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USING RAW POTATO PEEL IN THE PRODUCTION OF EXTRUDED FEED ADDITIVE

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Abstract. The paper is concerned with some aspects of processing raw potato peelings. It presents the dynamics of potato production in the world and in Ukraine, and analyses the figures on yields of this crop. Methods of processing potatoes at Ukrainian enterprises have been considered. It has been found that the bulk of the waste (15–60%) is formed during peeling raw potatoes. Methods of utilisation of potato peelings have been analysed. Problems of using fresh potato peel in the diet of farm livestock have been analysed. The technological operations of potato waste processing have been considered, and it has been substantiated how practical the method of extrusion is. The advantages of manufacturing an extruded feed additive with the use of potato peel have been shown. The physical properties, chemical composition, and term of storage of fresh potato peel have been determined. It has been found that fresh potato peel is poorly storable and hardly flowable, so it must be processed within 48 hours. To produce an extruded feed additive including crushed wheat grain and fresh potato peel in the ratio 9:1, a step-by-step scheme has been developed. The physical properties, the content of individual nutrients and minerals, and the shelf life of the extruded additive have been determined. It has been established that manufacturing the feed additive by the method suggested allows increasing the product's nutritional value, prolonging its shelf life, improving its sanitary quality, technological properties, and conditions of feeding potato peel to livestock. It has been found that when the amount of potato peel introduced is 10% and that of crushed wheat grain is 90%, the optimal moisture content is 16.5%. Besides, this ratio results in the minimum energy consumption and in a coefficient of expansion high enough. During extrusion, the physical properties change: the moisture content, angle of repose, and bulk density decrease, while the flowability increases, which makes the feed additive suitable for use in the feed products technology. Besides, extrusion of the feed additive is accompanied by reduction in crude protein, crude fibre, and crude fat. It has been established that the shelf life of the additive is 4 months.

Keywords: potato peel, extruded feed additive, animal feed production, physical properties, chemical composition, microbiological parameters.

Introduction. Formulation of the problem

Potato farming is an important branch of Ukraine's agroindustrial complex. After cereals, potatoes are the fifth most important source of energy and nitrogen-free extractives in people's diet today.

Ukraine is one of the world leaders in gross potato production: it ranks fourth among other countries, producing more than 6% of the world's yield of this crop [1-3]. According to statistics, about half of potatoes produced worldwide are used for food, 35% is used to feed livestock, and about 10% is used for further planting [4-6]. Ukraine grows more than 100 potato varieties, of which 60% are of domestic selective breeding [2]. According to State Statistics Committee of Ukraine, in 2019, the areas under this crop amounted to 1309 thousand hectares.

Over the past few years, the dynamics of potato production in Ukraine has been unstable (Table 1), but since 2015, its production volume has been increasing [2].

The regions of Vinnytsia, Kyiv, Lviv, Zhytomyr, Chernihiv, Khmelnytsky, Rivne, Volyn, Sumy, and Kharkiv are the main ones where potatoes are produced commercially. Taken together, these regions produce about 65% of the total volume of potatoes in the country [3]. Potato yields have been increasing since 2015 (Fig. 1) [2].

Table 1 – Dynamics of potato in Ukraine for all categories of farming enterprises, million tonnes

Year	Potato production volumes
2010	18.71
2011	24.25
2012	23.25
2013	22.26
2014	23.69
2015	20.84
2016	21.75
2017	22.21
2018	22.50
2019	20.27

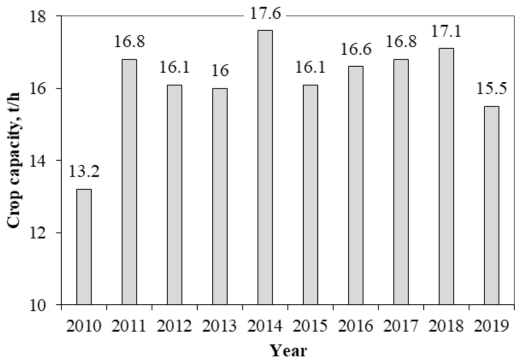

Fig. 1. Potato yields in Ukraine, tonnes per hectare

Potatoes are processed into semi-finished products, ready-made dried foods, canned in the form of first-course and second-course dishes and canned snacks. It is a raw material for starch, alcohol, glucose, hydrol, and other substances. Now in Ukraine, there are two factories manufacturing crisps, the production volumes of which are quite enough to meet the demand for this product nationwide. There are also 4 starch factories, among them the starch factory *Vimal* (Chernihiv) and the starch factory of the corporate agricultural group *Mriya* (Ternopil region) [7].

The significant volumes of cultivation and processing of potatoes result, among other things, in quite a lot of waste (up to 60% of the weight of processed raw materials). However, Ukraine still has no effective technology for its disposal. This situation leads to environmental problems and is economically impractical. The global trends, on the contrary, are towards the fullest possible use of all available types of food and feed raw materials and towards proper environmental management.

