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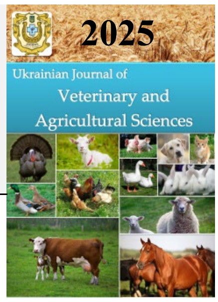

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It uses non-traditional ingredients in complete feed for fattening piglets

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Contents

Abstract

The experimental research aimed to study the effect of feeding compound feed to fattening piglets with different proportions of flour from apple pomace on the quality of their slaughter products. The research was conducted on piglets of a large white breed of French breeding. During the fattening period, the piglets of the research groups were fed compound feed with different proportions of apple flour (5 %, 10 and 15 % by weight). It was established that compared to the control group, in the pigs' meat from the experimental groups, total moisture content decreased by 0.4–0.6 % and fat by 0.1–0.5 %. Regarding protein content, the piglets from the experimental groups prevailed by 0.5–1.0 % of their peers from the control group. At the same time, there is a tendency to increase the energy and biological value of the pigs' meat, which, during the fattening period, were fed apple pomace flour in the amount of 5 and 10 % by weight instead of barley grain. Regarding the quality of adipose tissue, a slight increase in total moisture content by 0.1–0.8 % and a decrease in fat content by 0.5–1.7 % was observed in the piglets from experimental groups, compared to similar indicators in the control group. The results of studies of physicochemical indicators of adipose tissue indicate some advantages of the fat of piglets from the control group. In particular, the melting temperature of pig fat in experimental groups was higher by 0.9–1.7 °C, and the iodine value of fat was lower by 3.3–7.1 % compared to the control group. It has been proven that using flour from apple pomace in the composition of compound feed for fattening piglets does not significantly affect the quality of their muscle and fatty tissues. At the same time, it saves part of expensive grain feed and thereby increases the efficiency of pork production.

Keywords: pigs; apple pomace; combined fodder; meat; fat.

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1. Introduction

The system of development of social production attaches great importance to a reasonable mode of economy in the national economy, to the economical and full use of raw materials, including agricultural ones.

As a rule, vegetable agricultural raw materials are multi-component; they contain, in addition to the main components to be separated during the processing process (flour, sugar, oil, juice, etc.), other useful organic and mineral substances.

The main difference between agricultural raw materials and raw materials of other origins is that they are the primary source for producing food products and a significant amount of feed (Goljan & Shmarov, 2018).

Even though agricultural raw materials are continuously reproduced, it should not be assumed that there is an excess of them. Therefore, the task of rational use of agricultural raw materials will be at all stages of the development of the economy of Ukraine.

Currently, the problem of complex processing of agricultural raw materials is quite relevant for the food industry. This is due to the fact that the current level of production from the processing of agricultural raw materials is characterized by increasingly more profound contradictions between the need to gradually increase the amount of processing the weak technical equipment of enterprises and the incompleteness of the technological cycle. In this situation, the low coefficient of its use and the annual increase of so-called “waste” have an increasingly detrimental effect on the economic activity of enterprises processing raw materials. As a result, there is not only a deterioration of general economic indicators but also the emergence of a real ecological threat to the environment. Similar negative trends are characteristic of almost all processing branches of the agricultural industry, but they are especially clearly visible in the example of fruit and vegetable processing enterprises.

Food industry enterprises annually accumulate thousands of tons of unused production waste, which pollutes areas of fertile land, often gets into rivers and reservoirs, rots and thereby pollutes the air space, and worsens the sanitary condition of the regions. The complex processing of raw materials with the use of waste makes it possible to eliminate these shortcomings and obtain products from waste that are burdensome for production. The quality of this product is not inferior to that of products made from natural raw materials (Bugaichuk et al., 2019).

