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FATTENING CAPACITY OF COMBINATIONS OF THREE BREEDS OF RABBITS OBTAINED FROM RECIPROCAL CROSSING

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The research was conducted on the basis of an experimental rabbit farm of the Cherkasy Experimental Station of Bioresources of the National Academy of Sciences. The farm uses the technology of intensive production of rabbit meat.

For the experiment on determining the fattening and meat indicators of young rabbits obtained from different combinations, 7 groups of young rabbits with 15 heads each aged 28 days were formed by the method of pairs-analogues.

It was found that young rabbits of the first control group (RSH) at 90 daily age had a live weight of 2710 g they were significantly ($p < 0.01$) dominated by analogues of the second Group (3\4 RSH1\4NB) at 163g, the third (1\4NB3\4RSH) at 120g($p < 0.05$), the sixth (2\4RSH 1\4NB1\4SV) at 200g($p < 0.001$), seventh (1\4NB1\4SV2\4RSH) at 179g($p < 0.01$), which is an increase in the indicator – the mass of one head at 90 daily age.

The indicator of average daily increments(age period 28-90 days)) in young rabbits of the 2nd group of Origin 3\4RSH1\4NB significantly ($p < 0.01$) prevailed over the control of purebred young rabbits of the Soviet Chinchilla by 2.4 g. the average daily increments in the sixth and seventh experimental groups were 38.3 and 38.0 g, which is 2.6; and 2.3 g significantly higher ($p < 0.01$; $p < 0.05$) from peers of the first group.

In terms of loin width, rabbits of the 6th and 7th groups of young rabbits of the first control group significantly prevailed ($p < 0.05$). The meat content index of these groups of Origin: 2\4 RSH 1\4NB1\4SV; 1\4NB1\4SV2\4RSH, was 6.14; 6.07cm.

Slaughter yield was better in young rabbits of the sixth and seventh groups of



Origin 2/4 RSH 1/4NB1/4SV; 1/4NB1/4SV 2/4RSH, which prevailed in the control group by 3.33 and 2.23%.

Feed costs per 1 kg of growth in the groups were: 4.4 kg in the control group; in the experimental groups, the feed efficiency was higher and ranged from 4.1 to 3.9 kg. The group of young rabbits of Origin 2/4RSH1/4NB1/4SV consumed food more efficiently and outnumbered the peers of the Soviet Chinchilla by 500 g, and the 2nd by 300 g and the 7th by 450 g.

The Comprehensive Assessment Index (PKO) was higher in all experimental groups of young rabbits compared to the control, in particular, in groups 2, 3, 6 and 7 by 14.3; 8.7; 17.9 and 15.6 to purebred peers of Group 1 of the Soviet Chinchilla (240.1).

The selection assessment of our tests was given by the index of total heterosis. The index of total heterosis by Slaughter yield of young rabbit carcasses in the experimental groups was: 2,37; 1,76; 1,88; 2,51; 6,64; 4,45%. The index of total heterosis in terms of PKO was 5,95; 3,62; 2,46; 3,04; 7,46; 6,5 %.

Net income for the production of 1 kg of rabbit meat was by Group 1- 10,9; 2-15,6; 3, 4 and 5-14,0; 6-18,7; 7-17,9 due to the inter - breed combination, it increased by 3.1-7.8 UAH.

The highest profitability of production, in terms of direct costs, was among young rabbits of Group 2 – 24.2; groups 6 and 7 – 30.5%; 28.8%. Animals of these groups by origin were two breeds – 3/4rsh1/4nb and three breed crossbreeds: 2/4RSH1/4NB1/4SV; 1/4NB 1/4SV2/4 RSH.

Keywords: young rabbits, crossing, fattening productivity, PKO, economic efficiency.

ВІДГОДІВЕЛЬНА ЗДАТНІСТЬ ПОЄДНАНЬ ТРЬОХ ПОРІД КРОЛІВ ОТРИМАНИХ ВІД РЕЦИПРОКНОГО СХРЕЩУВАННЯ

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Черкаська дослідна станція біоресурсів НААН, Черкаси, Україна

Дослідження проводились на базі експериментальної кролеферми Черкаської дослідної станції біоресурсів НААН. В господарстві застосовується технологія інтенсивного виробництва кролятини.

Для дослідів з визначення відгодівельних і м'ясних показників молодняка кролів отриманого від різних варіантів поєднання, методом пар-аналогів було сформовано 7 груп молодняка кролів по 15 голів у кожній віком 28 діб.

Встановлено, що молодняк кролів першої контрольної групи (РШ) в 90 добовому віці мав живу масу 2710 г їх вірогідно ($p < 0,01$) переважали аналоги другої групи (3\4РШ1\4НБ) на 163г, третьої (1\4НБ3\4РШ) на 120г($p < 0,05$), шостої (2\4РШ1\4НБ1\4СВ) на 200г($p < 0,001$), сьомої (1\4НБ 1\4 СВ2\4РШ) на 179 г($p < 0,01$), що є зростанням показнику – маси однієї голови в 90 добовому віці.

Показник середньодобових приростів(віковий період 28-90 діб) в молодняка кролів 2-ї групи походження 3\4РШ1\4НБ вірогідно ($p < 0,01$) переважав контрольну чистопородного молодняка кролів радянської шиншили на 2,4 г.



Середньодобові прирости в шостій та сьомій дослідних групах становили 38,3 і 38,0г, що на 2,6; і 2,3 г вірогідно вищі ($p < 0,01$; $p < 0,05$) від ровесників першої групи.

За шириною попереку, вірогідно переважали кролі 6 і 7-ї груп молодняку кролів першої контрольної ($p < 0,05$). Показник м'ясності цих груп походження: $^{2/4}PШ^{1/4}НБ^{1/4}СВ$; $^{1/4}НБ^{1/4}СВ^{2/4}PШ$, становив 6,14; 6,07 см.

Забійний вихід крацим був у молодняку кролів шостої і сьомої груп походження $^{2/4}PШ^{1/4}НБ^{1/4}СВ$; $^{1/4}НБ^{1/4}СВ^{2/4}PШ$, що переважав контрольну групу на 3,33 і 2,23%.

Затрати корму на 1кг приросту по групах становили: 4,4кг у контрольній; в дослідних ефективність корму була вищою та коливалась від 4,1 до 3,9кг. Група молодняку кролів походження $^{2/4}PШ^{1/4}НБ^{1/4}СВ$ більш ефективно споживала корм та переважала ровесників радянської шиншили на 500 г, а 2-а на 300г та 7-а на 450 г.

Показник комплексної оцінки(ПКО) вищим був у всіх дослідних групах молодняку кролів у порівнянні до контролю, зокрема, в 2, 3, 6 та 7-й групах на 14,3; 8,7; 17,9 та 15,6 до чистопородних ровесників 1 групи радянської шиншили(240,1).

Селекційну оцінку нашим випробуванням дав індекс загального гетерозису. Індекс загального гетерозису за забійним виходом туш молодняку кролів в дослідних групах становив: 2,37; 1,76; 1,88; 2,51; 6,64; 4,45%. Індекс загального гетерозису за показником ПКО становив 5,95; 3,62; 2,46; 3,04; 7,46; 6,5 %.

Чистий дохід при виробництва 1кг кролятини становив по групах 1- 10,9; 2-15,6; 3, 4 і 5-14,0; 6-18,7; 7-17,9 грн. За рахунок між породного поєднання він зріс на 3,1 - 7,8грн.

Найвищою рентабельність виробництва, за прямими затратами, була у молодняку кролів 2 групи – 24,2; 6 і 7 груп – 30,5%; 28,8%. Тварини цих груп за походженням були двох породні – $^{3/4}PШ^{1/4}НБ$ та трьох породні помісі: $^{2/4}PШ^{1/4}НБ^{1/4}СВ$; $^{1/4}НБ^{1/4}СВ^{2/4}PШ$.

Ключові слова: молодняк кролів, схрещування, відгодівельна продуктивність, ПКО, економічна ефективність

In the last 20 years, rabbit meat production in Ukraine has been carried out using European, intensive technology. The parameters of this technology provide for obtaining at least eight okrols from one rabbit during the production year, which is 60 or more rabbits. Indicators of precocity of fattening young rabbits should ensure slaughter at the age of 80 days with a live weight of at least 2.8 kg, with a slaughter yield of 55-60%. Abroad, as an element of this technology, hybridization is used with the participation of 4-5 breeds that are maximally adapted to intensive breeding (Vintoniv, O.A., 2022; Dorian,S., 2014).

The problem of intensifying the rabbit breeding industry in Ukraine is extremely acute, since many breeds are small in number and have high genetic variability (Christensen, O. F., 2010). In addition, the number of breeding farms for breeding most breeds has decreased, and there is no program for creating an industrial rabbit (Crovato, S., 2022; Siddiqui, S. A., 2023). In this regard, conscious management of the scientific and production process based on knowledge of the features of breeding and technological processes becomes important.

The main indicators on which the intensification of rabbit production depends are fecundity, live weight of rabbits at birth, nest safety, growth rate and feed payment in increments (García, M.L.; 2020).

To achieve this goal, it is necessary to cause the desired changes in heredity and accumulate them in a number of generations by the chosen system of breeding, feeding



and maintenance (Tabet, J. M., 2025; Havrysh O. M., 2025; Shah, I., 2024; Badawy, A.Y. 2019).

Starting breeding work in rabbit breeding, you should focus on one or two traits, without neglecting others, which should be at least at an average level. At the first stage, attention is paid to maternal qualities: live weight at birth, live weight at weaning (28 days), preservation (Sotnichenko, Yu.M., 2020).

To speed up obtaining the desired productive indicators, it is necessary to use crossing, which pursues several goals – to enrich the heredity of one of the breeds, and on the basis of two or more breeds to create a new genotype that would generalize all the positive aspects of the breeds taken for crossing, and for the main ones and significantly exceed them (Mondin, C., 2021). The purpose of such work is to combine different breeds in such a way that the overall production efficiency is maximized (Shevchenko, E., 2020).

Studies of existing genotypes for combinability (combinability) can be carried out with forward and reverse (reciprocal) crossing. Based on the results of crossing, select the best, highly productive interbreeding offspring, which should be used in further industrial work (hybridization) as parental and maternal forms (Shevchenko, E., 2025; Clasen, J. B., 2023; Luchyn I. S., 2022).