Thus, it is a topical task to find effective ways of making potato peel a link in the chain of creating products of practical utility. Perhaps, the best variant is using this waste in the compound feed industry, since this will increase the production of animal protein.

Analysis of recent research and publications

Food waste obtained when making potato-based products falls into solid and liquid. Solid waste includes substandard potatoes, waste obtained after secondary peeling of potatoes, their drying, inspection, packaging, etc. Liquid waste is obtained from primary peeling, blanching, boiling, and other operations of preparing potatoes for drying. Besides, this type of waste includes pulp left after processing small substandard potatoes and their pieces into starch [9-12].

Waste is mostly obtained by peeling potatoes. Its amount depends on the quality of raw materials and the deskinning method used: mechanical, thermal, or chemical. With the mechanical method of peeling potatoes, 15–60% of waste is formed, the thermal one (with steam) can yield 10–48% [13]. Potato peel is rich in nutrients and bioactive substances, the content of which varies and depends on the potato cultivar and on the growing and storage conditions [10,13].

Analysis of data from literature has shown that the existing technologies of processing potatoes industrially result in obtaining as much waste as 10–60% of the mass of the source material, depending on the type of the final product and the technological level of manufacture [9-12]. The moisture content of potato peelings amounts to more than 60%, that is why they have always been considered unsuitable for animal feed production. Due to oxidative processes and the vital activity of microorganisms, waste acquires an unpleasant odour. That is why the maximum storage time of fresh potato waste is no more than a day. If it is necessary to use it longer, it should be processed.

Substandard potatoes and waste formed after secondary peeling and mechanical deskinning can be materials to make starch from. Waste from potato production can be used in the field as fertiliser, but the disadvantage is that up to 95% of water must be transported. Potato peel can be stored in special storage houses, in inground trenches and pits, or in storage clamps [13,15].

During potato processing, most secondary raw materials (peelings, pulp, etc.) are utilised to feed animals [13,14]. Various technological processes are used to process potato waste into animal feed products: drying (obtaining feed flour), boiling, extruding, ensiling. All of them have their own advantages and disadvantages [16-20,21].

Mary Ellen Camire et al. [16] suggested extruding potato peel in a twin-screw extruder at +(110–150)°C. Due to the extrusion process, the starch content is reduced and the total amount of dietary fibre increases. This method involves hot extrusion and requires appropriate equipment, which in practice is seldom used in feed mills. Single-screw extruders, though, have found wide application in grain processing. This results from increased requirements for the feed products safety, frequent instances of the low sanitary quality of grain raw materials due to unfavourable harvesting conditions, high humidity. Thus, this method of extrusion is chosen because it allows manufacturing extruded additives with a certain proportion of high-moisture feed materials and because it improves the general quality of feed products.

S. M. Yashim [17] studied the use of dried potato peelings that could be fed to animals in the amount up to 20%. M. A. Kairalla et al [18] suggest using up to 10% of potato peel flour in rabbits' diets, because it has a good effect on productivity and can be considered a cheap source of fibre. This method of disposal of potato peelings is zootechnically efficient, allows reducing the proportion of cereals in compound feed recipes, and has environmental value. However, it has not become widespread due to the high cost of the final product.

J. W. G. Nicholson et al. [19] studied the use of boiled peelings of potatoes in pig diets. The level of assimilation of boiled peelings by the body was compared to that of barley grain. This method of utilising potato peel has some disadvantages, though. It cannot be introduced at feed mills, but at livestock breeding complexes only, it requires special equipment, and it increases the cost of livestock products. All this significantly limits the use of peel, does not allow optimising the structure of the raw material base, and thus prevents the wide practical use of this method.

M. Faramarzi [20] suggests including up to 15% of potato peel in the fish diet in order to reduce the cost of fish farming.

Products obtained by ensilage are mainly used for cattle. With the significant reduction in livestock, only a small part of peel can be utilised by this method. Another disadvantage is the impossibility of introducing it at feed mills.

Thus, fresh potato peel is produced in significant amounts, has obvious practical value for the compound feed industry (it can help use grain resources rationally, expand the raw materials base, and reduce the cost of final products), is highly nutritive, and there are methods of processing it. Nevertheless, the problem of how to use it effectively in the composition of compound feed is still unresolved.

Considering the above, it was proposed to improve the technology of processing potato peelings into feed additives.

The purpose of the study is to prove the practical value of producing an extruded feed additive (EFA) that includes fresh potato peel. For this purpose, it is necessary to achieve the following **objectives**:

– to determine the physical properties of potato peel, the content of the main nutrients and minerals in it, and the dynamics with which microflora develops in it during storage;

– to substantiate the composition and method of production of the extruded feed additive;

– to determine the physical properties of the feed additive, the content of its main nutrients and minerals, and the dynamics of the microflora development in it before and after extrusion.

Research materials and methods

We have studied the peel of potatoes (the cultivar Borodyanskya Rozheva, harvested in 2019) and wheat grain (DSTU 3768:2019).