Complex processing of raw materials serves as the main principle of waste-free production. The economic side of waste-free production has its own characteristics. With the complex processing of raw materials, production's technical and economic indicators are significantly improved. The cost price of each type of product obtained from the same raw materials decreases because the mass of products increases, and the cost of the used raw materials remains constant. There are no procurement losses in producing products from secondary types of raw materials. The primary and working funds of production and the labor force are used more efficiently, due to the maintenance of all processes by the same services. The specific costs of auxiliary materials (fuel and electricity) are reduced. There is a decrease in the wage fund, overhead costs, etc.

The effectiveness of complex processing of raw materials is not limited to improving technical and economic indicators of production and reducing the price of additional types of products. The complex processing of raw materials requires an additional increase in the labor force, which is important in solving the problem of employment of the population, which arises in connection with the high growth rates of labor productivity and the crisis phenomena of today (Andrejchenko, 2020; Lojko & Shemchuk, 2021).

Special attention should be paid to the in-depth processing of secondary material resources, which are characterized by a high potential for annual accumulation. Without modern complex processing, it has become a serious source of environmental problems. The transition of the food industry to waste-free and low-waste technologies will make it possible to reduce the amount of "waste", which causes significant damage to the environment due to the presence of biogenic and mineral components in it – a favorable environment for putrefactive and pathogenic bacteria.

The problem of waste disposal is relevant worldwide because, in many cases, the natural environment cannot cope with the growing flow of pollution, and conditions are created to violate the ecological balance. The collection and removal of waste in landfills require significant funds. Building and operating reliable waste storage facilities is expensive (Stratichuk, 2020).

In this regard, the interest of all countries in the utilization of secondary material resources was reflected in the materials of the European Commission. They emphasize the demand for complete collection and disposal of waste by processing it into livestock and poultry feed, burning it for heat, and using it as raw material for industry. This waste disposal approach meets today's objective requirements and production as a whole (Allacker et al., 2014).

However, obtaining the maximum effect from the utilization of waste processing of agricultural raw materials is complicated to a great extent by the uncertainty of management conditions. The output of secondary material resources fluctuates over the years, and the necessity for them from the users' side also changes. Due to this, the amount of agricultural raw material waste increases in the harvest years. As a rule, there is no need to use secondary material resources in animal husbandry due to a sufficient supply of livestock with complete feed. In years with a low harvest and a drop in the actual volume of production of secondary material resources. The demand for them increases sharply.

In addition, the need for and output of secondary material resources is influenced by the current year's conditions. Some include changes in the number of animals and how they are kept, the adopted technology for obtaining and collecting waste, the availability of special equipment, the amount of capital investments, the availability of personnel, etc. A systematic approach to waste disposal is necessary to account for a significant number of factors and make the right decision in specific conditions.

Products that utilize secondary material resources of the food industry are primarily a source of replenishment of animal feedstocks. In recent years, animal husbandry has increasingly experienced a lack of proteins of plant origin, which hinders its development. Fodder, which is used for feeding animals, is produced mainly at the expense of field fodder production and natural fodder lands. The prospects for the expansion of crops and fodder lands are relatively insignificant. Increasing the yield of fodder crops and rational use of land contributes to the increase of fodder production to some extent but does not entirely solve the problem. Therefore, work is being carried out abroad and in Ukraine to develop technologies for obtaining feed and feed additives from waste, and the procedure for their use in animal husbandry is recommended (Vikrant, 2024).

The issues of rational use of such waste as cake, bran, and pulp have already been developed and widely covered in the scientific literature. This waste organically entered the feed balance of animals and became traditional fodder for them. At the same time, there is a large group of wastes that, for one reason or another (mainly due to insufficient research), do not find use or are used little in animal husbandry. These are non-traditional feeds (Chharang, 2022).

By definition, non-traditional feeds should be considered all those that were considered unsuitable for feeding animals until recently, but with the help of which their diet can be enriched with essential nutrients, vitamins, minerals, or other biologically active substances. Only if they are absolutely not harmful or do not contain harmful components in unacceptable concentrations (Singh, 2018).

According to other scientists, non-traditional can be considered not only fodder that has not been used until now but also those that have been poorly used in certain branches of animal husbandry. Unconventionality is conditional. Some feed means are traditional for some industries but not used in others. They are non-traditional for them (for example, fodder molasses is a traditional feed for livestock and non-traditional for pig farming).