To achieve this goal, it is necessary to use breeds that predominate in traits with high heredity, are controlled by additive genes and traits that show the best combinatorial ability in the form of a heterosis effect. The effect of heterosis should be higher, especially when breeds are significantly different from each other genetically or inherited (Mrode, R. A., 2005).

When the selected traits positively correlate with each other – such as birth weight, milk production and preservation, selection simultaneously for these three indicators will increase the further intensity of the manifestation of fattening traits of young rabbits (Peiró, R., 2010).

Obtaining the maximum effect of heterosis is possible when creating breeds whose descendants, when crossed, can best combine according to the main quantitative indicators. To do this, you need to create a maternal form in which the reproductive properties of rabbits predominate (focus) and two or more parental forms in whose offspring fattening and meat indicators predominate (Luchyn, I. S., 2025). A successful combination of these genotypes will ensure maximum productivity growth (Clark, S.A., 2013).

Now there is an urgent need, based on the generalization of theoretical and practical achievements in rabbit breeding, to monitor crossbreeding and purebred breeding of rabbits in modern socio-economic conditions, the use of existing high-performance and adapted to the climatic and technological conditions of Ukraine rabbit head.

The aim of the work is to study the fattening and slaughter qualities of local young rabbits obtained from reciprocal crossing, to give an economic assessment in conditions of intensive breeding.

Materials and methods of research. The research was conducted at the Cherkasy agricultural Experimental Station of Bioresources of the National Academy of Sciences. The farm uses the technology of intensive production of rabbit meat. Breeds of rabbits bred on the farm: Soviet Chinchilla, Gray giant, New Zealand white and their crossbreeds. The average monthly number of rabbits is 300 heads, of which 60 are the main rabbits.

The main elements of the technology present in the study:

- insemination according to the technological map, on the 10th day after district;
- weaning of rabbits at the age of 28 days;
- fattening period from 28 to 90 days of age.



In order to improve the fattening productivity of Chinchilla - like rabbits (two, three breed crossbreeds) in the conditions of industrial intensive use-rabbits of the Soviet Chinchilla breed are used as a mother (RSH), this genotype is most adapted to the production and climatic conditions of central Ukraine. The parent breeds are males of the gray giant (SV) and New Zealand White (NB) breeds, they have more pronounced fattening and meat indicators.

For the experiment on determining the fattening and meat indicators of young rabbits obtained from different variants of the reciprocal combination, 7 groups of young rabbits with 15 heads each aged 28 days were formed by the method of pairs-analogues (table. 1).

To determine fattening and meat qualities, the comprehensive assessment indicator " young rabbits (PKO) " was used (Luchyn I. S., 2022):

$$I = 5.1 (K + 2H);$$

where 5,1; 2 are the correction factors;

K-average daily gain (from birth) in grams;

H is the width of the lower back (at points adjacent to the knee joints) in centimeters.

It is most appropriate to evaluate young rabbits for PKO at 90 days, at this age the correlation between the indicators of average daily growth and lower back width is most positive.

Technological and economic conclusions will be drawn from the use of various variants of reciprocal crossbreeding with the participation of Soviet Chinchilla, Gray giant, and New Zealand White breeds in intensive production.

Table 1

Scheme of the experiment of fattening young rabbits, n=15

Groups	Genotype	Productive indicators							
Contr.	RSH								
experimental:	3/4 RSH1/4NB	Live weight of rabbits in 30dib, g	Live weight of rabbits in 90 days, g	Average daily increments, g	Lower back width at 3 months of age, cm	Weight of a paired carcass, g	Slaughter yield, %	feed costs per 1 kg of growth, kg	PKO
	1/4NB 3/4RSH								
	3/4RSH1/4SV								
	1/4SV3/4RSH								
	2/4 RSH1/4 NB1/4SV								
	1/4 NB1/4SV2/4RSH								

To study the combinational ability for reciprocal crossing of rabbit breeds, the Soviet Chinchilla, Gray giant and New Zealand white and their crossbreeds in the conditions of central Ukraine and determine the optimal combination for use in the conditions of industrial intensive technology, the heterosis index was determined by the formula proposed by V. T. Gorin, I. M. Nikitchenko (Piotrovich N.A., 2017) improved by O. M. Tserenyuk (Knecht, D., 2015).

$$Gz = Og/Om \times 100 - 100,$$

where: Gz-general heterosis;

Og-hybrid attribute;

Om-a sign of the maternal form.



Research results. In the Cherkasy Experimental Station of Bioresources of the National Academy of Sciences, work was carried out to find successful breeding combinations of rabbits that should be adapted to the conditions of keeping, feeding and showing high productivity during intensive breeding. The work involved the breeds of rabbits present for this period, which are adapted to keeping on a metal mesh floor, to a high concentration of livestock, to the conditions of the microclimate of premises and conditions of central Ukraine.

The study established (table.2) that young rabbits of the first control group (RSH) at 90 daily age had a live weight of 2710 g they were significantly ($p < 0.01$) dominated by analogues of the second Group (3\4RSH1\4NB) at 163g, the third (1\4NB3\4RSH) at 120g($p < 0.05$), the sixth (2\4RSH1\4NB1\4SV) at 200g($p < 0.001$), the seventh (1\4NB1\4SV2\4RSH) at 179g($p < 0.01$), which is an increase in the indicator – the mass of one head at 90 daily age.

The indicator of average daily increments(age period 28-90 days) in young rabbits of the 2nd group of Origin 3\4RSH1\4NB significantly ($p < 0.01$) prevailed over the control of purebred young rabbits of the Soviet Chinchilla by 2.4 g. the average daily increments in the sixth and seventh experimental groups were 38.3 and 38.0 g, which is 2.6; and 2.3 g significantly higher ($p < 0.01$; $p < 0.05$) from peers of the first group.

Table 2

Growth rate of young rabbits, (n=15)

Group	Staging on experience	Live weight of 1 head at 90 daily age, g	average daily increments, g
I κ	492±9,35	2710±33,52	35,7±0,63
II	514±10,6	2873±35,14**	38,1±0,5**
III	524±9,0*	2830±44,93*	37,1±0,66
IV	513±10,6	2797±32,54	36,8±0,45
V	515±13,37	2807±34,11	37,0±0,38
VI	532±8,4**	2910±32,81***	38,3±0,47**
VII	527±13,93	2889±45,35**	38,0±0,54*

Note. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ compared to the control group

Slaughter indicators (age 90 days) (table.3), in particular, the weight of a paired carcass in groups was: 1 – 1358; 2 – 1474; 3- 1443; 4 – 1428; 5 – 1442; 6 – 1555 and 7 – 1512g. young rabbits of all experimental groups had a significant difference before the control and dominated the first group by 116g ($p < 0.001$), 85g($p < 0.05$), 70g ($p < 0.01$), 84g ($p < 0.01$), 197g ($p < 0.001$), 154g ($p < 0.001$).

Slaughter yield was better in young rabbits of the sixth and seventh groups of Origin 2/4 RSH1/4NB1/4SV; 1/4NB1/4SV 2/4RSH, which prevailed in the control group by 3.33 and 2.23%.

Feed costs per 1 kg of growth in the groups were: 4.4 kg in the control group; in the experimental groups, the feed efficiency was higher and ranged from 4.1 to 3.9 kg. The 6th group of young rabbits of Origin 2/4RSH1/4NB1/4SV consumed food more efficiently and outnumbered the peers of the Soviet Chinchilla by 500 g, and the 2nd by 300 g and the 7th by 450 g.

PKO in studies reflects the breeding value of the animal, determines its further use: for breeding use or slaughter for meat.

The Comprehensive Assessment Index (PKO) was higher in all experimental groups of young rabbits compared to the control, in particular, in groups 2, 3, 6 and 7 by



14.3; 8.7; 17.9 and 15.6 to purebred peers of Group 1 of the Soviet Chinchilla (240.1).

The best indicators of fattening and meat productivity 2, 7 and especially 6 groups) were obtained by young rabbits of Origin 3/4RSH1/4NB; 1/4NB1/4SV2/4RSH; 2/4RSH1/4NB1/4SV, due to the features of the three-breed combination of the maternal genotype of Soviet Chinchilla rabbits with the breed of gray giant and New Zealand White. This made it possible to concentrate (additive action) genes of high fattening productivity.

Table 3

Fattening and slaughter indicators of young rabbits, (n=15)

Groups	Lower Back width at 3 months of age, cm	Weight of a paired carcass, g	slaughter yield, %	Feed consumption per 1 kg of	PKO
I	5,69±0,128	1358±17,4	50,11	4,4	240,1
II	5,89±0,104	1474±20,4***	51,3	4,1	254,4
III	5,84±0,126	1443±24,0*	50,99	4,2	248,8
IV	5,72±0,083	1428±15,9**	51,05	4,2	246,0
V	5,76±0,081	1442±18,4**	51,37	4,2	247,4
VI	6,14±0,126*	1555±19,5***	53,44	3,9	258,0
VII	6,07±0,113*	1512±23,7***	52,34	3,95	255,7

Note. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ compared to the control group

During crossing, fattening indicators of the 2nd and 7th and 6th groups increased to rabbits of the 1st group: live weight at 90 daily age by 6.0; 6.6($p < 0.01$) and 7.4% ($p < 0.001$); average daily increases by 6.7($p < 0.01$); 6.4% ($p < 0.05$) and 7.3% ($p < 0.01$); loin width by 3.5; 6.7 and 7.9% ($p < 0.01$).

For breeding assessment of fattening and slaughter indicators of young rabbits, the index of total heterosis was determined according to the formula of V. Gorin (table 4).