The research was carried out in the laboratories at the Department of Mixed Feeds and Biofuel Technology and the Department of Biochemistry, Microbiology and Nutrition Physiology (ONAFT).

The physical properties of fresh potato peelings and the finished feed additive were evaluated by their moisture content, bulk density, flowability, angle of repose, and coefficient of expansion. in accordance with standard methods and techniques recommended for scientific research (Table 1). To study the chemical composition of the potato peelings and the finished feed additive, the mass fractions were determined for crude protein, crude fat, crude fibre, nitrogen-free extractives, calcium, and phosphorus. The chemical composition was determined according to the procedures described below (Table 1).

The changes in the composition and amount of microflora in the potato peel during storage and in the finished feed additive were assessed according to the following microbiological parameters:

– the total quantity of mesophilic aerobic and facultative anaerobic microorganisms (QMAFAnM), CFU in 1g of the product;

– the presence of mould fungi, CFU in 1g of the product;

– the quantity of micromycetes (fungi and yeast);

– the presence of bacteria of the paratyphoid group (*Salmonella*), in 25g of the product;

– the presence of bacteria of the *Escherichia coli* group (coliforms), in 0.1g of the product.

The determination was carried out by inoculating cells on thick media: QMAFAnM on meat-and-peptone agar, micromycetes on wort agar, paratyphoid bacteria (*Salmonella*) and *Escherichia coli* on Endo agar, after their accumulation in special liquid media.

The potato peel was kept in glass containers under unregulated conditions at the temperature 15±5°C and the relative humidity 65–75%. The EFA was stored under unregulated conditions at 15±5°C and the relative air humidity 65–75% for 4 months.

Model samples of feed additives contained wheat grain and potato peelings in the amount 5, 10, 15 and 20%.

The extruded feed additive containing potato peel was made in the laboratory as follows. Wheat was purified from nonfeed-grade waste, ground on a hammer mill to obtain a fraction of outsiftings from a punching sieve with holes of 3mm in diameter, and dosed together with fresh potato peel in the ratio 9 to 1 respectively. Potato peelings were chopped in a blade grinder, with the working element rotating at 12 s^{-1}, and dosed.

Table 1 – Parameters and research methods used to determine the physical properties and chemical characteristics of the potato peel and the finished feed additive

Parameters	Principle and specific features of a method	Standard
Moisture content, %	Drying a weighed portion of the sample in an electric drying cabinet Thermal gravimetric analysis	DSTU ISO 6496:2005; DSTU 7804:2015
Bulk density, kg/m^3	Using a 1-litre chondrometer	–
Flowability, cm/s	The product's outflow through a hole of a certain diameter	–
Angle of repose, degree	Using R. L. Zenkov's equipment, by pouring out of a funnel	–
Coefficient of expansion	The ratio of the diameter of the extrudate to the diameter of the hole in the extrusion die	–
Crude protein, %	The Kjeldahl method	DSTU ISO 5983:2003
Crude fibre, %	The method of determining with the use of intermediate filtration. Treatment with sulphuric acid and sodium hydroxide (both are boiling and diluted), followed by filtration and drying of the residue.	DSTU ISO 6865:2004
Crude fat, %	The method based on extracting fat with petroleum ether; The gravimetric method involving fat extraction with a mixture of chloroform and ethanol	ISO 6492:1999; DSTU 4941:2008
Crude ash, %	Burning a weighed portion of the sample in a muffle furnace at 500–600°C; Ashing of the sample at 525°C	DSTU ISO 5985:2004; ISO 763:2003
Starch, %	Polarimetry	ISO 6493:2000; DSTU 4953:2008
Calcium, %	Titrimetry	ISO 6490-1:1985
Phosphorus, %	Spectrometric method	ISO 6491:1998
Sugars,%	Photocolourimetry	DSTU 4954:2008
Pectins, %	Titrimetry	DSTU 8069:2015

In order to obtain a homogeneous mixture, the mixing included two stages, since the components significantly differed in their physical properties due to different moisture contents.

At the first stage, to obtain a pre-mixture, the components were mixed in the ratio 1:1. At the second stage, the remaining wheat grains were added to the pre-mixture. The resulting feed additive was sent to extrusion. It was carried out on an industrial extruding press EZ-150 (manufactured by *Cherkassyelevatormash*). The extrusion parameters were as follows: pressure in the working zone of the extruder 2.0–3.0 MPa, temperature of the product on leaving the extruder 110–120°C, duration 60–120s. The extruded feed additive was cooled to a temperature that did not exceed the ambient temperature by more than 10°C, and was crushed in a hammer mill with a sieve with holes of 3.0mm in diameter.

Results of the research and their discussion

At the first stage of research, we determined the nutritional value of the raw materials under study (Table 2).

From the analysis of the data in Table 2, it can be seen that potato peel contains a significant amount of nitrogen-free extractives – 84.2%, which is by 10.3% higher than in wheat grain. Nitrogen-free extractives in the studied feed products are mostly represented by starch (74.6% in potato peel and 55.6% in wheat grain). Not only does such a significant amount of starch in potato peel increase the product's nutritional and calorific value, but it will also make the extrusion process more efficient, since it will contribute to the formation of a homogeneous porous structure of the product.

