



## Chemical composition, energy content, and nutrient digestibility of rye grain in broiler chickens

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**Abstract.** The development of livestock farming is always associated with the search for new dietary components that increase feed efficiency or reduce feed costs. The maximum use of regional, conventional feed in the feeding of farm animals is quite relevant today. Furthermore, certain feeds, the production of which is accompanied by low greenhouse gas emissions, help reduce the carbon footprint of the diet as a whole. The purpose of this study was to determine the nutritional value of rye grain of the modern hybrid KWS Tayo and the digestibility of nutrients in poultry. The chemical composition of grain, digestibility of nutrients in broiler chickens, and total energy content were investigated. The chemical composition of feed, compound feed, and litter was determined according to the Wende method. Nutrient digestibility studies were conducted on broiler chickens of the ROSS-308 cross. For the physiological experiment, 5 chickens aged 22 days were selected. The experiment was carried out using a complex method, by replacing part of the basic diet. The experiment consisted of 2 parts. In the first experiment, the nutrient digestibility of the main diet was determined – compound feed containing 5% rye grain; in the second, the main diet with an additional 5% rye grain was used. The calculation was made on the assumption that the digestibility of nutrients in the main diet was the same in both experiments. The compound feed was balanced according to the recommendations of the cross developer. The energy content of rye grain was calculated in J of metabolisable energy by the regression equation, based on the data on the content

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of digestible protein, fat, fibre, and NFES determined in the physiological experiment. The average dry matter content of the rye samples was 87.4%. The content of the main nutrients in the grain of natural moisture was as follows: crude protein –  $8.87 \pm 0.484\%$ ; crude fat –  $1.63 \pm 0.105\%$ ; NFES –  $73.95 \pm 0.494\%$ , and crude ash –  $0.53 \pm 0.109\%$ . The nutrient digestibility of rye grain was as follows: crude protein – 76%; crude fat – 82%, crude fibre – 8%; NFES – 81% and organic matter – 78%. The total energy value of rye grain was  $12.420 \pm 0.2573$  MJ/kg of metabolic energy for poultry. Nutritionists can use the nutritional and nutrient digestibility data of rye grain to develop practical recipes for poultry compound feed

**Keywords:** feeding; poultry; compound feed components; carbon footprint; feed efficiency

## Introduction

The development of livestock farming is always associated with the search for new dietary components that increase feed efficiency or reduce feed costs. The maximum use of regional, conventional feed in the feeding of farm animals is quite relevant today. Chernozem soils cover up to 60% of Ukraine's territory. Sod-podzolic soils, which are found mainly in Polissia and contain up to 1.5% humus, are quite common. Grey forest soils in the southern part of Polissia and in the west and right bank of Ukraine also contain low humus content of up to 3% (Raza *et al.*, 2019). Oats and rye are conventional cereals that provide high yields under the prevailing soil and climatic conditions. Oats are a fairly conventional crop, but the situation with the use of rye in livestock feeding requires additional scientific research in Ukraine. Due to the rising cost of logistics, the existing local raw material base should be used as much as possible in feeding. The use of rye grain in livestock feeding will help reduce the carbon footprint of diets and the cost of logistics of feed components in conventional areas of its cultivation, as well as stimulate the development of livestock production.

According to the International Feed Industry Federation (n.d.), cereals, mainly maize, wheat, and sorghum, are the main components of poultry diets. Together with protein components, they form the basis of compound feed and meet the poultry's needs for essential nutrients and energy. The issue of using cheap local energy and

protein sources is now very acute, as livestock production is expected to increase by 60% by 2050 amid population growth.

To meet the need for feed, a considerable number of alternative energy sources are being researched, including wheat, barley, and rye. D. Bederska-Łojewska *et al.* (2017) found that rye (*Secale cereale*) is resistant to fungal diseases, has a high tolerance to low temperatures, drought, and soil acidity, and provides high yields.

