Sunflower husk processing technology for fodder production

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Abstract. The article considers the possibilities of environmental protection from agricultural waste - sunflower husks. A technology for processing this waste from the oil extraction industry into a feed product using ultrasonic treatment (cavitation) is proposed. The chemical changes of this product after processing, including nutritional value, were studied. The indicators of the use of this product under the conditions of incubation of an analogue of the rumen of ruminants were studied. Positive changes in the chemical composition of the processed product and its more active fermentation in the ruminal fluid of ruminants were revealed.

1 Introduction

Agriculture generates a significant amount of waste, for example, in the production of vegetable oils (sunflower husks). Food waste per year is approximately 30% for cereals, 40–50% for root crops, fruits and vegetables, and 20% for oilseeds, meat and dairy products [1]. Due to the lack of biological stability, the high content of indigestible substances (lignin), water, and the ability to rapidly oxidize [2], waste disposal is often a difficult task. Thus, the application of pulsed electric field treatment prior to solid-liquid extraction may represent a sustainable approach to the extraction of natural compounds from aromatic plants and food by-products [3]. Hydrodistillation using microwaves makes it possible to extract more volatile hop fractions [4]. As for sunflower husk, it is known to be used in the production of biochar to change the water-retaining characteristics of arable sandy soil [5]. Husk can be an alternative fuel with a relatively high calorific value [6]. Pig diets based on sunflower husks were rated as less harmful as they affect the chemical composition and smell of slurry [7].

2 Materials and methods

The object of research is sunflower husk. Husk treatment was carried out using an ultrasonic disperser under the following modes: preliminary mechanical grinding of husk (1-2 mm) + hydromodule (water) + ultrasonic treatment at 20 C, 15 minutes, 27 kHz; sample 3 - sample 2 + UHF Zn at a dosage of 3.0 mg per 1 kg of dry matter; sample 4 -

sample 2 + CoCl2 at a dosage of 1.5 mg per 1 kg of DS. UHF zinc particles (Zn - size 110 nm, Zn content 90%) were used for the study (table 1).
Ultrafine zinc particles (Zn size 110 nm, Zn content 90%) were used for the study. Cobalt chloride (CoCl2) (OOO "NPK "Askont+", Moscow region, Russia). Before inclusion in the diet, the particles were dispersed in saline.

Table 1. Experiment scheme.

Sample	Treatment
1	Mechanical grinding
2	Mechanical grinding + hydro module (water) + ultrasonic treatment at 20 C, 15 minutes, 27 kHz
3	Mechanical grinding + hydromodule (water) + ultrasonic treatment (20 °C, 15 minutes, 27 kHz) + Zn 3.0 mg
4	Mechanical grinding + hydromodule (water) + ultrasonic treatment (20 °C, 15 minutes, 27 kHz) + $CoCl_2$ 1.5 mg

The study of the chemical composition of the test samples was carried out after incubation by the in vitro method using the "ANKOM DaisyII" incubator (modifications D200 and D200I) according to a specialized method. Distilled water was chosen as the dispersion medium. Each experiment was carried out in four repetitions. In the substrates after incubation, the mass fraction of dry matter (GOST 31640-2012), crude protein (GOST 13496.4-2019), mass fraction of crude fat (GOST 13496.15-2016), mass fraction of crude fiber (GOST 31675-2012), mass fraction of crude ash (GOST 26226-95). As a substrate, cicatricial contents obtained from bulls of the Kazakh white-headed breed with a chronic fistula of the scar, with an average weight of 240-245 kg, at the age of 11-12 months, were used.
Laboratory studies were carried out at the Testing Center of the Central Collective Use Center of the Federal Scientific Center of the BST RAS: the level of volatile fatty acids (VFA) in the contents of the rumen was determined by gas chromatography on a gas chromatograph "Crystallux-4000M", determination of nitrogen forms according to GOST 26180-84.
Statistical analysis. Numerical data were processed using the SPSS "Statistics 20" program ("IBM", USA), the means (M), standard deviations (±σ), standard deviation errors (±SE) were calculated. The variants were compared using a nonparametric method of analysis. Differences were considered statistically significant at $p \leq 0.05$.

3 Results

As a result of the evaluation of the chemical composition of the test samples, it was found that after incubation, compared with the control sample, in experimental 2, 3 and 4 samples, an increase in dry matter was noted by 1.72%, 2.63% and 2.83%, respectively (table 2).
The level of crude protein relative to the control was higher in sample 4 by 1.71%. Cavitation treatment of sample 2 and inclusion of Zn in sample 3 reduced the content of crude protein in the feed substrate.
Differences in the content of crude fiber in the control and experimental groups were not significant (no more than 0.5%), but there was a tendency to increase this indicator relative to the control.