Table 2 – Content of nutrients and minerals in the feeds (on a dry basis) (n=3, P≥0.95)

Parameter	Content, %	
	Raw potato peel	Wheat
Mass fraction of: crude protein	7.5	12.7
crude fat	0.4	2.5
crude fibre	4.3	2.9
crude ash	3.6	5.6
nitrogen-free extractives in particular: starch pectins + pentosans sugars	84.2 74.6 6.4 3.2	76.3 55.6 – –
phosphorus	1.6	3.8
calcium	0.4	1.3

Potato peelings are by 40.9% lower in crude protein than wheat grain is. However, it should be noted that it has a significantly higher biological value of 85% (ideal protein is 70%). The data obtained are consistent with the results of domestic and foreign scientists who studied nutritional value [21,22]. Potato protein contains a balanced set of essential amino acids and is not much inferior to protein of eggs or meat. It is known that for zootechnical efficiency, the quality of protein is far more significant than its amount in the diet. This confirms how practical it is to use wheat grain in combination with potato peel.

As can be seen from Table 2, potato peel contains 6.4% of pectins, which are highly active physiologically and functionally. Pectins promote digestion and help the body resist many diseases, normalise the amount of cholesterol in the blood, play a role in the repair of the mucous membrane of the respiratory and digestive tracts after irritation or inflammation, have a beneficial effect on the cellular respiration in tissues and on the general metabolism. Also, pectin substances, due to their complexing properties, can remove heavy metal ions and radioactive substances from the body of animals. This is very important for the safety of livestock products, especially in case of excessive accumulation of these substances in feed. This ability significantly facilitates the detoxifying function of the liver and kidneys, reduces the risk of cardiovascular pathology, gallstone disease, and even malignant neoplasms [23].

At the next stage of the research, the main physical properties of fresh potato peel were determined. These properties influence the choice of certain technological modes and the efficiency of such processes as grinding, dosing, mixing, extrusion. The physical properties were studied for the peel of Borodyanska Rozheva potatoes: its moisture content, which amounted to 69.6%, and its bulk density, which amounted to 620kg/m^3. The physical properties of potato peel are unsatisfactory: they are unstable during storage and almost unflowable. This distinguishes them from traditional raw materials: they belong to the class of hard-flowing materials, which must be taken into account when they are included in the composition of feeds.

Raw materials and finished products are a favourable breeding ground for many bacteria, especially for moulds. The development of microorganisms can lead to a complete loss of the original properties of raw materials or finished products and make them unsuitable for feeding farm animals and poultry due to accumulation of mycotoxins. Table 3 shows the results of studying the sanitary quality parameters of the raw materials under analysis during their storage.

Table 3 – Dynamics of the microflora development in the potato peel during storage (n=3, P≥0.95)

Storage time, days	QMAFAnM, CFU/g	Filamentous fungi, CFU/g	Yeast, CFU/g	Coliform bacteria titre, g	*Salmonella*
0	$3.2\cdot10^3$	$0.4\cdot10^3$	Not found		
24	$90\cdot10^3$	$8\cdot10^3$	Not found		
48	$160\cdot10^3$	$17\cdot10^3$	Not found		
72	Spoilage				

The research results (Table 3) indicate that at the end of 48 hours of storage, the total number of microorganisms increased 50 times, and the number of filamentous fungi increased 43 times. After 72 hours, the raw materials spoil, so potato peel should be processed within 48 hours. This is consistent with similar conclusions of other scientists [10,13,21].

Considering the above, potato peel can be delivered to the neighbouring agricultural enterprises and used as it is.

As noted earlier, extrusion has been suggested as a way to extend the shelf life and increase the efficiency of using potato peelings. At the next stage of the research, samples of feed additives were made that contained wheat grain and potato peelings in the amounts 5, 10, 15, 20%.

The process of extruding mixtures of wheat grain and fresh potato peel, with different ratios of the components, has been investigated. It has been found that with larger proportions of potato peelings introduced into the composition of each sample, the mass fraction of moisture increases (Fig. 2). This can complicate further processing and storage of EFA. The moisture content of the mixture before extrusion should not be higher than 16.0–18.0% [22].

As can be seen from Fig. 2, the highest moisture content in the extrudate is that of the sample containing 20% of potato peel, which means that it needs drying. The samples with the optimal moisture content of the final product are those with 5–10% of potato peel introduced. With this amount of peel, the above-mentioned parameter fluctuates within 10.9–11.5% and does not exceed the prescribed values. This regularity is consistent with the results of similar studies by other scientists [22].