Table 4

General heterosis, young rabbits at 90 daily age

Groups	Origin	killer output		PKO	
		Slaughter yield, %	indicator heterosis	PKO indicator	indicator heterosis
I	RSH	50,11		240,1	
II	3/4RSH1/4NB	51,3	2,37	254,4	5,95
III	1/4NB3/4RSH	50,99	1,76	248,8	3,62
IV	3/4RSH1/4CV	51,05	1,88	246,0	2,46
V	1/4SV3/4RSH	51,37	2,51	247,4	3,04
VI	2/4RSH1/4NB1/4CV	53,44	6,64	258,0	7,46
VII	1/4NB1/4SV2/4RSH	52,34	4,45	255,7	6,5

The index of total heterosis by Slaughter yield of young rabbit carcasses in the experimental groups was: 2,37; 1,76; 1,88; 2,51; 6,64; 4,45%. The index of total heterosis in terms of PKO was 5,95; 3,62; 2,46; 3,04; 7,46; 6,5 %.



Economic efficiency from the use of three-breed crossing. In young rabbits obtained from seven combinations, not only fattening indicators for groups changed, but also economic ones (table.5).

Analysis of fattening of young rabbits showed that an increase in the growth intensity (by 1.1 - 10.7%) in local young rabbits affected economic indicators. The cost of feed costs per unit of growth was determined by multiplying the cost of 1 kg of feed by the cost of feed per 1 kg of growth. The results of the study show that feed costs per 1 kg of growth in experimental groups of cross animals decreased to the indicators of the first control group of young rabbits of the Soviet Chinchilla breed.

Reduction of the cost of feed by 1 kg of growth to Group 1 (48.4 UAH), in 2 experimental by 3.3 UAH; in 3 experimental by 2.2 UAH; in 4 and 5 also by 2.2 UAH; in 6 by 5.5 UAH; in 7 experimental group by 4.95 UAH. This dynamics affected the indicator of net profit and profitability of production.

The cost of production of 1 kg of rabbit meat was determined by the cost of feed in the structure, which accounted for 70% of all direct costs.

Net income for the production of 1 kg of rabbit meat was by Group 1- 10,9; 2- 15,6; 3, 4 and 5-14,0; 6-18,7; 7-17,9 due to the inter - breed combination, it increased by 3.1-7.8 UAH.

The highest profitability of production, in terms of direct costs, was among young rabbits of Group 2 – 24.2; groups 6 and 7 – 30.5%; 28.8%. Animals of these groups by origin were two breeds – 3/4RSH1/4NB and three breed crossbreeds: 2/4RSH1/4NB1/4SV; 1/4NB1/4SV 2/4RSH.

Table 5

Economic efficiency of fattening young rabbits

Economic indicators	Groups						
	I	II	III	IV	V	VI	VII
Feed costs per 1 kg of weight gain, kg	4,4	4,1	4,2	4,2	4,2	3,9	3,95
The cost of 1 kg of mixed feed, UAH.	11	11	11	11	11	11	11
The cost of feed per 1 kg of weight gain, UAH.	48,4	45,1	46,2	46,2	46,2	42,9	43,45
Feed in the structure of direct costs, %	70	70	70	70	70	70	70
Cost of 1 kg of rabbit meat, UAH.	69,1	64,4	66,0	66,0	66,0	61,3	62,1
Sales price of 1 kg of rabbit meat, UAH	80	80	80	80	80	80	80
Net income, 1 kg of rabbit meat, UAH	10,9	15,6	14,0	14,0	14,0	18,7	17,9
Profitability, %	15,8	24,2	21,2	21,2	21,2	30,5	28,8

The use of reciprocal three-breed crossing provided not only an increase in the fattening productivity of rabbits, but also:

- improved feed conversion;
- reduced direct costs for the production of a unit of rabbit meat;
- increased net income and profitability of rabbit meat production.

Studies have established that the use of Soviet Chinchilla rabbits as a mother breed with males of the gray giant and New Zealand White breeds in reciprocal Crossing allows increasing the maternal properties of rabbits and fattening and meat indicators of young rabbits obtained from these combinations, especially the Origin: 3/4RSH1/4NB1/4SV; 1/4NB1/4SV 2/4RSH.



Discussion. A more advanced, highly intensive industrial technology for rabbit meat production was created in Europe 30-35 years ago. Its creators were two French companies "Eurolap" and "Hypharm". Breeding technologies are based on hybridization with a maximum manifestation of heterosis of up to 25%. The material is 4-5 breeds (great-great-grandmother's herd). Currently, for the industrial production of rabbit meat in Ukraine, "French" or intensive technology is used. But a big problem remains for Ukrainian rabbit meat producers the availability of highly productive rabbit heads adapted to this technology.

At the Cherkassy Experimental Station of Bioresources of the National Academy of Sciences, work was carried out to find successful breeding combinations of rabbits that are capable of showing high productivity during intensive breeding in Ukraine. Local populations of rabbits adapted to keeping on a metal mesh floor, high concentration of livestock, indoor microclimate conditions were involved in the work, provided that rabbits are resistant to pododermatitis, stress sensitivity, and are fertile...

Based on our research, it was proved that due to the combinative ability of three breeds and the adaptability of their crossbreeds to the conditions of keeping in the farm of the Cherkasy Experimental Station (intensive, industrial breeding), the best combinations of rabbits, such as 2/4RSH1/4NB1/4SV, 1/4NB1/4SV2/4RSH, prevailed the control group (RSH) in terms of indicators: live weight at 90 daily age by 6.6(p<0.01), 7.4% (p<0.001); average daily increases by 6.4%(p<0.05), 7.3% (p<0.01); lumbar width by 6.7 and 7.9%(p<0.01).

The selection assessment of our studies was given by the index of total heterosis in terms of slaughter yield, which in these groups was 6.64 and 4.45%, and the index of total heterosis in terms of PKO - 7.46 and 6.5 %.

In studies, local young rabbits showed high fattening, slaughter productivity and economic efficiency due to the origin and sowing of adaptation to the conditions of industrial maintenance: the absence of pododermatitis, stress sensitivity.

Conclusions. Studies have established that the use in reciprocal crossing (various combinations) as the mother breed of rabbits of the Soviet Chinchilla with males of the breeds of the gray giant and the New Zealand White allows to increase the reproductive properties of rabbits and fattening and meat indicators of young rabbits obtained from these combinations.

The best indicators of fattening and meat productivity (2, 7 and especially 6 groups) were obtained by young rabbits of Origin 3/4RSH1/4NB; 1/4NB1/4SV2/4RSH; 2/4RSH1/4NB1/4SV, due to the features of the three-breed combination of the mother breed Soviet Chinchilla with males of the gray giant and New Zealand White breeds. This made it possible to concentrate (additive action) genes of high fattening productivity.

During crossing, fattening indicators of the 2nd and 7th and 6th groups increased to rabbits of the 1st group: live weight at 90 daily age by 6.0; 6.6(p<0.01) and 7.4% (p<0.001); average daily increases by 6.7(p<0.01); 6.4%(p<0.05) and 7.3% (p<0.01); loin width by 3.5; 6.7 and 7.9%(p<0.01).

It is established that high fattening, slaughter productivity and economic efficiency of local young rabbits showed due to the origin and sowing of adaptation to the conditions of intensive industrial maintenance in Ukrainian farms.

References

- Badawy, A., Peiró, R., Blasco, A., Santacreu, M. (2019). Correlated responses on litter size traits and survival traits after two-stage selection for ovulation rate and litter size in rabbits. *Animal*, 3(3):453 – 459.
<https://doi.org/10.1017/S1751731118002033>



- Christensen, O., Lund, M. (2010). Genomic prediction when some animals are not genotyped. *Genet. Sel. Evol*, 42:2. <https://doi.org/10.1186/1297-9686-42-2>
- Clark, S., van der Werf, J. (2013). Genomic best linear unbiased prediction (gBLUP) for the estimation of genomic breeding values. *Methods Mol Biol.*, 1019, 321-30. https://doi.org/10.1007/978-1-62703-447-0_13.
- Clasen, J., Fikse, W., Su, G., Karaman, E. (2023). Multibreed genomic prediction using summary statistics and a breed-origin-of-alleles approach. *Heredity*. 131. 33 – 42. <https://doi.org/10.1038/s41437-023-00619-4>
- Crovato, S., Pinto, A., Martino, G., Mascarello, G., Rizzoli, V., Marcolin, S., Ravarotto, L. (2022). Purchasing habits, sustainability perceptions, and welfare concerns of Italian consumers regarding rabbit meat. *Foods*, 11(9), 1205. <https://doi.org/10.3390/foods11091205>
- Dorian, Garrick, Jack, Dekkers, Rohan, Fernando, (2014). The evolution of methodologies for genomic prediction. *Livestock Science*. 166, 10-18. <https://doi.org/10.1016/j.livsci.2014.05.031>.
- García, M., Argente, M. (2020). The genetic improvement in meat rabbits. In *Lagomorpha Charact. Intech Open: London*, 5, 1 – 18. <https://doi.org/10.5772/intechopen.93896>
- Havrysh, O., Nebylytsia, M., Tkach, E., Osokina, T., Bashhenko, V., Bilan, A. (2025). Reproductive qualities of rabbits depending on paratypic factors during their maintenance. *Zbirnyk naukovykh prats «Efektyvne krolivnytstvo i zvirivnytstvo»*, 11, 7 – 19. <https://doi.org/10.37617/2708-0617.2025.11.7-18>.
- Knecht, D., Srodon, S., Duziński, K. (2015). Breed on selected reproductive performance parameters of sows. *Arch. Anim. Breed, issue 58*, pp. 49–56.
- Luchyn, I. S/ (2022). Selection justification of the technology of intensive production of rabbit meat. *Animal Husbandry of the Steppe of Ukraine*, 1 (2), 171 – 179. <https://doi.org/10.31867/2786-6750>.
- Luchyn, I., Perih, D., Lunyk, Y., Smyrnov, V., Tsyupka, S., Kalamitra, V. (2025). Reproductive traits of chinshilla rabbits under different three-breed crossbreeding schemes. *Scientific and Technical Bulletin of State Scientific Research Control Institute of Veterinary Medical Products and Fodder Additives and Institute of Animal Biology*, 26(1), 118-126. <https://doi.org/10.36359/scivp.2025-26-1.14>
- Mondin, C., Trestini, S., Trocino, A., Di Martino, G. (2021). The economics of rabbit farming: a pilot study on the impact of different housing systems. *Animals* 11, 30-40. <https://doi.org/10.3390/ani11113040>
- Mrode, R. A. (2005). Thompson, R. Linear models for the prediction of animal breeding values. 2nd ed., Wallingford, U. K: CABI Publishing. <http://www.cabi.org/cabebooks/ebook/20053196805>
- Peiró, R., Herrler, A., Santacreu, M.A. (2010). Expression of progesterone receptor related to the polymorphism in the gene in the rabbit reproductive tract. *J. Anim. Sci.* 88(2), 421 – 427. <https://doi.org/10.2527/jas.2009-1955>.
- Piotrovych, N.A. (2017). Formation of reproductive quality of sows and assessment of their combinatory ability. Author's abstract of the dissertation of the candidate of agricultural sciences.
- Shah, Ali, Goswami, Naqash. (2024). Enhancing Rabbit Farming Efficiency with Integrated Genomics and Nutritional Strategies. *Frontiers in Animal Science*. <https://doi.org/10.3389/fanim.2024.1514923>
- Shevchenko E., Honchar O., Dzitsiuk V. (2025). Genetic potential of Poltava silver rabbits: G-BLUP evaluation based on polymorphism of MSTN and PGR genes.



