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INFLUENCE OF THE PROCESS OF EXTRUDING ON THE VITAMIN AND MINERAL COMPOSITION OF GRAIN FEED

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Abstract

The article presents the results of studies on the effect of the extrusion process on the vitamin and mineral composition of grain feed. The control (CON) was a sample a mixture of raw grain (80% barley and 20% wheat), it was compared with 3 samples: extruded raw grain (Ext), raw materials with the inclusion of a premix before the extrusion process (CON+P+b), extruded raw material with the inclusion of a premix after the extrusion process (Ext+P+a). The preparation of extruded samples was carried out on an extruder with a capacity of 350 kg/h using a granulator at a temperature of 100-105 °C, a pressure of 30-50 atm., an exposure time of 3-5 seconds. The result of our research showed that in the Ext sample, the number of vitamins decreased by an average of 2.8 times, the mineral composition decreased by 7%. In the CON+P+b sample, the vitamin composition remained practically at the same level. In the Ext+P+a sample, the vitamin composition increased by 58% compared to Ext, and the mineral content became higher than in CON by an average of 20%. According to the results of our research, it is recommended to include a

premix after the extrusion process in the production of compound feed, as this contributes to a greater preservation of vitamins and increases the mineral composition.

Key words: extrusion; feed composition; premix; vitamins; minerals.

Introduction

In his comprehensive review titled "Redefining the Prospects of Utilizing Catering Waste in Animal Diets" Georganas A. asserts that food waste represents a highly promising resource for feed production. Nevertheless, its application in animal and bird feeding has been limited due to potential risks associated with various infections. To address this concern and mitigate the biological hazards, several methods have been explored, with extrusion emerging as one of the most effective approaches. Extrusion not only enhances the overall hygiene of the feed but also significantly reduces the presence of pathological microorganisms in the raw materials, yielding promising results in most instances [1]. For instance, Kelley T.R., while determining the bactericidal contamination, observed the absence of bacterial colonies in all sampled feeds. However, at the same time, the study highlights that some non-specific aerobic microorganisms do proliferate successfully in the feeds after extrusion. Consequently, the further contamination of the feeds depends on the storage conditions they are subjected to [2]. Authors such as Alonso R. and Decker E. A. state that apart from enhancing feed hygiene, extrusion also brings about modifications in the composition of nutrients, reduces the presence of anti-nutritional factors, and improves the efficient utilization of feed nutrients [3, 4]. In their work, Wang M. states that extrusion can be utilized for the production of feeds from microalgae. The results of the research revealed that cell disruption during the extrusion process led to a significant increase in lipid content by 94.3%, sugars by 68.7%, polyunsaturated fatty acids by 74.3%, and essential amino acids by 20.5%. These differences were found to be statistically significant compared to the control group of algae that did not undergo extrusion [5]. In his study, Williams, S.M. states that extrusion improves the digestibility of dry matter and the metabolic energy utilization [6]. We have also conducted several studies on the application of extruded feed on animals, and positive results have been obtained. In all these studies, the control group was fed with conventional feed without the extrusion process [7-11]. We became interested in examining how the extrusion process affects the mineral and vitamin composition of concentrated compound feed, which became the goal of this study.

In carrying out research during extrusion, a new granulator nozzle was used, which made it possible to reduce the temperature regime of extrusion and increase the productivity of the extruder. There is no data on the use of this method of extrusion, as well as no information about its effect on the vitamin and mineral composition of the feed, which is also a scientific novelty.

Materials and Methods

The goal of this study is to determine the influence of the extrusion process on the vitamin and mineral composition of the feed.

The extruded feed was produced at the university's platform. To achieve the goal, we produced 4 feed samples:

1 CON: Whole grains, mixture in the ratio of 20% wheat and 80% barley (raw material);

2 Ext: Extruded Raw Material;

3 CON+P+b: Raw material with the addition of a premix *before* the extrusion process;

4 Ext+P+a: Extruded raw material with the addition of a premix *after* the extrusion process.

The CON sample was prepared by blending whole grains, 20% wheat, and 80% barley, which were also used as raw materials for other samples. For the Ext sample, the extrusion of the CON sample was performed using a granulator with a matrix hole diameter of 8 mm, at an extruder temperature of 100-105 °C, pressure of 30-50 atm., and a processing duration of 3-5 seconds.