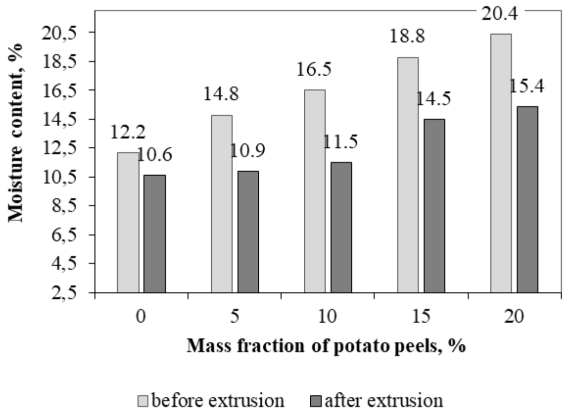

Fig. 2. Changes in the moisture content of the feed additive before and after extrusion

Fig. 3 shows how the specific power consumption and the coefficient of expansion depend on the moisture content in the extruded mixture.

As can be seen from the data obtained (Fig. 3), in the sample with 5% of potato peel introduced, the specific power consumption needed for the process is higher than in the samples with 10 and 15% of potato peel. This can be explained, firstly, by the lower initial moisture content of the mixture to be extruded (which, consequently, makes it difficult to transform the mixture in the working zone of the extruder into a state of viscous fluid), and, secondly, by its lower starch content due to a smaller proportion of peel. A similar pattern, which indicates the efficiency of the extrusion process, can be traced in the expansion index. However, despite the efficiency of the extrusion process in the sample with 15% of potato peel, the results of previous studies make it clear that it is not the optimal one as for the final moisture content of the product. This regularity is consistent with the results of similar studies by other scientists [22].

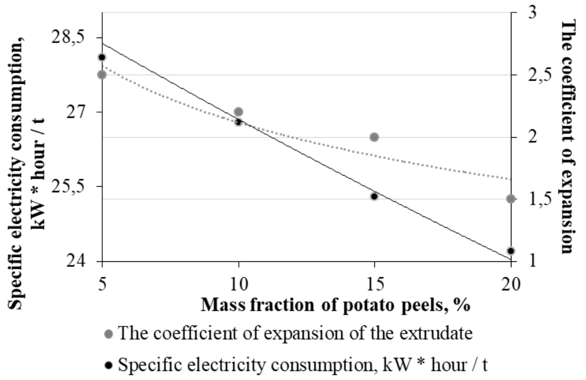

Fig. 3. Dependence of the specific power consumption and the coefficient of expansion of the extrudate on the mass fraction of potato peel

Summarising the above, it has been found that the optimal ratio of wheat grain and potato peel in the mixture is 90:10, with the moisture content of the mixture before extrusion 16.5%, with the minimum energy consumption and quite a high coefficient of expansion.

In the experimental sample of the feed additive, the physical properties were determined before and after extrusion (Table 4).

The data presented in Table 4 make it clear that in the course of extrusion, the moisture content of the feed additive decreased by about 30%, the angle of repose decreased by 9.1%, and the bulk density decreased by 53%. The decrease in the moisture and bulk density is due to the peculiarities of the extrusion process. In particular, it is explained by a significant pressure difference in the working zone of the extruder, and by the values of the corresponding environmental parameter, which results in swelling of the product and intensive evaporation of moisture. The above indicates the depth of the extrusion process, and therefore an increase in the availability of nutrients, inactivation of anti-nutrients, and higher sanitary quality. The flowability of the feed additive during extrusion increased by 16.4%. This, along with a smaller angle of repose, indicates a significant improvement in its technological properties: the additive can be further used as a component of feed products, no problems will arise with its transportation by gravity handling or with pouring it out of operational containers, etc.

The research has resulted in determining the content of the main nutrients and minerals of the feed additive before and after extrusion (Table 5).

Table 5 shows that extruding a feed additive is accompanied by losses in crude protein (by 6%), crude fibre (by 9.5%), and crude fat (by 6%). This is due to destruction of biopolymers and formation of simple compounds (amino acids, dextrins, etc.), which leads to better digestibility of nutrients and increases the zootechnical efficiency of the feed additive. The pattern revealed is consistent with the results of similar studies by other scientists [22].

The findings on the changes in the sanitary quality of the feed additive during storage are shown in Table 6.

Table 4 – Changes in the physical properties of the feed additive (n=3, P≥0.95)

Parameters	Feed additive	
	before extrusion	after extrusion
Moisture content, %	16.5	11.5
Angle of repose, degree	44	40
Flowability, cm/s	22.5	26.2
Bulk density kg/m^3	675	320
Coefficient of expansion	–	2

Table 5 – Content of the main nutrients and minerals of the feed additive before and after extrusion (on a dry basis) (n=3, P≥0.95)

Parameters	Feed additive	
	before extrusion	after extrusion
Moisture content, %	16.5	11.5
Crude protein	13.1	12.3
Crude fat	1.7	1.6
Crude fibre	2.1	1.9
Crude ash	1.9	2.0
Nitrogen-free extractives	60.3	60.8
Phosphorus	0.3	0.27
Calcium	0.05	0.04

From the data in Table 6, one can see a decrease in the QMAFAnM (quantity of mesophilic aerobic and facultative anaerobic microorganisms): from $3.9*10^2$ to $3.4*10^2$ CFU/g. In the experimental samples, yeast, coliform bacteria, and *Salmonella* were not found during the entire storage period. The decrease in the QMAFAnM during storage can be explained by the low moisture content of the extruded additive, which is a limiting factor for the development of microbiota.