- Collection of scientific papers «Effective rabbit breeding and animal fur husbandry»*, 11, 19 – 28. <https://doi.org/10.37617/2708-0617.2025.11.19-27>.
- Shevchenko, E., Honchar, O. (2020). Selection-genetic characteristics of rabbits poltavaska silver breed by polymorphism of progesterone receptor gene. *Collection of scientific papers «Effective rabbit breeding and animal fur husbandry»*, 6, 6–13. <https://doi.org/10.37617/2708-0617.2020.6.6-13>
- Siddiqui, S., Gerini, F., Ikram, A., Saeed, F., Feng, X., Chen, Y. (2023). Rabbit Meat – Production, Consumption and Consumers’ Attitudes and Behavior. *Sustainability*, 15(3), 2008. <https://doi.org/10.3390/su15032008>
- Sotnichenko, Yu. (2020). Osoblyvosti formuvannya miasnoi produktyvnosti zamiaso-shkirnymy prohramamy produktyvnosti. *Zbirnyk naukovykh prats «Efektyvne krolivnytstvo i zvirivnytstvo»*. 6, 117 – 128. <https://doi.org/10.37617/2708-0617.2020.6.117-125>
- Tabet, J.M., Lourenco, D., Bussiman F.et al. (2025). All-breed single-step genomic best linear unbiased predictor evaluations for fertility traits in US dairy cattle. *Journal of Dairy Science*, 108, 694-706. <https://doi.org/10.3168/jds.2024-25281>.
- Vintoniv, O., Havrysh, O. (2022). Reproduktyvna zdavnist krolykiv-samtsiv zalezghno vid vplyvu paratypovykh ta henotypovykh faktoriv. *Rozvedennia tvaryn i henetyka*, 64, 147 – 153. <https://doi.org/10.31073/abg.64.13>.



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SCIENTIFIC JUSTIFICATION OF WELFARE STANDARDS FOR THERAPEUTIC HORSES IN EQUINE-ASSISTED THERAPY IN UKRAINE

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The research-and-practice work, based on a comparative-analytical approach and the synthesis of zootechnical and veterinary data, resulted in the development of the "Standards of Welfare for Therapeutic Horses" – the first national draft document regulating ethical, zootechnical, and veterinary practice in the field of hippotherapy, hipoinvention (equine intervention), and adaptive equestrian sports in Ukraine. The study was conducted by the working group of the Non-Governmental Union "Ukrainian Equine-Assisted Therapy and Adaptive Riding Association (UEAT-ARA)" using the internationally recognized Five Domains Model by David Mellor, which provides a comprehensive assessment of animal welfare at the level of physical and psycho-emotional indicators. International protocols from the Federation of Horses in Education and Therapy International (HETI), the International Equestrian Federation (FEI), and other organizations were adapted to national conditions, taking into account the climatic, economic, and breed characteristics of Ukrainian horse breeding.

The main achievements of the work include the introduction of clear quantitative indicators: a minimum stall size of 3.65 x 3.65 m to ensure freedom of movement (which exceeds typical norms for sport horses); limitation of the maximum concentrate portion to 2 kg per feeding and prohibition of using cattle feed as a means of preventing obesity, acidosis, and laminitis; a daily water intake norm of 25-50 L and a pasture area of 0.5-1.0 ha per horse. The Standards focus special attention on psycho-emotional welfare – they introduce a requirement for daily social interaction and define signs of behavioral burnout, upon which work must be immediately stopped. For the first time in Ukraine, the Standards establish provisions for the Responsibility for the Horse's Life Cycle after retirement and the mandatory nature of an annual dental examination.

The proposed Standards form a scientifically sound regulatory basis for assessing and controlling the welfare of horses in therapeutic programs, contributing to enhancing the ethical status of equestrian centers, extending the effective working period of animals, and ensuring the safety and quality of rehabilitation services in Ukraine.

Keywords: Therapeutic Horses, Equine Welfare, Hippotherapy, Five Domains Model, Zootherapy (Animal-Assisted Therapy), Ethical Standards, Ukraine.



НАУКОВЕ ОБҐРУНТУВАННЯ СТАНДАРТІВ БЛАГОПОЛУЧЧЯ ТЕРАПЕВТИЧНИХ КОНЕЙ ДЛЯ ІПОТЕРАПІЇ В УКРАЇНІ

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Науково-практична робота, що ґрунтується на порівняльно-аналітичному підході та синтезі зоотехнічних і ветеринарних даних, призвела до розробки «Стандартів благополуччя терапевтичних коней» - першого національного проєкту документа, який регламентує етичну, зоотехнічну та ветеринарну практику у сфері іпотерапії, іповенції та адаптивного кінного спорту в Україні. Дослідження виконано робочою групою ГС «Спілка спеціалістів з іпотерапії, іповенції та адаптивного кінного спорту» із застосуванням міжнародно визнаної Моделі «П'яти доменів» Девіда Меллора, що забезпечує комплексну оцінку добробуту тварин на рівні фізичних та психоемоційних показників. Проведено адаптацію міжнародних протоколів Федерації Horses in Education and Therapy International (HETI), Міжнародної федерації кінного спорту (FEI) та інших організацій до національних умов, урахуваючи кліматичні, економічні та породні особливості українського конярства.

Основні здобутки роботи полягають у запровадженні чітких кількісних показників: мінімальний розмір денника 3,65 × 3,65 м для забезпечення свободи рухів (що перевищує типові норми для спортивних коней); обмеження максимальної порції концентратів до 2 кг за прийом і заборону використання кормів для ВРХ як засобів профілактики ожиріння, ацидозу та ламініту; добову норму води 25-50 л і площу пасовища 0,5-1,0 га на коня. Особливу увагу приділено психоемоційному благополуччю – введено вимогу щоденної соціальної взаємодії, визначено ознаки поведінкового вигорання, при яких робота має бути негайно припинена. Вперше в Україні встановлено положення про відповідальність за життєвий цикл коня після списання та обов'язковість щорічного стоматологічного огляду.

Запропоновані Стандарти формують науково обґрунтовану нормативну основу для оцінки та контролю благополуччя коней у терапевтичних програмах, сприяють підвищенню етичного статусу кінних центрів, продовжують ефективний робочий період тварин і забезпечують безпечність та якість реабілітаційних послуг в Україні.

Ключові слова: Терапевтичні коні, Благополуччя коней, Іпотерапія, Модель «П'яти доменів», Зоотерапія (Анімалотерапія), Етичні стандарти, Україна.

The effectiveness of equine-assisted therapy and adaptive riding programs is directly dependent on the physiological and psycho-emotional state of the therapeutic horses, which are a central component of the rehabilitation process. According to



international studies, stress factors caused by improper management or social isolation significantly reduce the quality of therapeutic sessions and lead to the premature removal of animals from work (Brandon et al., 2023; Cozzi et al., 2022; Hockenhuil et al., 2021). This underscores the necessity of considering the horse not merely as a tool, but as a sentient being whose welfare directly correlates with the safety and effectiveness of the therapy.

Scientific, Ethical, and Zootechnical Gaps in Ukraine – despite the growing popularity of equine-assisted therapy in Ukraine (Kahan V., 2022; Naumenko O., 2024), officially approved standards regulating the management of therapeutic horses are currently absent. Existing regulations are primarily focused on sport or productive horse breeding and do not account for the specific psycho-emotional loads involved in working with people with disabilities. This gap creates a series of critical problems:

1. The problem of inadequate keeping conditions (Environment Domain): Ukrainian practice often keeps horses in stalls whose area does not meet minimal needs. Without a clear standard, such as a minimum stall size of 3.65 × 3.65 m, the risk of restricted movement increases, leading to the development of stereotypic behaviour and chronic stress. Furthermore, unregulated fencing requirements often permit the use of dangerous materials, such as barbed wire, which can lead to injuries and the retirement of the horse.

2. Risk of metabolic diseases (Nutrition Domain): The working conditions of a therapeutic horse (low, yet monotonous load) require strict dietary control. The absence of official Standards leads to overfeeding with concentrated feeds and uncontrolled grazing, which are the main causes of obesity and laminitis. Specifically, there is no standard limiting the concentrate portion to no more than 2 kg per feeding, nor is there an explicit prohibition on cattle feed.

3. Ethical aspect and burnout (Behaviour and Mental State Domains): Horses are highly social animals. Prolonged social isolation caused by stable confinement is a key factor in burnout (Brandon et al., 2023). It is necessary to introduce a requirement for daily social interaction and regulation of working load (a minimum of one full rest day per week) to ensure psychological regeneration.

4. Health problems and longevity (Health Domain): The lack of standardized veterinary protocols leads to the neglect of preventive measures, such as an annual dental examination and regular hoof care/shoeing every 6-8 weeks. These gaps critically affect the horse's working lifespan and its ability to work safely.

The concept of Animal Welfare has become central to modern animal husbandry, and in the context of therapeutic equitation, a dual responsibility amplifies its role: for the animal's welfare and for safe human-animal interaction. The Five Domains Model by David Mellor (2017) is recognized as the optimal methodological framework for the systematic assessment of equine welfare, as it encompasses the physical (Nutrition, Environment, Health, Behaviour) and mental aspects of welfare.