R. Lazaro *et al.* (2004) recognised rye as one of the crops with the most negative impact on performance when fed to poultry. The high concentration of soluble non-structural polysaccharides in rye increases the viscosity of feed masses in the gastrointestinal tract. Rye contains non-starchy polysaccharides, which leads to a decrease in the absorption of nutrients in the diet. This is conditioned by the fact that poultry have few or no endogenous enzymes capable of hydrolysing these non-starch polysaccharides. J.D. Latorre *et al.* (2014) found that exogenous carbohydrates are used as feed additives to reduce the negative effects of polysaccharides. D. Boros & M.R. Bedford (1999) showed that the nutritional value of rye for broiler chickens can be improved by breeding and growing rye varieties and hybrids with lower levels of anti-nutrients and by selecting suitable feed enzymes that can hydrolyse and reduce the viscosity of feed in the gastrointestinal tract and increase nutrient absorption. The work of breeders E. Makarska *et al.* (2007) focuses on

the development of new rye varieties and hybrids with reduced concentrations of antinutrients. They achieved reductions in alkylresorcinols, trypsin inhibitors, and ergot damage.

According to the findings of A. Arczevska-Wlosek *et al.* (2019), modern rye hybrids can be used at the level of 20% of the diet of broiler chickens aged 22 to 42 days of life, without any negative impact on growth performance. The additional use of enzyme additives (xylanase) has a positive effect on live weight gain and feed digestibility in chickens aged 1 to 21 days. Furthermore, according to L. Riedesel *et al.* (2022), rye is characterised by a low carbon footprint, and breeding in recent years has reduced this figure by 13-23% (rye is 8% lower than wheat).

Many researchers are investigating the effectiveness of feeding different levels of rye grain in broiler diets and their impact on growth and development. The effectiveness of feed additives and their impact on the gastrointestinal tract of poultry are widely covered. Therewith, little is known about the digestibility of various components

of rye without the use of enzymes. This will allow for a better understanding of the selection of the best set of enzymes when formulating diets for broiler feeding, as well as assessing the effectiveness of their use in the future. Thus, the study of the digestibility of rye grain nutrients in broiler chickens is quite relevant.

The purpose of this study was to determine the nutritional value of rye grain of the modern hybrid KWS Tayo and the digestibility of nutrients in poultry.

## Materials and Methods

Studies of the chemical composition and digestibility of nutrients of rye grain of the KWS Tayo hybrid were conducted in 2023-2024 in the research laboratory of feed additives of the P.D. Pshenychnyi Department of Animal Nutrition and Feed Technology of the National University of Life and Environmental Sciences of Ukraine in physiological experiments on broiler chickens of the ROSS-308 cross, using a complex method, by replacing part of the main diet (Table 1).

**Table 1.** Scheme of physiological experiment to determine the digestibility of rye grain nutrients in broiler chickens

Experiment	Feeding	Experimental periods	Age, days
first	BR	preparatory	22-25
		accounting	26-30
		transitional	31-33
second	95% BR + 5% rye grain	preparatory	34-37
		accounting	38-42

**Note:** BR – basic ration (compound feed including 5% rye grain)

**Source:** developed by the authors of this study

All experimental studies were conducted following the modern methodological approaches and corresponding requirements and standards that follow DSTU ISO/IEC 17025:2005 (2006). The animals were kept and all manipulations were performed following the provisions of the Procedure for conducting experiments and experiments on animals by scientific institutions (European

convention for the protection of vertebrate animals..., 1986; Law of Ukraine No. 249, 2012).

The physiological experiment was conducted on 5 broiler chickens aged 22-42 days. The chickens were kept in individual cages. The area per head was 0.2 m<sup>2</sup>, the feeding front was 25 cm, and the watering front was 3 cm. The experiment consisted of 2 parts. In the first experiment, the

nutrient digestibility of the main diet was determined – compound feed containing 5% rye grain; in the second, the main diet with an additional 5% rye grain was used.

Each experiment consisted of a preparatory and a main period. During the preparatory period of the experiment, the chickens were accustomed to the consumption of the test feed and new housing conditions, and the level of feed consumption was established. During the accounting period, careful records were kept of the feed consumed by each animal, its residues, and the litter produced. The litter was collected from each animal separately in a corresponding container, weighed, and the samples were stored in glass jars, preserved with hydrochloric acid solution. Every day, samples of the feed and food consumed were taken into jars stored in the refrigerator. Between the first and second experiments, a 3-day transition period was introduced, during which the feed intake of the second experiment was checked. The nutrient digestibility of rye grains was calculated using two experiments. The calculation was made on the assumption that the digestibility of nutrients in the main diet was the same in both experiments.