According to the accepted taxonomy, non-traditional feeds can be divided into three large groups: feeds containing a large amount of fiber, feeds rich in carbohydrates, and protein feed. Non-traditional feeds are also classified by the nature of the raw materials from which they are produced. For example, wood processing, food, dairy, fruit and vegetable, petrochemical industries, leather production, and others (Beriso, 2022).

Currently, several methods of obtaining non-traditional fodder are well known. Their chemical composition and biological effect on the body of animals have been studied, and the quality of the obtained products has been determined. However, some aspects of their use require further development. Using them as part of the rations for some types of farm animals will make it possible to reduce the deficit of protein and other biologically active substances, which will lead to an increase in animal productivity with a significant reduction in the cost of scarce feed and, first of all, grain concentrates (Quintero-Herrera et al., 2023).

Thus, in the transition to resource-saving production, there is an opportunity to simultaneously solve the problems of raw materials and the environment, thanks to the maximum use of the mass of raw materials by the entire multi-industry production complex of the country.

Among a large number of non-traditional feeds, a prominent place is occupied by waste from the fruit and vegetable industry, in particular, apple pomace. Like raw materials, they contain many valuable components: carbohydrates, fats, proteins, pectin substances, vitamins, acids, mineral elements, and others (Ginni et al., 2020; Marcotte et al., 2022).

Ukrainian and worldwide experience convincingly shows that including apple pomace in animals' diets allows them to increase their productivity and obtain a significant amount of meat and dairy products. However, also to save a significant amount of grain fodder and prevent environmental pollution (Tkachuk et al., 2012; Fijalovych et al., 2018; Ginni et al., 2020). However, these valuable feeds are spoiled and destroyed in large quantities at many processing plants.

To date, experimental and production data have already been accumulated on the successful use of apple pomace in feeding various types of animals. However, until now, there have been no clear recommendations on the norms of introducing extracts into pigs' diets, taking into account age, sex, direction, and level of productivity.

In the scientific literature, there is also often conflicting information regarding the productive effect of this fodder on the body of pigs and the quality of their products. In addition, due to the volatility of the chemical composition, farms need to know the nutrient content of pomace, especially in the form in which it is directly fed to animals.

The experimental research aimed to study the effect of feeding compound feed to fattening piglets with different proportions of flour from apple pomace on the quality of their slaughter products.

2. Materials and methods

The object of the study was the waste of fruit and vegetable production of PJSC "Bilotserkivsky Cannery", which is obtained during the production of apple juice. Apple juice samples were taken before the scientific and economic experiments began. The content of nutrients and biologically active substances in dry apple pomace was determined according to generally accepted methods of zootechnical analysis (Lavrynjuk & Burlaka, 2016).

Based on the obtained data, the possibility of effectively replacing part of the concentrated feed (barley grain) with flour from apple pomace in pig diets was studied.

Experimental studies were carried out at Hors-KLM, located in the Popilnya district of the Zhytomyr region. The experimental study was conducted in compliance with the ethical principles and rules for the treatment of animals set out in the ARRIVE guidelines 2.0 (Percie du Sert et al., 2020).

To conduct a scientific and economic experiment, groups of young pigs of a large white breed of French breeding were formed according to the principle of analogs (piglets were selected at the age of 2.5 months), taking into account breed, age, live weight, sex, growth energy, and origin.

The scientific and economic experiment duration was 135 days and consisted of an equalization (15 days) and main (120 days) periods. In the comparison period, the feeding and maintenance conditions were the same for all young animals under test. In the main period, pigs of all groups received rations provided by the experiment scheme (Table 1).