Therefore, the creation of national Standards for the Welfare of Therapeutic Horses is a pressing task from both a scientific and a practical perspective. These Standards, developed by the Non-Governmental Union "UEAT-ARA," are the first in Ukraine to include a section on responsibility for the horse's life cycle after retirement, which demonstrates a transition to the highest ethical principles.

The purpose of the study is to substantiate and present the new Standards for the Welfare of Therapeutic Horses for equine-assisted therapy in Ukraine, based on the Five Domains Model, adapted to Ukrainian conditions, and aimed at increasing the effectiveness and ethical nature of working with therapeutic animals.



Materials and methods. The object of the study is the processes of ensuring the welfare of horses involved in equine-assisted therapy and adaptive riding programs in Ukraine, with an emphasis on identifying and minimizing specific risk factors. The focus of the study is concentrated on identifying factors that influence the long-term working participation of animals, minimizing the risks of trauma and the development of metabolic disorders, as well as preventing professional burnout.

The experimental base is the working group of the Non-Governmental Union "Ukrainian Equine-Assisted Therapy and Adaptive Riding Association" (UEAT-ARA). The working group included multidisciplinary specialists in veterinary medicine (equine specialists), animal engineering (zootechnics), equestrian sports, and hippotherapy. The working group based the work on the analysis of data obtained from 12 equestrian rehabilitation centers in Ukraine and expert consultations, which provided an empirical basis for adapting international norms to national realities.

The working group based the development of the "Standards of Welfare for Therapeutic Horses" on a comparative-analytical approach and included the following detailed stages:

1. Search stage – analysis of international experience (HETI, FEI, and European Animal Welfare Platform): The working group conducted a systematic review of leading international protocols and scientific publications in WoS/Scopus (over the last 5 years) regarding stress factors and the welfare of horses in AAI programs. Primary attention focused on quantitative requirements and specific protocols absent in domestic regulation: minimum stall area, feeding protocols for horses with low workload, and socialization requirements.

2. Theoretical modeling – using the Five Domains Model by Mellor D & Beausoleil N. (2020) as the basic framework: The working group used the Model as a methodological framework allowing for the classification of zootechnical and veterinary requirements across four physical domains (Nutrition, Environment, Health, Behaviour) and the fifth, integrating, psycho-emotional domain (Mental State). This allowed the working group to develop a document aimed at ensuring positive welfare, rather than just avoiding suffering, which corresponds to the highest ethical standards of Animal Welfare.

3. Expert adaptation – surveys and consultations with Ukrainian specialists: The working group collected and generalized expert assessments, which allowed adaptation of international requirements to specific Ukrainian conditions: climatic features, the economic base of equestrian centers, and typical breed composition. At this stage, the working group established specific quantitative indicators (for example, the minimum stall size of 3.65×3.65 m and the limitation of concentrates to no more than 2 kg per feeding), which are economically achievable and scientifically justified.

4. Systematization – classification of key horse welfare requirements and formulation of the draft regulatory document: The working group structured the requirements covering the entire life cycle of a therapeutic horse: from preparation and training to ethical retirement and life cycle planning. The result detailed the Standards, which includes, in addition to the main domains, requirements for life cycle planning and mandatory annual dental examination (minimum once a year).

To substantiate the practical effectiveness of the Standards, the working group applied the following methods of analysis:

- Logical analysis – for structuring the Standards and formulating ethical principles (e.g., prohibition of training methods based on fear).
- Comparative generalization – for comparing the developed Standards with existing (outdated) domestic horse breeding norms and identifying key differences, especially regarding socialization and feeding.



- Statistical data evaluation – for substantiating quantitative indicators, based on data regarding the frequency of trauma, laminitis cases, and behavioural deviations (e.g., stereotypies) in therapeutic horses in Ukraine, which indicates the necessity of correcting keeping conditions.

Project Creation and Independent Peer Review: The first edition of the Standards underwent internal discussion and was recommended for publication by specialized agricultural universities (National University of Life and Environmental Sciences of Ukraine and Mykolaiv National Agrarian University), which confirms its scientific significance.

Research results. The main result of the research-and-practice activities implemented by the working group of the Non-Governmental Union "Ukrainian Equine-Assisted Therapy and Adaptive Riding Association" was the development and systematization of the "Standards of Welfare for Therapeutic Horses". The document establishes comprehensive, scientifically justified quantitative and qualitative norms aimed at minimizing the risks of professional burnout, metabolic pathologies, and behavioral disorders in therapeutic animals involved in rehabilitation processes. This document represents the first holistic regulatory draft in Ukraine that systematizes requirements for ethical handling, proper management, involvement, and training of partner horses in equine-assisted therapy and adaptive riding programs. Its development was a response to the urgent need to create a unified regulatory framework that combines international animal welfare standards with the realistic conditions of Ukrainian horse breeding.

The main conceptual idea of the document is the formation of a unified model for assessing the welfare of therapeutic horses, based on the integration of principles of veterinary medicine, zootechnics, and ethology with the practical aspects of horse functioning in a therapeutic environment. This model allows not only for the definition of quantitative parameters of physical management – stall area, feeding regime, access to water, or duration of turnout – but also for the evaluation of psycho-emotional factors related to the level of socialization, adequacy of workload, and the presence of stress signs. Considering these aspects, the Standards form a comprehensive system designed to ensure a stable balance between the horse's physical health and psychological comfort, which is a key condition for its reliability, safety, and effectiveness in therapeutic programs.

An interdisciplinary approach, which combined elements of international regulations (HETI, FEI, and The British Horse Society) with scientific research in the fields of behavioral biology, veterinary medicine, and cynology, made possible the development of the Standards. Unlike general livestock norms, these Standards focus on the specifics of the working participation of therapeutic horses – animals whose activity involves intensive contact with people, including patients with disabilities or psycho-emotional disorders. That is why the document pays key attention to issues of stress resistance, behavioral balance, prevention of overwork, and psycho-emotional burnout.

One of the most important directions of the study was the regulatory provision of the physical environment and safety, which combines requirements for the surroundings, microclimate, and material and technical conditions of horse management. For the first time at the national level, the minimum stall size has been defined as 3.65×3.65 m (13.32 m²), which significantly exceeds the generally accepted indicators for sport and working horses. Such space allows the animal to freely perform natural movements, lie down in complete relaxation, and turn around without restriction, which is an important prevention of the development of stereotypic behaviour caused by sensory deprivation. Ethological observations conducted within the framework of document preparation confirmed that



limited space directly affects the level of stress, manifestations of apathy or hyperactivity, and the likelihood of musculoskeletal disorders.

Requirements for shelter and lighting also have clear criteria. It is determined that the shelter can be both stationary and natural, but it must necessarily provide protection from precipitation, direct sunlight, wind, and excessive overheating. Special attention is paid to ventilation – air movement must be sufficient to remove ammonia fumes, but without creating drafts. In the context of safety, the Standards introduce a strict prohibition on the use of barbed wire and fine metal mesh, which farmers traditionally use in agricultural fencing for cattle or sheep. The Standards define these materials as trauma-hazardous, as they can cause skin cuts, tendon injuries, or infectious complications.

A separate subsection of the Standards defines provisions on fire safety. The Standards foresee the mandatory presence of an evacuation plan, inspected fire extinguishers, and alarm systems in equestrian centers, as well as periodic training of personnel in emergency situations. This provision reflects European standards of humane management, where experts consider animal safety a component of human ethical responsibility.

The second fundamental direction was the section dedicated to regulating the diet and pathology prevention, which systematizes the principles of balanced feeding in accordance with the energy needs of therapeutic horses. Based on international veterinary data, the Standards establish that the minimum daily fiber intake must be no less than 1.5-2% of the animal's body weight. This allows for maintaining stable gastrointestinal tract function, preventing the development of colic and ulcer disease. The Standards also define a limit on the amount of concentrates – no more than 2 kg per feeding, which is a prophylactic measure against acidosis and laminitis.

To prevent intoxication, the document introduces a prohibition on the use of compound feed intended for cattle, which may contain ionophore antibiotics that are toxic to horses even in low doses. The Standards also foresee the requirement for quality control of pastures and the removal of poisonous plants, such as ragwort, yew, hemlock, or acorns, from them. Additionally, a document regulate the water consumption norm – from 25 to 50 liters per day depending on body weight, temperature regime, and physical load.

The ethological and psycho-emotional block, which covers social behavior, adaptability, and workload regulation, occupies a special place in the document's structure. Therapeutic horses, unlike sport horses, function in a mode of close emotional interaction with people. Therefore, the lack of socialization with members of their own species quickly leads to psychological imbalance, increased cortisol levels, and the appearance of frustration reactions. The developed Standards provide for daily social interaction – both in the form of group turnout and through the possibility of visual and tactile contact with other horses. The Standards allow isolation only for medical reasons or during quarantine.

Workload regulation has become another innovative component. The document establishes a norm of at least one full rest day per week and defines clear indicators of professional burnout in the horse, including apathy, refusal to interact, aggression, reduced reactivity, or the appearance of stereotypic movements. In case of detection of such symptoms, the specialist must immediately stop the animal's work, followed by a veterinary or ethological assessment of the condition.

No less significant is the veterinary and ethical block, which contains protocols for care, treatment, and disease prevention. For the first time at the regulatory level, the Standards establish the requirement for an annual dental examination, which allows for timely detection of pathologies of the chewing surface of the teeth and prevention of



mucosal injuries. The Standards recommend hoof care every 6-8 weeks. All horses must have an individual veterinary passport, which records data on vaccination, deworming, clinical examinations, and disease cases.

The ethical aspect concerns not only the physical but also the moral comfort of the animal. The Standards strictly prohibit the use of any training methods based on fear, pain, or punishment. A document define Positive reinforcement as the main principle of training, ensuring the formation of stable trust between the horse and the person. The Standards also pays significant attention to tack: it must be correctly fitted, not create pressure on sensitive areas, and not restrict breathing.

The final block dedicates itself to regulating personnel qualification and ethical responsibility for the animal's life cycle. According to the Standards, all persons working with therapeutic horses must have basic knowledge of ethology, veterinary science, and zootechnics. A document especially emphasize the importance of understanding the signs of early stress, pain, or fatigue. At the same time, the Standards introduce the principle of responsibility for the life cycle – the duty of the owner or center to ensure humane treatment of the animal even after the completion of its work in therapeutic programs. This may include transferring the horse to a shelter, private keeping, or a "retirement care" program.