Table 6 – Dynamics of the microflora development in the extruded feed additive during storage (n=3, P≥0.95)

Storage time, days	QMAFAnM, CFU/g	Filamentous fungi, CFU/g	Yeast, CFU/g	Coliform bacteria titre, g	*Salmonella*
0	$3.9 \cdot 10^2$	$0.1 \cdot 10^2$	Not found		
30	$3.7 \cdot 10^2$	$0.1 \cdot 10^2$	Not found		
60	$3.7 \cdot 10^2$	$0.1 \cdot 10^2$	Not found		
90	$3.4 \cdot 10^2$	$0.1 \cdot 10^2$	Not found		
120	$3.4 \cdot 10^2$	$0.1 \cdot 10^2$	Not found		

Conclusions

Based on the research carried out, the following conclusions can be made:

1. It has been determined how the quality parameters of fresh potato peel change during storage, and an admissible storage period of 48 hours has been established.

2. The technological conditions for the process of manufacturing the extruded feed additive have been substantiated: pressure in the working zone of the extruder 2.0–3.0MPa, temperature of the product on leaving the extruder +(110–120)°C.

3. It has been established that the extruded additive, by its technological characteristics, is suitable for use in compound feed production. In particular: its angle of repose is 40 degrees, flowability is 26.2cm/s, and bulk density is 320kg/m^3.

4. It has been theoretically grounded and experimentally confirmed that producing a feed additive from a mixture of wheat grain and potato peel (ratio 9:1) in extruded form has practical value, since it ensures preservation of the product's sanitary quality for 4 months.

References:

1. Rud VP, Muraviova OV, Sydora VV. Problemy rozvytku rynku kartopli v Ukrayini. Ovochivnytstvo i bashtannytstvo. 2015;61:193-199.
2. Derzhavna sluzhba statystyky Ukrayiny. Roslynnytstvo [Internet]. Kyiv: Derzhstat Ukrayiny; 2018 [onovleno 2021 Cher 13; tsytuietsia 2020 Cher 25]. Available from: http://www.ukrstat.gov.ua/
3. Krasovs′kyy S. Rankovyy 30-ty khvylynnyy ekspres analiz rynku kartopli v Ukrayini [Internet]. 2019 Aug [cited 2020 Jul 01]:[about 3pp.]. Available from: https://www.linkedin.com/pulse/ранковий-30-ти-хвилинний-експрес-аналіз-ринку-в-степан-красовський
4. Naumchuk VM. Urozhainist kartopli zalezhno vid sortu. Materialy Mizhnarodnoi naukovo-praktychnoi konferentsii «Aktualni pytannia suchasnoi ahrarnoi nauky». Unam`. 2013:71-72.
5. Beukema HP, Zaag DE. Introduction to potato production. Wageningen: Pudoc; 1990.
6. Lutaladio NB, Ortiz O, Haverkort A, Caldiz D. Sustainable potato production. Guidelines for developing countries. Roma: FAO; 2009.
7. Martsenyuk IM, Zavoloka KS. Kharakterystyka produktsiyi, shcho vyroblyayet′sya z kartopli // Suchasni pidkhody do vyroshchuvannya, upakovky ta zberihannya plodoovochevoyi produktsiyi: materialy mizhnarodnoyi nauk.-prakt. konf., 18-20 bereznya 2020 r. Mykolayiv: MNAU, 2020:177-179.
8. Ncobela CN, Kanengoni AT, Hlatini VA, Thomas RS, Chimonyo M. A review of the utility of potato by-products as a feed resource for smallholder pig production. Animal Feed Science and Technology. 2017;227:107-117. https://doi.org/10.1016/j.anifeedsci.2017.02.008
9. Popova SYu. Doslidzhennya fraktsiynoho skladu tsukriv vtorynnykh produktiv pererobky kartopli. Vostochno-Yevropeyskiy zhurnal peredovykh tekhnologiy. 2015;5/6(77):23-28. https://doi.org/10.15587/1729-4061.2015.51551
10. Gebrechristos HY, Chen W. Utilization of potato peel as eco- friendly products: A review. Food Science & Nutrition. 2018;6:1352-1356. https://doi.org/10.1002/fsn3.691
11. Devrani M, Pal M, Soi S. Utilization of potato waste for Animal Feed. Agriculture world. 2018;7:70-73.
12. Boyles St. Feeding potato processing wastes and culls to cattle. [Internet]. 2015 Apr [cited 2020 Jul 25]: [about 3pp.]. Available from: https://agnr.osu.edu/sites/agnr/files/imce/pdfs/Beef/FeedingPotatoProcessingWasteCulls.pdf
13. Wu D. Recycle technology for potato peel waste processing: A review. Procedia Environmental Sciences. 2016;31:103-107. https://doi.org/10.1016/j.proenv.2016.02.014
14. Limbo S, Piergiovanni L. Shelf life of minimally processed potatoes: Part 1. Effects of high oxygen partial pressures in combination with ascorbic and citric acids on enzymatic browning. Postharvest Biology and Technology. 2006;39(3):254-264. https://doi.org/10.1016/j.postharvbio.2005.10.016
15. Arapoglou D, Varzakas Th, Vlyssides A, Israilides C. Ethanol production from potato peel waste. Waste Management. 2010;30(10):1898-1902. https://doi.org/10.1016/j.wasman.2010.04.017
16. Arora A, Zhao J, Camire ME. Extruded potato peel functional properties affected by extrusion conditions. Journal of food science. 1993;58(2):335-337. doi.org/10.1111/j.1365-2621.1993.tb04269.x
17. Yashim SM. Growth Performance, Nutrient digestibility and haematological parameters of Red Sokoto bucks fed varied levels of Irish potato (Solanum tuberosum) peels. Nigerian J. Anim. Sci. 2017;19(2):226-234.
18. Kairalla MA, El-Rahman El-Safty SA, El-Deen MB. Utilization of potato peels as a fiber source in feeding two lines of growing rabbit. Egyptian Poultry Science Journal. 2016;36(2):513-532. https://doi.org/10.21608/epsj.2016.168794
19. Nicholson JWG, Snoddon PM, Dean PR. Digestibility and acceptability of potato steam peel by pigs. The Canadian veterinary journal. 1988; 68(1): 233-239. https://doi.org/10.4141/cjas88-023.
20. Faramarzi M, Lashkarboloki M, Kiaalvandi S, Iranshahi F. Influences of Different Levels of Sweet Potato Peels on Growth and Feeding Parameters and Biochemical Responses of Cyprinus carpio (Cyprinidae). American-Eurasian Journal of Agricultural & Environmental Sciences. 2012;12(4):449-455.
21. Denshchikov MT. Otkhody pishchevoy promyshlennosti i ikh ispol'zovaniye. Moskva: Pishchepromizdat, 1963.
22. Khorenzhyy NV, Kucheruk AH, Sharabayeva KM. Kompleksna tekhnolohiya pererobky volohykh kormovykh zasobiv na kombikormovykh pidpryyemstvakh. Zernovi produkty i kombikormy. 2015:1(58);36-42. https://doi.org/10.15673/2313-478x.58/2015.46014
23. Donchenko L.V. Tekhnologiya pektina i pektinoproduktov. Moskva: DeLi.2000.