The chemical composition of the compound feed was determined according to the Wende method. Laboratory analyses of feed and litter were performed according to current methodologies that follow Commission Regulation (EC) No. 152/2009 (2009) laying down methods of

sampling and laboratory testing for official feed control. Dry matter was determined by drying in an oven, total moisture – at  $65 \pm 2$  °C, hygroscopic moisture – at  $103 \pm 2$  °C, using a Labexpert 3030 drying oven (Ukraine). The following was determined in dry matter:

┆ Crude ash – by burning the sample in a muffle furnace at  $550 \pm 20$  °C. A muffle furnace SNOL-8.2/1100 (Lithuania) was used for combustion.

┆ Nitrogen was determined according to the Kjeldahl method. Gerhardt Turbotherm TT-625 (Germany) was used for ashing the feed, and Gerhardt Vapodest 300 (Germany) was used for distillation. Nitrogen was converted to crude protein by multiplying by a factor of 6.25. Urine nitrogen was separated from faecal nitrogen using the Dyakov method.

┆ Crude fat was determined according to the Soxhlet method using Gerhardt Soxtherm SOX 412 (Germany). Diethyl ether was used as an extractant.

┆ Crude fibre was determined according to the Henniberg and Stoeman method by washing the sample in dilute sulphuric acid and potassium hydroxide using the Gerhardt FibreBag-System FBS6 (Germany).

┆ Nitrogen-free extractables were determined by calculating the difference between the organic matter content and the sum of crude protein, crude fat, and crude fibre.

In the first experiment, the nutrient digestibility of the base compound feed was determined, the composition of which is presented in Table 2.

**Table 2.** Composition of basic compound feed for experimental broiler chickens, %

Component	Content
Rye grain (hybrid KWS Tayo)	5.00
Wheat grain	32.00
Maize grain	30.15
Soybean cake	19.00
Meat meal	12.00
Table salt	0.16
Limestone	0.40
DL-methionine for feed	0.29
Premix*	1.00

**Note:** the premix contained capillary wormwood (*Artemisia capillaris*) powder (Ibatullin et al., 2022)

**Source:** developed by the authors of this study

In the second experiment, chickens were fed a diet consisting of 95 parts of base compound feed and 5 parts of rye grain. The chemical composition and nutritional value of the compound feed is presented in Table 3. The compound feed was balanced according to the recommendations of the cross developer. The diets of experiments 1 and 2 differed in nutritional value by  $\pm 1.83\%$ . The energy

content of rye grains was calculated in J of metabolic energy using the regression equation, based on the data on the content of digestible protein, fat, fibre, and nitrogen-free extractive substances (NFES) determined in the physiological experiment:

$$ME = (17.84 \text{ dP} + 39.78 \text{ dF} + 17.71 \text{ dF} + 17.71 \text{ dNFES}) \times 10^{-3}. \quad (1)$$

**Table 3.** Nutritional value of 100 g of compound feed for broiler chickens in the first and second experiments

Indicator	First experiment	Second experiment
Metabolic energy, MJ	1.300	1.235
Crude protein, g	20.65	20.06
Crude fat, g	4.56	4.41
Crude fibre, g	2.62	2.61
Nitrogen-free extractive substances, g	58.64	59.42
Calcium, g	0.91	0.86
Phosphorus, g	0.64	0.63
Sodium, g	0.26	0.24
Lysine, g	1.06	1.03
Methionine + cystine, g	0.83	0.80
Tryptophan, g	0.22	0.21

**Source:** developed by the authors of this study

The biometric processing of the data obtained during the study was performed using MS Excel 2013 software with built-in statistical functions. The results are presented as mean  $\pm$  standard deviation ( $x \pm SD$ ). Differences between groups of birds were calculated using

the t-test. The following significance levels were used for the study:  $p < 0.05$ ,  $0.01$ , and  $0.001$ .

## Results and Discussion

The results of the study of the chemical composition of rye grain are presented in Table 4.

**Table 4.** Chemical composition of rye grain

Indicator	Content, %	
	in the dry matter of the feed	in terms of natural humidity
Water	–	$12.56 \pm 0.456$
Dry matter	100	$87.44 \pm 0.456$
Crude protein	$10.14 \pm 0.581$	$8.87 \pm 0.484$
Crude fat	$1.86 \pm 0.112$	$1.63 \pm 0.105$
Crude fibre	$2.82 \pm 0.252$	$2.47 \pm 0.231$
Nitrogen-free extractives	$84.57 \pm 0.437$	$73.95 \pm 0.494$
Crude ash	$0.60 \pm 0.122$	$0.53 \pm 0.109$