In sample 2 (mechanical grinding + hydromodule (water) + ultrasonic treatment at 20 C, 15 minutes, 27 kHz), a decrease in the content of crude fat (CF) by 1.9% was recorded when compared with the control. The additional inclusion of the chemical elements Zn and CoCl2 in samples 3 and 4 increased the content of crude fat by 1.4% and 1.5% relative to sample 2, however, relative to the control, the content of crude fat in these samples was lower.

Table 2. Chemical composition of sunflower husks in vitro (M±m, n = 12), %.

Index	1	2	3	4
Dry matter	22.52±0.13	24.24±0.14	25.15±0.14	25.35±0.15
Crude pro-tein	7.51±0.04	5.46±0.03*	6.37±0.04	9.22±0.05*
Crude fiber	56.61±0.25	56.97±0.33	57.05±0.33	56.68±0.33
Raw ash	3.94±0.02	3.94±0.02	4.04±0.02	4.24±0.02
Crude fat	2.41±0.01	0.51±0.001*	1.86±0.01*	1.97±0.01*

When the resulting product was incubated in an incubator, cavitation treatment of the husk increased the concentration of volatile fatty acids in the rumen fluid by 44.4% relative to the control, while the level of acetic acid increased by 43.3% ($p \leq 0.05$), propionic acid by 49.3 % ($p \leq 0.05$), oil by 40.4%, valerian by 31.9%, caproic by 16.7% (table 3).

Table 3. The level of volatile fatty acids in the rumen fluid when using sunflower husks (M±m, n=12), mg/l.

Sample	Volatile fatty acids, mg/l				
	Acetic	Propionic	Oily	Valerian	Caproic
1	56.4±0.06	58.3±0.08	51.3±0.06	4.12±0.08	0.9±0.04
2	99.5±0.09*	114.9±0.10*	86.1±0.02*	6.05±0.04	1.08±0.06
3	129.9±0.12*	160.8±0.04**	113.7±0.10**	7.49±0.04*	1.11±0.11
4	145.2±0.18*	185.7±0.04**	125.4±0.09**	8.25±0.04*	1.11±0.12

The introduction of UHF zinc at a dosage of 3.0 mg against the background of the use of treated sunflower husks showed an increase in the level of volatile fatty acids relative to the control sample: acetic acid by 56.6% ($p \leq 0.05$), propionic acid by 63.7% ($p \leq 0.05$), butyric acid by 54.9% ($p \leq 0.05$), caproic acid by 18.9%, valeric acid significantly decreased by 45%.

The inclusion of CoCl2 at a dosage of 1.5 mg significantly increased the concentration of acetate, propionate, butyrate and valeric acid by 61.2% ($p \leq 0.05$), 68.6% ($p \leq 0.01$), 59.1% ($p \leq 0.01$) and 50.1% ($p \leq 0.05$) relative to the control. The level of total nitrogen in the test samples relative to the control decreased by 15.2% in 2, 16.2% in 3, 25.7% in 4 samples.

The level of protein nitrogen in the rumen fluid of the experimental samples, when compared with the control, tended to decrease: in the 2nd sample, this indicator was lower by 1.3%, in the 3rd by 2.6%, in the 4th by 6.6% ($p \leq 0.05$).

4 Discussion

The high-energy microenvironment created by cavitation largely contributes to the rapid deconstruction of biomass with low energy consumption, and promotes the release of biologically active substances, fatty acids [8]. In our experiment, cavitation treatment of husks increased the content of chemicals and the concentration of volatile fatty acids in the rumen fluid. Similar effects were established earlier by researchers in the ultrasonic treatment of other by-products [9-10]. The decrease in protein substances can be explained by the ability of the husk to absorb nitrogen-containing substances [11]. An increase in the nutritional value of the feed subjected to cavitation was previously established when receiving a feed product based on vegetable oil extraction waste enriched with zeolite powder, and the effectiveness of its use in poultry feeding was shown [12]. In addition, cavitation treatment can cause the death of the microflora of feed additives, at the same time, as a result of the dissociation of a complex of organic polymers that contribute to a positive reaction of probiotic strains [13], thereby improving the nutritional value of the feed. It is also known that cavitation treatment of a fat-containing product formed as a result of sunflower processing, against the background of its enrichment with zeolite particles in the composition of feed mixtures, leads to an increase in the content of macro- and microelements with a significant decrease in antagonist elements [14-15].