The CON+P+b sample utilized the same raw materials as the CON sample, but with the addition of a vitamin-mineral premix according to the dosage suggested by the manufacturer, 10-12 g per 100 g of feed. The ingredients were mixed in a paddle mixer and then subjected to extrusion under the aforementioned conditions.

As for the Ext+P+a sample, it was produced by employing the raw materials used in the Ext sample. After the extrusion process, a vitamin-mineral premix was added according to the dosage suggested by the manufacturer, 10-12 g per 100 g of feed, and the mixture was further blended in the mixer.

An application (patent No. 2023/0077.1) has been submitted for the proposed manufacturing technique titled "Method for the Preparation of Resource-Efficient, Highly Digestible Compound Feed for Rumen Development in Animals."

A large number of premixes for various types of animals are available on the market. Since our objective was not to assess the quality of a specific commercial premix (thus, its name is not mentioned), we randomly selected a commercial premix for analysis. The manufacturer of this premix did not provide numerical values for the proportions or volumes of vitamins and minerals in the composition. To gather this information, we visited the manufacturer's website [12], where the following details regarding the premix composition were provided (Table 1).

Table 1 - Vitamin and mineral composition of the premix used in the study

Indicators	Units rev.	Quantity per 1 kg of premix
Vitamins		
A	IU	1 400 000
E	g.	1
K	g.	0,2
H	mg.	20

D3	IU	300 000
B1	g.	0,4
B12	mg.	5
B2	g.	0,6
B3	g.	4
B4	g.	50
B5	g.	4
B6	g.	0,8
Minerals		
Fe	g.	2
Mn	g.	10
Cu	g.	0,5
I	g.	0,14
Co	g.	0,2
Zn	g.	12

The situation on the market is such that the composition of premixes is not monitored according to any state standard, the manufacturer also indicates the presence of a filler (waste from flour milling), the inclusion of amino acids, but there is no exact amount in the composition of the finished premix on the website.

Mineral and vitamin analysis was carried out in the laboratory of Almaty Technological University, the arithmetic mean and its error are also indicated in the protocols received from the laboratory.

Results

It is a well-known fact that vitamins do not carry any nutritional component in the feed (i.e. they have an energy function), however, in their absence, many biological processes of the body are disturbed. Vitamins are involved in the formation and maintenance of tissues, regulate metabolism, are part of enzymes and much more. Their distinctive property is that they can accumulate in the body, and then consumed when they are deficient in diets. However, it must be remembered that each vitamin in the body plays a role and cannot be replaced by others. Table 2 shows the chemical analysis of samples by vitamin composition.

Table 2 - Analysis of samples by vitamin composition, mg/100 g

Vitamins	Samples			
	CON	Ext	CON+P+b	Ext+P+a
E	18,6±2,9	9,02±1,2	10,3±1,7	11,86±2,0
B1	0,191±0,038	0,068±0,007	0,072±0,014	0,076±0,015
B2	0,102±0,043	0,068±0,014	0,069±0,029	0,080±0,034
B6	0,147±0,029	0,057±0,029	0,058±0,012	0,112±0,022
C	0,755±0,257	0,252±0,086	0,254±0,086	0,473±0,161

B3	0,329±0,066	0,080±0,016	0,102±0,023	0,135±0,027
B5	0,107±0,019	0,021±0,004	0,029±0,011	0,040±0,007

As we can see, the extrusion process negatively affects the vitamin composition. The extrusion process reduces the level of vitamin B2 by one and a half times, reduces the level of vitamin E by two times, B1, B6 and C by almost three times, B3 and B5, B2 by four times. On average, the level of vitamins decreases by 2.8 times. In the CON+P+b sample, the average vitamin levels increased by approximately 13%. The most significant increases between the Ext and CON+P+b samples were observed for vitamin E, with a retention rate of 14%, vitamin B3 increased by 28%, and vitamin B5 increased by 38%. The inclusion of the premix before extrusion had little effect on the levels of vitamin C, B2, and B6, while vitamin B1 increased by only 6%.

The modification of the feed manufacturing process, specifically changing the sequence to include the premix after extrusion, significantly alters its vitamin composition. This method is considered gentle or sparing for preserving the vitamins present in the feed. In the Ext+P+a sample, the average increasing of vitamin level was approximately 58%, which is 45% higher than in the CON+P+b sample. Compared to the Ext sample, there was a substantial B6 vitamin's increase of 96%, B5 – 90% and C – 88%. Vitamins E, B1, and B2 were preserved at levels ranging from 12% to 32%, while vitamin B3 was retained at nearly 70%. The overall difference in the total vitamin content between the CON+P+b and Ext+P+a samples was 45%. Consequently, altering the stage of including the premix in the feed, specifically after extrusion, can increase vitamin retention by up to two times.