Table 1
Scheme of a scientific and economic experiment

Group	Numbers	Additions of flour from apple pomace to the diet instead of concentrated feed (% by mass)
1 control	15	Complete mixed feed **(**CMF) – CMF (100 %)
2 experimental	15	CMF (95 %) + 5 %
3 experimental	15	CMF (90 %) + 10 %
4 experimental	15	CMF (85 %) + 15 %

In the experiment, piglets were fed with dry compound feed, the composition of which is typical for the Central zone of Ukraine (corn, pea, barley grits; meat and bone meal, salt, premix).

According to existing norms, the diets fed to experimental piglets were balanced in terms of essential and biologically active nutrients, taking into account age and live weight (Provatorov, 2019). Access to water was free.

At the end of the scientific and economic experiment, a controlled slaughter of three individuals from each experimental group was carried out to evaluate the quality of pig slaughter products. In selecting animals for control slaughter, their average live weight corresponded to the average weight of the given group at the end of the scientific and economic experiment.

During anatomical dissection and collapsing of pig carcasses, muscle, and fat tissue samples were taken for their chemical analysis. From each half-carcass taken for analysis, point samples of meat were taken, in a piece, weighing at least 0.2 kg, from the following places: near the place of incision, opposite the 4–5th cervical vertebrae, in the areas of the shoulder blade, thigh and thick parts of the muscles. A combined sample weighing at least 2.0 kg was formed and passed through a meat grinder with a 3 mm mesh from the obtained point samples. For research, it was thoroughly mixed, and the quartering method selected an average sample of minced meat in the amount of 400 g.

Kidney, abdominal, and subcutaneous fat were taken from each slaughtered animal to study adipose tissue. Selected adipose tissue samples were crushed and thoroughly mixed. The size of the combined sample was at least 0.6 kg. Melting of fat was carried out in a Würp flask.

During the chemical analysis of muscle and fat tissue, the following indicators were determined:

– a mass fraction of total moisture content (%) – by drying the weight to a constant mass in a drying cabinet at a temperature of 100-105 °C to a constant mass (DSTU ISO 1442: 2005, 2008);

– a mass fraction of nitrogen and protein (%) – by the Kjeldahl method (DSTU ISO 937: 2005, 2007);

– mass fraction of fat (%) – extraction with ethyl alcohol in a Soxhlet apparatus (DSTU ISO 1443:2005, 2008);

– a mass fraction of ash (%) – with the help of ashing of the weight in a muffle furnace at a temperature of 525–550 °C (DSTU ISO 936:2008, 2008);

– caloric value (energy value) of meat (kJ) – by the calculation method according to the formula:

$C = [D – (F + A)] \times 4.0 + (F \times 9.0)$, (1)

Where C – the calorie content of 100 g of meat of natural moisture, kcal; D – the content of dry matter in meat, %; F – the fat in meat, %; A –ash content in meat, %.

To obtain the energy value in units of the SI system, that is, in kilojoules, the conversion factor was used: 1 kcal = 4.184 kJ (Sobolev et al., 2022);

– relative biological value of meat – micromethod using the test organism Tetrachymena piriformis, strain WH14 (Mykytjuk et al., 2004).

The melting temperature of fat was determined by the rise of fat in a U-shaped capillary open on both sides (Sobolev et al., 2022).

The iodometric method was used to determine fat iodine value (DSTU 4569:2006, 2008).

The statistical processing software Microsoft Excel 2010 was used for the mathematical processing of the obtained results. To identify a statistically significant difference between the average values in the control and experimental groups, variance analysis (one-factor variance analysis procedure) was used. Differences in mean values were considered statistically significant at $P < 0.05$.

3. Results and discussion

It was established that dried and crushed apple pomace contains 87.0 % of dry matter, which consists of 10.8 % crude protein, 4.6 % crude fat, 22.1 % crude fiber, 47.2 % nitrogen-free extractives, and 2.1 ashes. 1 kg of such extracts contains 10.1 g of calcium and 2.3 g of phosphorus.

The analysis of the amino acid composition made it possible to identify all 10 essential amino acids in apple flour, among which valine (3.7 g/kg), phenylalanine (3.3 g/kg), isoleucine (2.3 g/kg), threonine (2.3 g/kg) and leucine (1.9 g/kg).