ВИКОРИСТАННЯ СВІЖИХ КАРТОПЛЯНИХ ОЧИСТОК У ВИРОБНИЦТВІ ЕКСТРУДОВАНОЇ КОРМОВОЇ ДОБАВКИ

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Анотація. Статтю присвячено питанням переробки свіжих картопляних очисток. В статті наведено динаміку виробництва картоплі у світі, Україні, проаналізовано показники урожайності. Розглянуто способи переробки картоплі та підприємствах України. Встановлено, що основна маса відходів (15–60%) утворюється при очистці сировини. Проаналізовано способи утилізації картопляних очисток. Проаналізовано проблеми використання свіжих картопляних очисток в раціонах сільськогосподарських тварин. Проаналізовано технологічні процеси переробки відходів картоплі, обґрунтовано доцільність застосування екструдування. Показано переваги виробництва екструдованої кормової добавки із включенням картопляних очисток. Визначено фізичні властивості, хімічний склад та терміни зберігання свіжих картопляних очисток. Встановлено, що свіжі картопляні очистки не стійкі при зберіганні та майже несипкі, тому їх необхідно переробляти протягом 48 годин. Розроблено поетапну схему виробництва екструдованої кормової добавки, яка включає подрібнене зерно пшениці та свіжі картопляні очистки у співвідношенні 9:1. Визначено фізичні властивості, вміст окремих поживних та мінеральних речовин та терміни зберігання екструдованої добавки. Встановлено, що виробництво кормової добавки запропонованим способом дозволяє підвищити поживну цінність, покращити санітарну якість, технологічні властивості, термін придатності, умови згодовування картопляних очисток. Встановлено, що оптимальний показник вологості – 16.5% при введенні картопляних очисток у кількості 10%, а подрібненого зерна пшениці 90%, також таке співвідношення дає мінімальні енерговитрати і задовільний коефіцієнт розширення. В процесі екструдування відбуваються зміни фізичних властивостей: вологість, кут природного ухилу та об'ємна маса знижуються, а сипкість збільшується, що зумовлює технологічну придатність кормової добавки для виробництва комбікормової продукції. Також процес екструдування кормової добавки супроводжується втратами сирого протеїну, сирої клітковини та сирого жиру. Встановлено термін зберігання добавки – 4 місяці.

Ключові слова: картопляні очистки, екструдована кормова добавка, комбікормове виробництво, фізичні властивості, хімічний склад, мікробіологічні показники.