**Source:** developed by the authors of this study

The average dry matter content of the rye samples was 874 g/kg, and the moisture content was 126 g/kg. The crude protein content was 101.4 g/kg in dry matter and 88.7 g/kg in natural moisture feed. M. Nilsson *et al.* (1997) obtained an analogous crude protein content in rye grain – 87 g/kg. However, most researchers report 3-35% more crude protein compared to the results obtained in the laboratory. Thus, in the feed nutrition guide for the Polissia Zone of Ukraine, the crude protein content of rye grain is 91 g/kg, which is 2.6% higher (Karpus *et al.*, 1994). For the natural and climatic zone of the Forest-Steppe of Ukraine, the crude protein content is 102 g/kg, which is 15.0% higher (Karpus *et al.*, 1995). For the Steppe zone, this figure is 117 g/kg, which is 31.9% higher than the data obtained in this experiment (Karpus *et al.*, 1993). I. Ibatullin & O.M. Zhukorskyi (2016) indicate a possible fluctuation in crude protein content from 90 to 110 g/kg with an average in Ukraine of 98 g/kg, but this figure also exceeds the one obtained in the experiment by 10.5%. Comparable data were obtained in studies of rye grain by D. Boros *et al.* (1995) and T. Antoniou & R.R. Marquardt (1981), where the crude protein content ranged within 94-99 g/kg. Somewhat higher values of crude protein content in rye grain were obtained by American scientists M.E. Ensminger *et al.* (1990) and M.H. Jurgens & K. Bregendahl (2007) – within 120 g/kg, which is 35% higher than the value obtained in this study.

The study of crude fat in rye grain showed its content of 18.6 g/kg dry matter and 16.3 g/kg natural moisture. The crude fat content of rye in the Polissia zone of Ukraine is 27 g/kg, which is 65% higher (Karpus *et al.*, 1994). In the Forest-Steppe zone, researchers report a slightly lower fat content of 15 g/kg (Karpus *et al.*, 1995). A comparable figure for rye was obtained in the Steppe zone of

Ukraine – 16 g/kg (Karpus *et al.*, 1993). Researchers from the USA M.E. Ensminger *et al.* (1990) and M.H. Jurgens & K. Bregendahl (2007) report the same crude fat content in rye grain as in the Forest-Steppe zone of Ukraine – 15 g/kg. I. Ibatullin & O.M. Zhukorskyi (2016) indicate a possible crude fat content of up to 29.9 g/kg.

The crude fibre content of the natural moisture feed was 25 g/kg. This figure was slightly lower than previously published feed chemical composition data. In the Polissia zone of Ukraine, this figure was 34 g/kg, or 36% higher (Karpus *et al.*, 1994). In the Forest-Steppe zone of Ukraine, the crude fibre content is reported to be 45 g/kg, which is 80% higher than the research data (Karpus *et al.*, 1995). For the Steppe zone, the figure is 28% higher – 32 g/kg (Karpus *et al.*, 1993). I. Ibatullin & M.O. Zhukorskyi (2016) provide data on the possible crude fibre content in feed ranging within 20-47 g/kg, with the average for Ukraine being 33.7 g/kg. Researchers from the USA M.H. Jurgens & K. Bregendahl (2007) cite a fibre content of 22 g/kg.

The studied rye grain samples contained 739.5 g/kg of nitrogen-free extractive substances. This indicator corresponded to the highest possible values for Ukraine (Ibatullin & Zhukorskyi, 2016). However, the analysis of most of the data shows that the figure is 5-9% higher than the existing data. Thus, for the Polissia zone it is 675 g/kg, for the Forest-Steppe – 681 g/kg, and for the Steppe – 676 g/kg (Karpus *et al.*, 1993; 1994; 1995). Other researchers cite a slightly higher value of nitrogen-free extractive substances previously published for Ukraine, but lower than the one obtained by the laboratory – 700 g/kg (Ensminger *et al.*, 1990; Jurgens & Bregendahl, 2007).

The results of the study of nutrient digestibility of rye grains and the calculated digestibility coefficients are presented in Table 5.