The micromineral composition of flour from apple pomace is also quite indicative. It contains a lot of iron (1002.8 mg/kg), zinc (148.4 mg/kg), manganese (59.6 mg/kg) and copper (27.2 mg/kg).

The study of the vitamin composition revealed the presence of carotene, thiamine, riboflavin, pantatenic, and ascorbic acids in the following amounts (mg/kg): 4.0, 0.6; 2.7, 15.4, and 12.8, respectively.

The obtained results do not contradict the data of indian, Ukrainian, and Australian researchers (Beigh et al., 2015; Jegorov et al., 2018; Lyu et al., 2020) regarding the qualitative composition of apple pomace. However, they differ slightly from them in terms of the quantitative content of nutrients and biologically active substances. This confirms the conclusions of many scientists about the unstable composition of apple pomace, which probably depends on the variety of apples, their maturity, areas of cultivation, technological parameters of drying, and other factors.

In order to have an idea about the quality of the slaughter products of experimental piglets, which were fed compound feed during the fattening period with different proportions of flour from apple pomace, We studied some chemical and physicochemical parameters of their meat and fat (Table 2).

Table 2

Chemical and physicochemical indicators of the quality of meat and fat of fattening piglets ($\overline{X} \pm S_{\overline{X}}$ n=3)

Indicator	Group			
	1 control	2 experimental	3 experimental	4 experimental
Chemical composition of meat, %:				
water	72.6 ± 0.48	72.3 ± 0.28	72.0 ± 0.66	72.2 ± 0.74
protein	21.3 ± 0.19	21.8 ± 0.20	22.3 ± 0.37	22.2 ± 0.16*
fat	3.9 ± 0.22	3.8 ± 0.34	3.7 ± 0.41	3.4 ± 0.59
ash	1.1 ± 0.10	1.1 ± 0.09	1.0 ± 0.09	1.0 ± 0.06
Calorie content of meat, kJ/100 g	503.3	507.9	512.5	499.6
The average number of ciliates that grew piece in 1 ml	8.4 ± 0.80 ×10^4	8.9 ± 0.69 ×10^4	8.7 ± 1.24 ×10^4	8.4 ± 0.92× 10^4
Relative biological value, %	100.0	105.9	103.6	100.0
Chemical composition of adipose tissue, %:				
water	6.4 ± 0.58	7.2 ± 0.83	6.9 ± 0.61	6.5 ± 0.75
fat	86.3 ± 0.94	84.6 ± 1.44	84.9 ± 1.24	85.8 ± 0.80
Melting point of fat, °C	40.4 ± 1.15	41.7 ± 1.40	41.3 ± 1.24	42.1 ± 0.87
Iodine value of fat, I_2 g/100 g	55.0 ± 0.82	53.2 ± 1.89	52.2 ± 1.30	51.1 ± 1.08*

Note: * – $P < 0.05$ – probability of the difference between the control and experimental groups

The study of the chemical composition of the meat of fattening piglets of the control and experimental groups did not reveal any significant difference between them. However, according to most of the indicators that characterize the nutritional value of meat, the advantage of young animals raised on compound feed, which included flour from apple pomace, can be traced. Thus, in the meat of the pigs of the experimental groups, the total moisture content (due to the accumulation of dry substances) decreased slightly (by 0.4–0.6 %) compared to the control group and amounted to in the second by 72.3 %, in the third by 72.0 and the fourth by 72.2 %.

The increase in the mass fraction of dry matter in the meat of pigs of the experimental groups occurred due to an increase in the amount of protein. Regarding protein content, the piglets of the second experimental group exceeded their peers from the control group by 0.5 %, the third by 1.0, and the fourth by 0.9 % ($P < 0.05$), where the similar indicator was 21.3 %.

With an increase in the proportion of flour from apple pomace in the rations of the pigs of the research groups, there was a tendency to a slight decrease in the mass proportion of fat in their meat by 0.1–0.5 %, compared to the control group (3.9 %).