Список літератури:

1. Рудь В.П. Проблеми розвитку ринку картоплі в Україні // Овочівництво і баштанництво. 2015. Вип. 61. С. 193-199.
2. Державна служба статистики України: [Веб-сайт]. Київ, 2018. URL:http://www.ukrstat.gov.ua/ (дата звернення: 25.06.2020)
3. Красовський С. Ранковий 30-ти хвилинний експрес аналіз ринку картоплі в Україні. URL:https://www.linkedin.com/pulse/ранковий-30-ти-хвилинний-експрес-аналіз-ринку-в-степан-красовський
4. Наумчук В.М. Урожайність картоплі залежно від сорту // Матеріали Міжнародної науково-практичної конференції «Актуальні питання сучасної аграрної науки». Умань. 2013. С. 71-72.
5. Beukema H.P., Zaag D.E. Introduction to potato production. Wageningen: Pudoc, 1990. 208 p.
6. Sustainable potato production. Guidelines for developing countries / Lutaladio N.B. et al. Roma: FAO; 2009. 91 p.
7. Марценюк І. М., Заволока К. С. Характеристика продукції, що виробляється з картоплі // Сучасні підходи до вирощування, переробки і зберігання плодоовочевої продукції: матеріали міжнародної наук.-практ. конф., 18-20 березня 2020 р. Миколаїв : МНАУ, 2020. С. 177-179.
8. A review of the utility of potato by-products as a feed resource for smallholder pig production / Ncobela C.N. et al // Animal Feed Science and Technology. 2017. Vol. 227. P. 107-117. https://doi.org/10.1016/j.anifeedsci.2017.02.008
9. Попова С.Ю. Дослідження фракційного складу цукрів вторинних продуктів переробки картоплі // Восточно-Европейский журнал передових технологий. 2015. № 5/6 (77). С. 23-28. https://doi.org/10.15587/1729-4061.2015.51551
10. Gebrechristos H.Y., Chen W. Utilization of potato peel as eco- friendly products: A review // Food Science & Nutrition. 2018. Vol. 6. P. 1352-1356.
11. Devrani M., Pal M., Soi S. Utilization of potato waste for Animal Feed // Agriculture world. 2018. Vol.7. P. 70-73.
12. Boyles St. Feeding potato processing wastes and culls to cattle. URL:https://agnr.osu.edu/sites/agnr/files/imce/pdfs/Beef/FeedingPotatoProcessingWasteCulls.pdf (viewed on: 28.07.2020).
13. Wu D. Recycle technology for potato peel waste processing: A review // Procedia Environmental Sciences. 2016. Vol.31. P. 103-107. Limbo S., Piergiovanni L. Shelf life of minimally processed potatoes: Part 1. Effects of high oxygen partial pressures in combination with ascorbic and citric acids on enzymatic browning // Postharvest Biology and Technology. 2006. Vol.39, Issue 3. P. 254-264. Ethanol production from potato peel waste / Arapoglou D. et al // Waste Management. 2010. Vol.30, Issue 10. P.1898-1902. Arora A., Zhao J., Camire M.E. Extruded potato peel functional properties affected by extrusion conditions // Journal of food science. 1993. Vol.58, Issue 2. P. 335-337. doi.org/10.1111/j.1365-2621.1993.tb04269.x
14. Yashim S.M. Growth Performance, Nutrient digestibility and haematological parameters of Red Sokoto bucks fed varied levels of Irish potato (Solanum tuberosum) peels // Nigerian J. Anim. Sci. 2017. Vol.19, Issue 2. P. 226-234.
15. Kairalla M.A., El-Rahman El-Safty S.A., El-Deen M.B. Utilization of potato peels as a fiber source in feeding two lines of growing rabbit // Egyptian Poultry Science Journal. 2016. Vol.36, Issue 2. P. 513-532. https://doi.org/10.21608/epsj.2016.168794
16. Nicholson J.W.G., Snoddon P.M., Dean P.R. Digestibility and acceptability of potato steam peel by pigs // The Canadian veterinary journal. 1988. Vol. 68, Issue 1. P. 233-239. https://doi.org/10.4141/cjas88-023
17. Influences of Different Levels of Sweet Potato Peels on Growth and Feeding Parameters and Biochemical Responses of Cyprinus carpio (Cyprinidae) / Faramarzi M. et al // American-Eurasian Journal of Agricultural & Environmental Sciences. 2012. Vol.12, Issue 4. P.449-455.
18. Денщиков М.Т. Отходы пищевой промышленности и их использование. М.: Пищепромиздат, 1963. 613 с.
19. Хоренжий Н.В., Кучерук А.Г., Шарабаєва К.М. Комплексна технологія переробки вологих кормових засобів на комбікормових підприємствах // Зернові продукти і комбікорми. 2015. №1 (58). С. 36-42. https://doi.org/10.15673/2313-478x.58/2015.46014
20. Донченко Л.В. Технология пектина и пектинопродуктов: Учеб. пособие. М.: ДеЛи. 2000. 225 с.