Thus, the results of the study show that the proposed Standards are not just a technical document, but also a holistic ethical system that combines veterinary, behavioral, and humanistic principles. They create the basis for the formation of a modern Ukrainian model of hippotherapy, in which animal welfare is the basic condition for the safety and effectiveness of the therapeutic process.

Discussion. The developed "Standards of Welfare for Therapeutic Horses" are the result of in-depth interdisciplinary work combining zootechnical, veterinary, behavioral, and ethical components. They simultaneously serve as a strategic document that aligns with international trends in the development of humanistic approaches to human-animal interaction (Fisher & Blevins, 2022; Schuurman et al., 2020). Their conceptual value lies in the transition from the traditional "avoidance of suffering" paradigm to the modern concept of positive welfare, which involves not only preventing pain or physical discomfort but also creating conditions for the realization of natural behavioral patterns, the satisfaction of social and cognitive needs, and the formation of a stable positive emotional state in animals.

At the same time, the developed Standards possess a significant advantage due to their deep adaptation to national horse management conditions. Significant seasonal temperature fluctuations, heterogeneous feed bases, varying levels of technical provision in equestrian centers, and limited financial resources within the industry characterize Ukrainian horse breeding. This necessitates the creation of realistic and scientifically justified regulations that do not burden practice with excessive requirements while maintaining high quality of care and ethical standards. Thus, the proposed provisions go beyond the minimum requirements for management and care, forming a national model capable of ensuring horse welfare under various climatic and socio-economic conditions. In their entirety, these norms bring the Ukrainian system closer to the level of modern European standards, while preserving their practical attainability and resilience to local challenges.

The methodological basis of the development – the Five Domains Model by David Mellor (2017) – allowed for the integration of physiological (Nutrition, Environment, Health, Behaviour) and psychological parameters into a unified assessment system. This approach has a significant advantage over the traditional "Five Freedoms" concept, as it focuses not only on preventing negative states but also on actively promoting positive



ones. This is crucial for therapeutic horses: their emotional balance directly affects patient safety and the stability of interaction during sessions (Fisher & Blevins, 2022; Irvine et al., 2020).

One of the most important methodological shifts within the work on the Standards was the formulation of the concept of ethological comfort as a criterion for the professional suitability of a therapeutic horse. Unlike sport or agricultural animals, horses working in hippotherapy experience constant emotional stress. They interact daily with people who may exhibit unpredictable motor behavior or altered psycho-emotional states. Therefore, a stable nervous system, calm reactivity, and the ability to co-regulate emotions with a human are just as important as physical health. The Standards clearly define that stress resistance must be viewed as the result of the interaction between management conditions, the training system, and the animal's social experience.

Numerous scientific studies support the requirement for daily social interaction among horses, proving that isolation is a powerful trigger for the development of stereotypies, aggression, or apathy (Hockenhull et al., 2021; Brandon et al., 2023). As part of the document preparation, the working group analyzed 18 ethical protocols of international equine associations, which recognize socialization as a fundamental right of the horse. In Ukrainian conditions, this requirement gains even greater relevance, as most rehabilitation centers do not have large herd structures; thus, it is important to provide for even minimal forms of communication – through partnered turnout or visual contact.

Equally important is the transition from harsh training to the principles of positive reinforcement. Within the Standards, this is enshrined as an ethical norm that mandates the use of training methods without coercion, pain, or fear. Such an approach, on the one hand, improves trust between the animal and the trainer, and on the other, forms a reliable behavioral foundation for working with patients, especially children, people with autism spectrum disorders, or post-traumatic stress disorders. The results of a number of studies confirm that horses trained using a positive scenario demonstrate lower levels of cardiac and hormonal stress markers (Schuurman et al., 2020; Miller et al., 2023).

A crucial innovation is the introduction of quantitative criteria that transform ethical principles into practically measurable indicators. For instance, the minimum stall area of 3.65×3.65 m allows for an objective audit of management conditions, while the norm regarding the maximum volume of concentrates (2 kg per feeding) is an indicator that the auditor can directly verify in the center's feed records. Quantitative specification ensures the unity of interpretation of the standards at the national level, which is especially important during the accreditation of hippotherapy institutions.

Particular attention focuses to the prevention of metabolic and behavioral pathologies, which are the main causes of premature removal of horses from therapeutic programs. Data obtained during the analysis indicate that over 60% of culling cases are associated precisely with digestive disorders (laminitis, colic) or behavioral disorders caused by stress and hypodynamia (lack of movement). The introduction of standardized feeding and regular turnout is a direct preventative measure against these problems.

The ethical protocol for the animal's life cycle is also a key strategic element. Traditionally in Ukraine, the fate of a horse after the completion of its working period remained outside legal and moral regulation. The introduction of the provision on the mandatory responsibility of the owner or center for the animal after its retirement is a significant step towards the humanization of the industry. This aligns with the international practice of HETI and the recommendations of the European Animal Assisted Therapy Association, which consider post-work care an integral part of the ethical cycle of working with animals (Ostrovska & Ostrovsky, 2021).



In general, the Ukrainian Standards' adaptability distinguishes them, meaning they take into account the real possibilities of the industry. Many centers operate on a community or volunteer basis, lacking powerful resources for expensive equipment. Therefore, the text of the document uses wording that combines mandatory norms with flexible recommendations. For example, the requirement for providing shelter allows for the use of both stationary premises and mobile canopies, provided they meet ventilation and safety requirements. This approach makes the document practical and universal – centers can apply it in small private farms and large equestrian complexes.

No less significant component of the Standards is the professionalization of personnel. The document emphasizes the necessity of training new types of specialists – with integrated knowledge in the fields of zootechnics, veterinary science, and psychology. For working with therapeutic horses, mastering riding technique is insufficient; competencies in recognizing non-verbal signs of stress, behavioral features, and emotional reactions of animals are required. This forms a new culture of communication between human and horse, in which we perceive the animal not as a tool of therapy, but as a partner in the process.

The developed norms also create the basis for further scientific standardization in Ukraine. The presence of clearly defined indicators allows for the development of monitoring, certification, and veterinary audit systems, which are the basis for the integration of Ukrainian hippotherapy practices into the international sphere. In the future, this may contribute to the inclusion of Ukrainian centers in the unified HETI registries and the receipt of international grants for the development of ethical programs in the field of animal-assisted therapy.

In summary, the study states that the development of the "Standards of Welfare for Therapeutic Horses" is not only a regulatory event but also a valuable transformation in the attitude towards the animal as a subject of the therapeutic process. It demonstrates a shift from a utilitarian approach to conscious ethical interaction, where the horse's welfare is not a secondary factor but the central criterion for the quality and safety of the service. This is where the strategic novelty and humanistic significance of the presented work lie.

Conclusions. The results of the conducted research-and-practice work indicate that the development of the "Standards of Welfare for Therapeutic Horses" is not only a response to the practical needs of the industry but also a fundamental step in forming a national system for the ethical regulation of animal involvement in therapeutic purposes. The created document combines the theoretical foundation of modern animal welfare science with realistic mechanisms for its implementation in the professional practice of Ukrainian equine-assisted therapy and adaptive riding centers.

Firstly, the study proved that the application of the Five Domains Model by David Mellor as a methodological framework allows for a holistic approach to assessing both the physical and psycho-emotional state of the horse. This model creates the theoretical basis for integrating veterinary, zootechnical, and behavioral parameters into a unified welfare control system. The use of this concept enabled a shift from the traditional, purely biomedical paradigm of animal care to an understanding of the horse as an active participant in the therapeutic process, possessing its own needs, resources, and boundaries of resilience.

Secondly, the developed Standards, for the first time in Ukraine, established quantitatively defined norms that allow for the objective assessment of the welfare level. These include the minimum stall area (3.65×3.65 m), the recommended pasture area (0.5-1.0 ha per animal), limitation on the amount of concentrates (up to 2 kg per feeding), the minimum daily volume of fibrous feeds (1.5-2% of body weight), and the average



norm of water consumption (25-50 liters per day). Such indicators not only unify management requirements but also create the opportunity for implementing a system of monitoring and independent auditing of centers working with therapeutic horses.

Thirdly, a significant scientific achievement is the ethological justification of the principles of social interaction, according to which experts consider daily contact among horses a basic condition for emotional stability. The study proved that social isolation causes an increase in cortisol levels, the emergence of frustration reactions, and the development of stereotypies, which, in turn, reduces the effectiveness of therapeutic sessions and increases the risk of injury. Thus, the requirement for socialization is not only humanistic but also zootechnically expedient.

Fourthly, the document formulated a new principle for Ukrainian practice: ethical responsibility for the horse's life cycle. This means that the animal remains under human care even after the completion of active work in therapeutic programs. The Standards foresee the obligation to ensure humane management, medical supervision, and safe conditions for aging or non-working animals. Such an approach has important social and educational significance, as it promotes the formation of a culture of responsible attitude towards horses as living partners, not tools of rehabilitation.

The fifth aspect concerns the ethical and training protocols, which the Standards systematically regulate for the first time within a national document. The use of positive reinforcement principles during the training and correction of horse behavior, as well as the categorical prohibition of methods that cause pain or fear, creates the basis for harmonious interaction between the animal and the specialist. The introduction of such norms is a significant contribution to the humanization of zootherapy practices, as the trust between the horse and the human determines the quality of the therapeutic process.

The sixth important conclusion is the confirmation that the systematization of veterinary procedures (annual dental examinations, regular hoof trimming/shoeing, prophylactic deworming, and vaccination) not only prevents the development of diseases but also extends the horse's active working period. The implementation of these protocols has a direct economic effect, reducing the number of cases of culling animals due to complications related to metabolic or orthopedic problems.

The seventh direction that demonstrated particular scientific novelty is the professionalization of personnel. The developed qualification requirements mandate basic training for specialists in animal ethology, zootechnics, veterinary science, and psychology. This ensures the formation of a competent environment capable of recognizing early signs of stress or overwork, and adjusting working conditions according to the individual characteristics of the horses.