**Table 5. Nutrient digestibility coefficients of rye grain, %**

Nutrient	Experimental animal No.					x ± SD
	1	2	3	4	5	
Crude protein	77.96	76.09	75.44	75.72	74.40	75.92 ± 1.164

**Table 5.** Continued

Nutrient	Experimental animal No.					x ± SD
	1	2	3	4	5	
Crude fat	85.90	84.96	80.58	79.93	79.08	82.09 ± 2.782
Crude fibre	13.82	8.59	8.73	6.47	4.01	8.33 ± 3.240
Nitrogen-free extractives	83.40	81.28	80.71	78.97	80.52	80.98 ± 1.432
Organic matter	79.91	78.04	77.19	76.09	76.59	77.56 ± 1.342

**Source:** developed by the authors of this study

Crude protein digestibility averaged 75.92%. The fluctuations in the index among the experimental broiler chickens ranged within 74.40-77.96%. There is a limited amount of data in the literature on the digestibility of rye nutrients for poultry, but I. Ibatullin *et al.* (2015) reported a slightly lower crude protein digestibility of 69%. Comparing the data obtained with the experiments conducted on monogastric animals, such as pigs, the digestibility coefficients of crude rye protein range within 80-82% (Karpus *et al.*, 1993; 1994; 1995). M. Ensminger *et al.* (1990) reported a comparable crude protein

digestibility rate in pigs of 76%. The digestibility of crude fat averaged 82.09%, crude fibre – 8.33%, and nitrogen-free extractive substances – 80.98%. The data differ slightly from the digestibility coefficients for rye grain reported in the literature. I. Ibatullin *et al.* (2015) report crude fat digestibility coefficients of 25%, which is 57% lower, crude fibre digestibility of 3%, which is 5% lower, and nitrogen-free extractive substances of 85%, which is 3% higher than the data obtained.

The results of calculating the energy value of rye grain are presented in Table 6.

**Table 6.** Energy content of rye grain, MJ of metabolisable energy

Nutrient	Chemical composition, g/kg	Energy content, MJ					x ± SD
		1	2	3	4	5	
Crude protein	88.93	1.237	1.207	1.197	1.201	1.180	1.205 ± 0.0206
Crude fat	16.29	0.557	0.551	0.522	0.518	0.512	0.532 ± 0.0202
Crude fibre	24.73	0.061	0.038	0.038	0.028	0.018	0.036 ± 0.0159
Nitrogen-free extractives	742.40	10.965	10.687	10.612	10.383	10.587	10.647 ± 0.2107
Total energy content, MJ	–	12.819	12.482	12.369	12.131	12.297	12.420 ± 0.2573

**Source:** developed by the authors of this study

The total energy value of the rye grain was 12,420 MJ of metabolisable energy. The largest share of rye energy was provided by easily digestible carbohydrates of nitrogen-free extractive substances – 10,647 MJ, which was 85.7%. Crude protein energy accounted for 9.70%, or 1,205 MJ. Crude fat accounted for only 4.28%. Considering

the low digestibility of raw fibre, it accounted for only 0.32%.

The total energy value of rye grain calculated from the nutrient digestibility data obtained in these experiments differs slightly from that of other researchers. M. Ensminger *et al.* (1990) reported a 10.6% lower metabolisable energy

content for poultry in rye grain – 11.099 MJ/kg. M. Jurgens & K. Bregendahl, (2007) noted energy value of rye grain for poultry comparable to the findings of previous researchers – 11.103 MJ/kg. I. Ibatullin & O.M. Zhukorskyi (2016) report fluctuations in the energy value of rye grain within 11.34-14.22 MJ/kg, with an average value of 13.85 MJ in Ukraine, which is 12% higher than the data obtained.

Thus, the analysis of the chemical composition of a modern rye hybrid, its energy value, and nutrient digestibility allows revising the previously existing standards for its introduction into animal diets and compound feed. Lower crude fibre levels by 28-80% compared to previously published data, and low alkylresorcinols in modern rye hybrids (Milczarek *et al.*, 2020; Janiszewski *et al.*, 2021; Grabiński *et al.*, 2021) require further investigation.

The results of the chemical composition of rye grain showed that the content of the main nutrients, such as crude protein, crude fat, and crude fibre was lower than in the literature. The largest deviations were recorded in crude fibre content, which is 28-80% lower than previously published data, which may affect animal diets. The nutrient digestibility analysis confirmed that rye grain has good protein and carbohydrate digestibility, but low fibre digestibility. The findings underline the need to revise the standards for rye grain inclusion in animal diets.