The mass fraction of ash in the meat of piglets of the control and experimental groups was practically the same and ranged from 1.0 to 1.1 %.

Based on the data on the chemical composition of the meat, its calorie content was determined. Calculations showed that the energy value of 100 g of pig meat of the second experimental group was 507.9 kJ, and that of the third was 512.5 kJ, 0.9 % and 1.8 % higher than the control group. This indicator was 0.7 % lower in the fourth experimental group than in the control group and amounted to 499.6 kJ/100 g.

It is known that a product's high energy value does not always guarantee its high quality. The product's actual value depends on its chemical composition and the degree of assimilation and harmlessness for the body.

Today, for a more complete assessment of the quality of the meat of farm animals and poultry, biological methods are increasingly used in scientific research and practice, allowing us to conclude the biological value of the product. Its physiological usefulness is to the needs of the human body. For express methods of determining the biological value of a product, one of the most convenient and promising test objects is the ciliated ciliate Tetrachymena piriformis.

The criterion for the relative biological value of pig meat was the number (expressed as a percentage) of ciliates grown in three days in experimental samples relative to the number of cells grown in control samples on standard protein (casein).

The research results showed that the relative biological value of the meat of the pigs of the second and third research groups, compared to the control group, was higher by 5.9 and 3.6 % (however, it was not statistically significant). According to this indicator, there was no difference between the control and the fourth experimental group.

Partial replacement of grain components in compound feed for fattening piglets with flour from apple pomace did not have a noticeable effect on the chemical composition of their adipose tissue. However, in the adipose tissue of the piglets of the experimental groups, a slight increase in the total moisture content by 0.1–0.8 % and a decrease in the fat content by 0.5–1.7 % was observed, compared to similar indicators in the control group (6.4 and 86.3 %, respectively).

The results of studies of some physicochemical parameters of adipose tissue, on which its quality depends, testify to some advantages of lard from young pigs of the control group. For example, the melting temperature of the fat of pigs in the control group was 40.4 °C; the similar indicator in the experimental groups was slightly higher and was 41.3-42.1 °C (the difference between the control and experimental groups is unlikely). The melting point characterizes the digestibility of fat. Fat with a low melting point is better absorbed because when it enters the human body, it quickly becomes liquid and is well emulsified in the digestive tract. The melting point of fat will be lower, and the more unsaturated fatty acids, especially stearic, are in its composition. In addition, the melting point is a constant that is very sensitive to impurities, so it can be used to identify the fat and determine its degree of purity.

The iodine value is another indicator that characterizes the quality of lard, on which its consistency depends, and the presence of saturated and unsaturated fatty acids. The more unsaturated fatty acids a fat contains, the higher the iodine value and the softer the fat. The iodine value of the fat of piglets of the second research group was 3.3 %, the third was 5.1, and the fourth was 7.1 % ($P < 0.05$) lower than in the control group (55.0 I_2 g/100 g). This indicates that the fat of pigs in the control group contains more unsaturated fatty acids. As a result, it is softer. At the same time, it should also be noted that a high iodine fat value indicates a shorter shelf life. The iodine number varies depending on seasonal factors, the feeding ratio of animals, their breed, and individual characteristics.

4. Conclusions

Replacing grain components of compound feed (up to 15 % by weight) with flour from apple pomace followed by feeding it as part of the diet of young fattening pigs did not significantly affect the quality of their muscle and fat tissues. At the same time, a trend was established to improve the chemical composition and increase the energy and biological value of the meat of piglets, which, during the fattening period, flour from apple pomace in the amount of 5 and 10 % by weight was introduced into compound feed instead of barley grain.

In addition, using flour from apple pomace in the composition of compound feed for fattening piglets up to 15 % (by weight) will save a part of expensive grain feed and thereby increase the efficiency of pork production without reducing the quality of products.

Conflict of interest
The authors declare that there is no conflict of interest.

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