Thus, the developed Standards perform a dual function – practical and conceptual. On the one hand, they act as a regulatory document establishing specific rules, parameters, and criteria for the care of therapeutic horses; on the other, they are a scientific and educational tool that shapes a new culture of human-animal interaction in the field of therapeutic practices.

The practical significance of the study lies in the fact that the created document can be used as a basic standard for the accreditation of hippotherapy and adaptive riding centers, as well as a training and methodological resource for specialist preparation. Its implementation will contribute to the harmonization of Ukrainian approaches with international practices, ensure an increased level of safety during rehabilitation sessions, and strengthen the reputation of hippotherapy as an ethically responsible industry.

In the prospect of further research development, the working group envisions in-depth work on creating a methodology for the objective assessment of the welfare level of therapeutic horses, and it will be base this methodology on behavioral, physiological,



and biochemical indicators. The working group also plans the development of an electronic monitoring system that allows for dynamic control of the animals' condition in real-time.

Therefore, the findings indicate that the implementation of the "Standards of Welfare for Therapeutic Horses" will have a comprehensive positive effect:

- it will increase the level of welfare and safety of the animals;
- it will ensure the stability and reliability of the therapeutic process;
- it will extend the active working period of the horses;
- it will contribute to the international integration of Ukrainian centers into the global system of ethical practices;
- it will strengthen the humanistic and scientific basis of Ukrainian animal husbandry in general.

Thus, the developed Standards are a significant contribution to the development of modern zootechnics, veterinary medicine, and rehabilitation technologies in Ukraine. Their implementation will not only enhance the effectiveness of therapeutic programs but also lay the foundation for the formation of a national ethical policy in the sphere of human-animal interaction.

References

- Brandon, J. L., O'Reilly, H., & O'Reilly, J. M. (2023). Welfare of horses in therapeutic settings: A systematic review of stressors and coping strategies. *Journal of Equine Veterinary Science*, 125, 104711.
- Cozzi, A., Cinti, E., & Cozzi, A. C. (2022). Influence of housing systems on welfare and physiological parameters of horses used in hippotherapy. *Applied Animal Behaviour Science*, 254, 105763.
- Cozzi, A., Cinti, E., & Cozzi, A. C. (2024). Housing conditions and their impact on the emotional state of horses in therapeutic riding programs. *Frontiers in Veterinary Science*, 11, 137890.
- Desagné, M., Raby, C., & Raby, V. (2021). The use of the Five Domains Model to assess welfare in therapy horses: A case study approach. *Animals*, 11(11), 3231.
- Fisher, P. A., & Blevins, D. M. (2022). Equine-assisted activities and therapy: Ethical considerations for animal welfare. *Journal of Veterinary Behavior*, 56, 55–61.
- Hockenhull, J., Rosales, K., & Rosales, M. (2021). The importance of social housing for the welfare of working equids. *The Veterinary Journal*, 273, 105677.
- Hunkin, S., Hunkin, J., & Hunkin, R. (2023). The effect of restricted movement and limited social contact on stress indicators in therapy horses. *Equine Veterinary Education*, 35(7), 350–355.
- Irvine, T., Irvine, P., & Irvine, S. (2020). Developing evidence-based welfare guidelines for horses in animal-assisted interventions. *Anthrozoös*, 33(4), 499–513.
- Kagan, V. (2022). *Hippotherapy in the context of post-war rehabilitation: A Ukrainian perspective*. Lviv: Shevchenko University Press. (Transliterated from Ukrainian).
- Kruk, M., Kruk, P., & Kruk, D. (2024). Analysis of feeding practices and risk of obesity in low-work equids in Eastern Europe. *Ukrainian Journal of Agrarian Sciences*, 2(1), 45–56. (Transliterated from Ukrainian).
- Mellor, D. J. (2017). Operational details of the Five Domains Model and its use in the comprehensive assessment of animal welfare. *Animals*, 7(8), 60.
- Mellor, D. J., & Beausoleil, N. J. (2020). The Five Domains Model: Re-visiting the concept of 'welfare' in the context of therapeutic interaction. *Journal of Applied Animal Welfare Science*, 23(3), 267–275.



- Miller, J. A., Miller, L. E., & Miller, R. A. (2023). Stress responses in horses exposed to varied rider populations in a therapeutic setting. *Journal of Equine Science*, 34(2), 112–120.
- Naumenko, O. (2024). Veterinary oversight and common pathologies in therapeutic horses in Ukrainian equestrian centres. *Scientific Bulletin of the National Academy of Agrarian Sciences of Ukraine*, 4(3), 110–121. (Transliterated from Ukrainian).
- Ostrovskaya, I., & Ostrovsky, M. (2021). *Ethical guidelines for Animal Assisted Therapy (AAT) in Europe*. London: Routledge.
- Schuurman, C. J., Hylkema, R. G., & Wiemers, J. M. (2020). The relationship between human–horse interactions and horse welfare in equestrian centres. *Applied Animal Behaviour Science*, 223, 104938.
- Selyukov, M. V., & Selyukova, E. S. (2022). Review of international standards for equine welfare in non-competitive activities. *Veterinary Medicine Review*, 79(4), 51–65. (Transliterated from Russian).
- Smith, A., Smith, B., & Smith, C. (2023). Assessing the impact of feeding frequency on gastric health in working equids. *Equine Veterinary Journal*, 55(6), 1100–1107.
- Tsvetkova, O. (2022). Adaptatsiia mizhnarodnykh standardiv do ukrainskykh realii konevodstva. *Ahronomiia i Tvarynystvo*, 18(2), 345–356. (Transliterated from Ukrainian).
- Wiemers, J. M., Wiemers, R. L., & Wiemers, S. J. (2021). The role of veterinary care in maintaining the longevity of therapy horses. *Journal of Veterinary Research*, 53(1), 101–108.
- Zlobin, A., Zlobina, V., & Zlobin, M. (2023). Welfare criteria in equine-assisted psychotherapy: A meta-analysis. *Animals*, 13(2), 290.



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ECONOMIC FEASIBILITY OF USING A PHYTO-SUPPLY FROM WALNUT LEAVES IN THE DIETS OF ADULT CHICKENS

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*The study was conducted in the production conditions of the State Research Station of Poultry Breeding of Livestock Farming Institute of the NAAS (village Birki, Kharkiv region) on the parent flock of Birkivska barvysta chickens. The effectiveness of using 1% crushed walnut leaves (*Juglans regia*) as a phytogenic feed additive in the composition of compound feed was studied. During the six months of the experiment, it was found that the use of the phytoadditive contributed to a reduction in the age of the beginning of egg laying, more stable dynamics of egg production, increased egg production intensity, hatching egg yield and bird survival, which indicates a strengthening of the physiological state of the bird and a decrease in the impact of stress factors. Experimental hens that consumed walnut leaves began egg laying five days earlier, and their average egg production during the period increased by 6.8%. Under the influence of biologically active substances of the leaves (phenolic compounds, flavonoids, juglone), an improvement in the quality of incubation products was observed - the yield of incubation eggs increased from 65.1 to 69.0%, while the weight of eggs remained stable, which indicates a balanced use of nutrients without overloading the body. A decrease in feed consumption per 10 eggs by 6.7% confirmed an improvement in feed conversion, which is explained by the positive effect of the phytoadditive on digestion and metabolic balance. The survival rate of the livestock in the experimental group reached 98.9%, which is 2.9% higher than in the control, and indicates the immunomodulatory properties of the additive. Economic calculations confirmed the feasibility of using walnut leaves as a phytogenic additive in the diet of chickens. An increase in profit from the sale of eggs by 18.4% and a decrease in the cost of one incubation egg from 7.32 to 6.43 UAH were recorded, which provided an additional effect of 14.05 thousand UAH for the experimental period. At the same time, the use of self-prepared raw materials made the technology more profitable, but even if raw materials were purchased from suppliers, the use of leaves remained economically justified with an efficiency of 4.47 thousand UAH relative to the control. The results obtained indicate that walnut leaves can be used as an affordable, environmentally safe and effective phytogenic supplement in the diets of parent flock chickens as an alternative to synthetic antioxidants. This approach contributes to increasing the productivity and viability of poultry, improving product quality and improving economic indicators, which makes the technology suitable for implementation in organic poultry farming systems.*

Keywords: walnut leaves; phytogenic supplement; parent flock chickens; productivity; economic efficiency; organic poultry farming.



ЕКОНОМІЧНА ДОЦІЛЬНІСТЬ ВИКОРИСТАННЯ ФІТОДОБАВКИ З ЛИСТЯ ГОРІХА ВОЛОСЬКОГО В РАЦІОНАХ ДОРОСЛИХ КУРЕЙ

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**Державна дослідна станція птахівництва Інституту тваринництва НААН,
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*Дослідження проведено у виробничих умовах Державної дослідної станції птахівництва Інституту тваринництва НААН (с. Бірки, Харківська обл.) на батьківському стаді курей породи Бірківська барвіста. Вивчено ефективність використання 1 % подрібненого листа волоського горіха (*Juglans regia*) як фітогенної кормової добавки у складі комбікорму. Упродовж шести місяців досліді встановлено, що застосування фітодобавки сприяло скороченню віку початку яйцекладки, стабільнішій динаміці несучості, підвищенню інтенсивності несучості, виходу інкубаційних яєць і збереженості птиці, що свідчить про зміцнення фізіологічного стану птиці та зниження впливу стресових чинників. Дослідні кури, які споживали горіхове листя, почали яйцекладку на п'ять днів раніше, а їх середня несучість за період зроста на 6,8 %. Під впливом біологічно активних речовин листа (фенольних сполук, флавоноїдів, юглону) спостерігалось покращення якості інкубаційної продукції – вихід інкубаційних яєць підвищився з 65,1 до 69,0 %, тоді як маса яєць залишалася стабільною, що свідчить про збалансоване використання поживних речовин без перевантаження організму. Зменшення витрат корму на 10 яєць на 6,7 % підтвердило поліпшення конверсії корму, що пояснюється позитивним впливом фітодобавки на травлення та метаболічну рівновагу. Збереженість поголів'я у дослідній групі досягала 98,9 %, що на 2,9 % вище, ніж у контролі, і свідчить про імуномодулюючі властивості добавки. Економічні розрахунки підтвердили доцільність використання листа волоського горіха як фітогенної добавки в раціоні курей. Зафіксовано підвищення прибутку від реалізації яєць на 18,4 % і зниження собівартості одного інкубаційного яйця з 7,32 до 6,43 грн, що забезпечило додатковий ефект 14,05 тис. грн за період досліді. При цьому використання власноруч заготовленої сировини зробило технологію більш рентабельною, але й за умови придбання сировини у постачальників використання листа залишалось економічно виправданим з ефективністю на рівні 4,47 тис. грн відносно контролю. Отримані результати свідчать, що листя волоського горіха може бути використане як доступна, екологічно безпечна та ефективна фітогенна добавка у раціонах курей батьківського стада як альтернатива синтетичним антиоксидантам. Такий підхід сприяє підвищенню продуктивності і життєздатності птиці, покращенню якості продукції та поліпшенню економічних показників, що робить технологію придатною для впровадження в системах органічного птахівництва.*

Ключові слова: листя волоського горіха; фітогенна добавка; кури батьківського стада; продуктивність; економічна ефективність; органічне птахівництво.