## Conclusions

The data on the chemical composition, energy value, and digestibility of nutrients of rye grain of the hybrid KWS Tayo in broiler chickens were obtained. 1 kg of rye grain contained: water –  $12.56 \pm 0.456\%$ ; dry matter –  $87.44 \pm 0.456\%$ ; crude protein –  $8.87 \pm 0.484\%$ ; crude fat –  $1.63 \pm 0.105\%$ ; crude fibre –  $2.47 \pm 0.231\%$ ; nitrogen-free extractive substances –  $73.95 \pm 0.494\%$ , and crude ash –  $0.53 \pm 0.109\%$ . The nutrient

digestibility of rye grain was as follows: crude protein – 76%; crude fat – 82%; crude fibre – 8%; nitrogen-free extractive substances – 81%; and organic matter – 78%. The total energy value of rye grain was 12.420 MJ/kg of metabolisable energy for poultry. The obtained data on the chemical composition, energy value, and digestibility of nutrients of modern rye hybrid grain will be the basis for further research on the maximum levels of inclusion in poultry compound feed. Research also needs to be conducted on the impact of rye grain on the carbon footprint of broiler chicken compound feed.

The obtained findings confirm the possibility of using rye grain as an effective component of diets for broiler chickens, which has a significant potential in meeting their energy needs. However, the low digestibility of crude fibre can limit the share of rye in compound feed, especially for young poultry. The study also points to the need for more experiments on combining rye with other feed ingredients and enzyme preparations to ensure the best balance of nutrients. Specifically, this applies to determining the optimum levels of rye inclusion in diets depending on the age group of the poultry and the conditions of housing. Further research is needed to determine the maximum and effective levels of this component in broiler chicken compound feed, at different age periods, in combination with enzyme preparations, their impact on productivity, product quality, feed consumption and costs, production efficiency, and carbon footprint of diets.

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## Conflict of Interest

The authors of this study declare no conflict of interest.

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## Хімічний склад, енергетична поживність та перетравність поживних речовин зерна жита у курчат-бройлерів

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**Анотація.** Розвиток тваринництва завжди пов'язується з пошуком нових компонентів раціону, які підвищують ефективність годівлі, або знижують вартість корму. Максимальне використання регіональних, традиційних кормів в годівлі сільськогосподарських тварин є досить актуальним в наш час. Крім того, окремі корми, виробництво яких супроводжується невисокими викидами парникових газів у атмосферу сприяють зниженню карбонового сліду раціону в цілому. Метою досліджень було визначити поживність зерна жита сучасного гібриду КВС Тайо та перетравність поживних речовин у птиці. Досліджено хімічний склад зерна, перетравність поживних речовин у курчат-бройлерів, розрахована загальна енергетична поживність. Визначення хімічного складу кормів, комбікормів та посліду проводили методом Венде. Дослідження перетравності поживних речовин проводили на курчатах-бройлерах кросу «РОСС-308». Для фізіологічного дослідження було відібрано 5 курчат віком 22 доби. Дослід проводили складним методом, шляхом заміни частини основного раціону. Дослід складався із 2 частин. У першому досліді визначали перетравність поживних речовин основного раціону – комбікорму до якого входило 5 % зерна жита; у другому – основного раціону з введенням додатково 5 % зерна жита. Розрахунок вівся з умовою, що перетравність поживних речовин основного раціону під час обох дослідів була однаковою. Комбікорми були збалансовані за рекомендаціями розробника кросу. Енергетичну поживність зерна жита розраховували у Дж обмінної енергії за рівнянням регресії, за даними вмісту перетравних протеїну, жиру, клітковини та БЕР, визначеними у фізіологічному досліді. Середній вміст сухої речовини у дослідних зразках жита становив 87,4 %. Вміст основних поживних речовин у зерні натуральної вологості був наступним: сирого протеїну –  $8,87 \pm 0,484$  %; сирого жиру –  $1,63 \pm 0,105$  %; БЕР –  $73,95 \pm 0,494$  % та сирій золи –  $0,53 \pm 0,109$  %. Перетравність поживних речовин зерна жита складала: сирого протеїну – 76 %; сирого жиру – 82 %, сирій клітковини – 8 %; БЕР – 81 % та органічної речовини – 78 %. Загальна енергетична цінність зерна жита склала –  $12,420 \pm 0,2573$  МДж/кг обмінної енергії для птиці. Дані поживності і перетравності поживних речовин зерна жита можуть використовуватись нутриціоністами за складання практичних рецептів комбікормів для птиці

**Ключові слова:** годівля; птиця; компоненти комбікормів; карбоновий слід; ефективність використання корму