5 Conclusion

Additional processing of sunflower husks improves the nutritional value of the feed product by increasing the content of dry matter, crude protein and crude fiber. The use of the resulting product increases the level of volatile fatty acids, which indicates an increase in metabolic processes in the ruminal fluid of ruminants.

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References

1. Food and Agriculture Organization of the United Nations. Key Facts on Food Loss and Waste You Should Know! Retrieved from Food and Agriculture Organization of the United Nations. Retrieved from: http://www.fao.org/save-food/resources/keyfindings/en (2016)
2. L. Barbosa-Pereira, A. Bilbao, P. Vilches, I. Angulo, J. Luis, B. Fité, P. Paseiro-Losada, J.M. Cruz. Brewery waste as a potential source of phenolic compounds: optimisation of the extraction process and evaluation of antioxidant and antimicrobial activities. Food Chem. 145, 191-197 (2014)
3. S. Carpentieri, A. Režek Jambrak, G.Ferrari, G. Pataro. Pulsed Electric Field-Assisted Extraction of Aroma and Bioactive Compounds From Aromatic Plants and Food By-Products. Front Nutr. 27(8), 792203 (2022)
4. L. Lamberti, G. Grillo, L. Gallina, D. Carnaroglio,F. Chemat, G. Cravotto icrowave-Assisted Hydrodistillation of Hop (Humulus lupulus L.) Terpenes: A Pilot-Scale Study. Foods. 10(11), 2726 (2021)
5. L. Gluba, A. Rafalska-Przysucha, K. Szewczak, M. Łukowski, R. Szlązak, J. Vitková, R. Kobyłecki, Z. Bis, M. Wichliński, R. Zarzycki, A. Kacprzak, B. Usowicz Effect of Fine Size-Fractionated Sunflower Husk Biochar on Water Retention Properties of Arable Sandy Soil. Materials (Basel). 14(6), 1335 (2021)

6. T. Turzyński, J. Kluska, M. Ochnio, D. Kardaś . Comparative Analysis of Pelletized and Unpelletized Sunflower Husks Combustion Process in a Batch-Type Reactor. Materials (Basel). 14(10), 2484 (2021)
7. C.T. Mpendulo, V.A. Hlatini, C.N. Ncobela, M. Chimonyo. Effect of fibrous diets on chemical composition and odours from pig slurry. Asian-Australas J Anim Sci. 31(11), 1833-1839 (2018)
8. G. Grillo, L. Boffa, A. Binello, S. Mantegna, G. Cravotto, F. Chemat , T. Dizhbite, L. Lauberte, G. Telysheva. Cocoa bean shell waste valorisation; extraction from lab to pilot-scale cavitational reactors. Food Res Int. 115, 200-208 (2019)
9. K. Asgari, M. Labbafi , F. Khodaiyan, M. Kazemi, S.S. Hosseini. High-methylated pectin from walnut processing wastes as a potential resource: Ultrasound assisted extraction and physicochemical, structural and functional analysis. Int J Biol Macromol. 152, 1274-1282 (2020)
10. C.A. Bizzi, D. Santos, T.C. Sieben, G.V. Motta, P.A. Mello, E.M.M. Flores. Furfural production from lignocellulosic biomass by ultrasound-assisted acid hydrolysis. Ultrason Sonochem. 51, 332-339 (2019)
11. L. Xu, J. Su, A. Ali, T. Huang , Y. Yang, J. Shi, E. Liang. Magnetite-loaded rice husk biochar promoted the denitrification performance of Aquabacterium sp. XL4 under low carbon to nitrogen ratio: Optimization and mechanism. Bioresour Technol. 348, 126802 (2022)
12. A.V. Bykov. IOP Conf. Ser.: Earth Environ. Sci. 624 012191(2021)
13. A. Bykov , O. Kvan, I. Gavrish. Cavitation treatment as a means of modifying the antibacterial activity of various feed additives. Environ Sci Pollut Res 26, 2845–2850 (2019)
14. A. Bykov, L. Mezhueva, Kh. Dusaeva, T. Krakmaleva, E. Maneeva. Effects of fat-containing feed after ultrasound treatment with zeolite on the metabolism. E3S Web Conf. 164, 06020 (2020)
15. A.V. Bykov, O.V. Kvan, G.K. Duskaev The influence of cavitation processing on biotechnological aspects of feed application. Paper presented at the IOP Conference Series: Earth and Environmental Science. 624(1), 012192 (2021)