ultrasound was $10\times10^7$ CFU/g. With technological parameters of power $-0.4$ kW, temperature of the treated medium from 20 to 60 °C, processing time from 12.5 to 20 minutes, complete depletion of sunflower husks was observed.

Solving the problem of increasing the digestibility and assimilability of hard-to-translate carbohydrates - sunflower husk, can be done by cavitation treatment at different pH of the medium [19-20].

The process of cavitation treatment is used to purposefully change the chemical composition of polymeric carbohydrates, converting cellulose into dextrins and simple sugars. The combined effect of physical and chemical factors that occur during cavitation treatment cause quantitative and qualitative changes in the structure of carbohydrates. We have proposed the use of joint acid-base cavitation treatment, which makes it possible to quantitatively change the digestibility of indigestible carbohydrates and thereby increase the nutritional value of sunflower husks from 14.4% to 53.6%.

Figure 4 shows the dependence of the in vitro digestibility of dry matter of sunflower husk on the type of processing.

![Digestibility vs Processing Time](image)

**Figure 4.** Studies have shown that when hydrochloric acid is introduced to pH 3.

### 4. Conclusion

Based on the studies carried out, it can be noted that the most pronounced changes in the chemical composition of sunflower husks are observed at pH 3. So, after treatment in an acidic medium, the content of crude fiber is 35-40%, while the digestibility increases to 53.6%. In an alkaline medium, these values were on average 5-10% lower than in an acidic medium [21].

The depth of interaction of the cavitation treatment of sunflower husk depends on the exposure time, temperature and ultrasound intensity. It is technologically expedient to carry out cavitation treatment with the following parameters: hydromolule 1: 3, medium temperature from 40 to 60 °C, time 15-20 minutes, ultrasound intensity 0.3-0.35 kW.
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