The mineral composition of feed is one of the limiting factors affecting the animals' productivity. Because minerals are essential components of the body's structural systems, cells, tissues, and so on, and they participate in biochemical processes at all levels. Despite their regulatory abilities in terms of accumulation, mineral homeostasis is not unlimited. Table 3 provides the analysis of the samples regarding their mineral composition.

Table 3 - Analysis of samples by mineral composition, mg/100 g

Minerals	Samples			
	CON	Ext	CON+P+b	Ext+P+a
Ca	1,7±0,01	1,5±0,02	1,6±0,01	2,0±0,03
Mg	138,42±0,51	125,81±0,40	128,52±0,71	149,63±0,35
Na	39,9±0,12	39,18±0,13	42,77±0,10	48,59±0,08
Fe	7,03±0,05	6,52±0,02	6,72±0,04	7,43±0,01
P	412,15±2,14	397,03±1,13	401,64±2,10	486,97±3,12
Zn	3,12±0,05	2,87±0,03	3,01±0,05	3,15±0,04
Cu	0,475±0,010	0,497±0,011	0,505±0,009	0,919±0,012
I	0,007±0,0001	0,006±0,0002	0,007±0,0001	0,008±0,0002

The chemical determination of the feed's mineral composition involves measuring the amount of ash, which is obtained by burning a sample of the feed in a muffle furnace at temperatures between 460-500°C. The raw ash content is considered an indicator of the level of mineral substances in the feed. During extrusion, the feed is not exposed to such high temperatures, but it experiences high pressure, leading to the disruption of double bonds and the degradation of feed components.

As expected, extrusion reduces the mineral content of the feed, on average, by only 7%. The most vulnerable minerals to extrusion were Ca and I, with reductions of 14% and 12%, respectively. Minerals such as Mg, Fe, and Zn were less affected, experiencing reductions of 7% to 9%, while other minerals decreased by only 2%. The average difference between the Ext and CON+P+b samples was 6%. Nearly all minerals returned to their initial levels, and in some cases, Na and Cu even surpassed the levels in the CON sample. The difference between the Ext and Ext+P+a samples was +31% when compared to CON and +21% when compared to Ext.

Discussions

It is well-known that thermal treatment affects the nutrient content of feed, especially when combined with high pressure. Similar studies conducted by researchers worldwide have explored the impact of extrusion on the nutritional content of feed materials.

Rodrigues E.J.D. et al. conducted studies on the protection of mineral composition in tilapia feed. The polymer to protect the apparent digestibility coefficient of calcium and phosphorus was used before the extrusion and granulation process, during the extrusion and granulation process itself, the absence of polymer in the feed served as a control. The result showed that polymer incorporation prior to the extrusion process resulted in higher values of apparent calcium and phosphorus digestibility compared to the method of polymer incorporation during extrusion and no polymer incorporation ($P<0.05$) [13].

In our research, we have observed a decrease in the content of vitamins, while we have found a large number of articles that indicate that the extrusion process changes the nutrients of the feed and its digestibility.

Costa M.M. et al. in their article write that the blue-green algae Arthrospira platensis is an excellent source of protein. The objectives of the study were to determine which of the types of pre-treatments for feed (grinding, extrusion, heating, microwaves, etc.) would have a greater effect on the level of algae protein. As a result of the study, it was determined that there was no significant difference between the types of influences, however, extrusion increased the associated protein. In addition, extrusion and microwaves resulted in a reduction in total protein, Costa M.M.

relates this to protein denaturation. Thus, they concluded that extrusion is one of the promising methods for pretreatment of algae to destroy cell walls [14].

Liao K. et al. write that extrusion improves the apparent digestibility of ADP and NDP (P<0.05). Also, in these studies, the results of changes in other nutrients (protein and starch) were also presented. Liao K. concludes that extrusion is one of the best feed pretreatment methods [15].

Dust J.M. writes in his article that extrusion can change the amount and type of fiber in the feed or improve the quality of fiber and its fractions, the results of his study indicate that after extrusion the amount of crude fiber decreased, but the amount of soluble fiber increased (P<0.05) [16].

Cargo-Froom C.L. et al. conducted their study showed that extrusion increases the amount of crude protein in peas and lentils (P<0.05), methionine in chickpeas and lentils (P<0.05), cysteine in peas (P<0.05), in other words, it has a positive effect on the protein and amino acid content of legumes [17]. Murray S. M. et al. report that extrusion can increase the gelatinization of starch, making it more digestible [18].

Conclusions

Considering the results of the study and literature, extrusion is one of the best methods of feed pre-treatment, which improves the overall status of the feed. The results of our study indicate a decrease in the content of vitamins in raw materials after extrusion by an average of 2.8 times, and a decrease in the mineral composition by 7%. If the premix is added to the raw material before the extrusion process, the content of vitamins remains practically at the same level. In the feed with the addition of the premix after the extrusion process, an increase in the vitamin composition by 58% was observed compared to the extrudate without the premix, and the mineral content exceeded the average by 20%. According to the results of the study, it is recommended to include a premix after extrusion in the production of compound feed, as this contributes to the preservation of vitamins and an increase in the content of minerals in the compound feed.

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ДӘНДІ АЗЫҚТЫҢ ВИТАМИНДІ-МИНЕРАЛДЫҚ ҚҰРАМЫНА ЭКСТРУЗИЯ ҮРДІСІНІҢ ӘСЕРІ

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Түйін

Мақалада дәнді азықтың витаминді-минералды құрамына экструзия үрдісінің әсері туралы зерттеулердің нәтижелері берілген. Бақылау (CON) астық шикізатының (80% арпа және 20% бидай) қоспасынан алынған үлгі болды, ол 3 үлгімен салыстырылды: экструдталған астық шикізаты (Ext), экструзия үрдісіне дейін премикс қосылған шикізат (CON+P+b), экструзия үрдісіне дейін премикс қосылған экструдталған шикізат (Ext+P+a). Экструдталған үлгілерді дайындау өнімділігі 350 кг/сағ экструдерде 100-105 °C температурада, 30-50 атм қысымда, 3-5 секунд экспозиция уақытында грануляторды қолдану арқылы жүзеге асырылды. Біздің зерттеулеріміздің нәтижесі Ext үлгісінде витаминдердің мөлшері орта есеппен 2,8 есеге, минералдық құрамы 7%-ға төмендегенін көрсетті. CON+P+b үлгісінде витаминдік құрамы іс жүзінде бұрынғы деңгейде қалды. Ext+P+a үлгісінде дәрумендердің құрамы Ext-мен салыстырғанда 58%-ға өсті, ал минералдық құрамы CON-ға қарағанда орта есеппен 20%-ға жоғары болды. Біздің зерттеулеріміздің нәтижелері бойынша дәнді азық өндірісінде экструзиялық үрдісінен кейін премиксті қосу ұсынылады, өйткені бұл витаминдердің көбірек сақталуына ықпал етеді және дәнді азықтың минералды құрамын арттырады.

Кілт сөздер: экструзия; азық құрамы; премикс; витаминдер; минералдар.

ВЛИЯНИЕ ПРОЦЕССА ЭКСТРУДИРОВАНИЯ НА ВИТАМИННО-МИНЕРАЛЬНЫЙ СОСТАВ ЗЕРНОВОГО КОРМА

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Аннотация

В статье представлены результаты исследований по влиянию процесса экструдирования на витаминно-минеральный состав зернового корма. Контролем (CON) служила проба из смеси зернового сырья (80% ячменя и 20% пшеницы), его сравнивали с 3-мя пробами: экструдированное зерновое сырье (Ext), сырье с включением премикса до процесса экструдирования (CON+P+b), экструдированное сырье с включением премикса после процесса экструдирования (Ext+P+a). Подготовка экструдированных проб проводилась на экструдере производительностью 350 кг/ч с использованием грануляторной установки при температуре 100-105°С, давлении 30-50 атм., продолжительностью воздействия 3-5 секунд. Результат наших исследований показал, что в пробе Ext снизилось количество витаминов, в среднем 2,8 раз, минеральный состав снизился на 7%. В пробе CON+P+b витаминный состав остался практический на том же уровне. В пробе Ext+P+a витаминный состав повысился на 58% по сравнению с Ext, а минеральный стал выше, чем в CON в среднем на 20%. Согласно результатам наших исследований рекомендуем при производстве кормов включать премикс после процесса экструдирования, так как это способствует большему сохранению витаминов, и повышает минеральный состав корма.

Ключевые слова: экструдирование; состав корма; премикс; витамины; минералы.