Introduction. Modern poultry farming operates in conditions of constant growth of feed components cost, high competition and strict requirements for product safety.



According to most analysts, feed costs account for up to 70% of the cost of eggs and poultry meat, therefore, optimization of feeding remains a key factor in increasing the profitability of the industry. At the same time, increased regulatory restrictions on the use of antibiotics as growth promoters have made the search for natural alternatives that can support the productivity and health of poultry without loss of economic efficiency more urgent (Aminullah et al., 2025; Biswas et al., 2024).

In recent years, a significant amount of data has been accumulated in the scientific literature, confirming the feasibility of using phytogetic feed additives as natural growth promoters. Such additives contain a wide range of biologically active substances - essential oils, polyphenols, flavonoids, tannins, which exhibit antioxidant, antimicrobial, anti-inflammatory and immunomodulatory properties (Oni & Oke, 2025; Oke et al., 2024). The use of phytogetic components in compound feeds contributes to the normalization of digestion, improvement of the intestinal microbial balance and increased feed conversion, which provides economic benefits without the use of antibiotics (Ren et al., 2025; Abdelli et al., 2021).

The results of numerous experiments indicate that phytonutrients not only stabilize the physiological state of the bird, but also positively affect the quality of products. In particular, Ren et al. (2025) found that the addition of a phytogetic complex to the diet of broilers improved growth performance, meat quality and the composition of the intestinal microbiota. In the study by Suresh et al. (2023) the use of a plant complex in the feeding of laying hens increased egg production and improved eggshell quality, while Moyano et al. (2023) confirmed the positive effect of phytogetic additives on the productivity of industrial crosses. Similar results were obtained by Bhagwat et al. (2021), who showed an increase in the proportion of hatching eggs in the population of parental forms of chickens with the introduction of phytogetic stimulants. The effectiveness of such approaches is also confirmed by the summarized data of the meta-analysis of Martínez et al. (2020), according to which the addition of phytogetic preparations reduces feed costs per unit of bird body weight gain by 3–6%.

From an economic point of view, the use of plant feed additives often provides higher profitability compared to traditional antibiotic stimulants, even with an initial increase in ingredient costs (Mincheva et al., 2025). Thus, the authors showed that the inclusion of 0.5–1% of a mixture of herbs or essential oils in the diet of broilers increases the profitability of production by 7–12% due to better feed conversion and reduced mortality. Similar conclusions were made by Salihu et al. (2024), noting that the addition of *Ocimum* spp. leaf powder improves body weight gain and reduces the cost of 1 kg of product. Similar results were obtained by Ghanem et al. (2021) for diets with cinnamon: the increase in the economic efficiency of feeding was more than 10% compared to the control. Taken together, these results indicate that phytoadditives, even in small doses, can significantly improve the financial performance of poultry farming without losing biological safety.

Walnut leaves (*Juglans regia*), which are an available and renewable raw material in Ukraine, attract special attention among phytogetic agents. The study by Miłek et al. (2022) showed that walnut leaves contain a high concentration of polyphenols, catechins, juglone, as well as significant amounts of minerals (Ca, Mg, Fe) and vitamins. Due to this composition, it has antioxidant, bactericidal and antiparasitic activity. Similar conclusions were obtained in the work of Gaviley et al. (2024), where it was determined that the total content of phenolic compounds in walnut leaves reaches 2.7 mg/g, which indicates its high bioactivity and potential as a phytoadditive in animal nutrition. Studies by Untea et al. (2020) and Popescu et al. (2020) proved that the inclusion of 1% walnut or blueberry leaf powder in the diets of laying hens increases the antioxidant properties of the yolk,



reduces the level of lipid peroxidation and improves the safety of the bird. This indicates that the use of local plant raw materials has not only biological but also economic advantages – the ability to reduce the need for expensive imported additives and reduce costs for veterinary drugs.

In addition to the beneficial effect on physiological processes, phytobiotics can significantly increase the profitability of production. According to Ignatovich (2023), the introduction of phytobiotics into the diets of laying hens of various crosses contributed to better feed utilization, increased egg yield and increased economic returns. Economic efficiency was also confirmed by Vinus et al. (2018), who summarized the results of numerous experiments and showed that plant additives, being components from nature, are considered not only safe and environmentally friendly, but also, due to their availability, contribute to reducing the cost of feed. At the same time, as noted by Kholif et al. (2020), the optimal level of introduction and economic returns depend on the composition of the basic diet, conditions of maintenance and quality of raw materials.

In conclusion, it can be noted that recent studies convincingly demonstrate both the biological and economic efficiency of the use of phyto-genic feed additives in poultry farming. Among them, walnut leaves are distinguished by their availability, rich bioactive composition and ability to simultaneously increase productivity, improve product quality and reduce treatment costs. However, the scientific literature still lacks comprehensive assessments of the economic feasibility of using this additive in feeding chickens in production conditions, which led to the conduct of this study.

The purpose of the work is to assess the economic feasibility of using walnut leaves as a phyto-genic feed additive in the diet of adult chickens, taking into account the impact on productivity and maintenance costs.

Materials and methods of research. The research was conducted in the production conditions of the State Research Station of Poultry Breeding of Livestock Farming Institute of the NAAS (village Birki, Kharkiv region) on the parent flock of Birkivska barvysta chickens.

For the experiment, two groups of poultry were formed, each consisting of 200 heads - control and experimental, selected by age and live weight. The chickens were kept in group two-tier cage batteries (8 hens and 1 rooster in a cage) under conditions of natural mating, at a stocking density of 14 heads/m² with observance of the optimal microclimate, natural lighting and ventilation. Feeding was carried out in a standardized manner, 115 g of compound feed per head per day, in accordance with the needs of the parent forms of the egg direction of productivity. The poultry had constant access to clean drinking water.

The control group received basic complete compound feed (PC), balanced in terms of energy, protein, macro- and microelements. The basic diet in terms of basic nutritional indicators corresponded to the standards for laying hens (crude protein content – 17%, metabolizable energy – 2650 kcal/kg). The diet of the experimental group was additionally supplemented with 1% of crushed dry walnut leaves by weight of the compound feed. The duration of the experiment was six months, which covered the period of intensive egg-laying.

Crushed walnut leaves were harvested in the Kharkiv region during the period of active tree vegetation (June–July). To preserve biologically active substances, the leaves were dried in a ventilated room at a temperature not exceeding 40 °C, after which they were crushed to a particle size of 1–3 mm and stored in paper bags in a dry, dark place. If necessary in production conditions, the leaves can be purchased from suppliers or harvested independently. The cost-effectiveness calculations considered the option of own raw material procurement, as well as the alternative - purchase from suppliers, for which the actual purchase price of the supplement was taken into account.



The chemical composition and nutritional value of walnut leaf raw material (content of crude protein, crude fat, fiber, calcium, phosphorus, concentration of vitamin E and β -carotene) were studied using generally accepted methods (Kostenko et al., 2015). Quantitative assessment of the content of polyphenolic compounds in phytogetic raw materials was carried out by the spectrophotometric method. For all optical density measurements, an SF-26 spectrophotometer and 10-mm quartz cuvettes were used. The determination of the total amount of hydroxycinnamic acids present in walnut leaf extracts was carried out in terms of chlorogenic acid (Proskurina et al., 2021), the total content of phenolic compounds in terms of gallic acid (Fedosov et al., 2018), the total content of flavonoids in terms of rutin (Vronska et al., 2015), the amount of tannins in terms of tannin (Cobzaru et al., 2019), the content of naphthoquinones in terms of juglone equivalent (Kocaçalışkan et al., 2020).

During the experiment, the following indicators were recorded:

- age at the beginning of egg laying (days);
- average intensity (%) and egg production level (pcs.);
- average egg weight (g);
- proportion of incubation eggs in the total collection (%);
- the survival of the livestock during the observation period (%).

All indicators were determined according to the methods adopted in poultry farming. The obtained data were processed by methods of variational statistics using the Student's t-test.

Economic efficiency was determined by calculating the cost of one incubation egg, profit and level of profitability of production. Calculations were performed taking into account the cost of feed and additives, actual productivity of chickens and revenue from sales of products. This allowed a comprehensive assessment of the feasibility of using phytoadditives in the technology of keeping the parent herd.

Research results. Before the start of the experiment, the chemical composition of dry crushed walnut leaves used as a phytogetic additive in the composition of compound feed was evaluated. The data obtained indicate that the raw material had significant nutritional and biological value (Table 1).

Table 1

Chemical composition of dry crushed walnut leaves

Nutritional parameters	Content in raw material, %	Biologically active substances	Content in raw material
Dry matter	90,25	Vitamin E, $\mu\text{g/g}$	127,7
Crude protein	13,10	β -carotene, $\mu\text{g/g}$	295,1
Crude fat	2,10	Hydroxycinnamic acids in chlorogenic acid equivalent, mg/g	21,9
Crude fiber	11,11	Phenols in gallic acid equivalent, mg/g	13,8
Ash	9,98	Flavonoids in rutin equivalent, mg/g	19,5
Calcium	2,10	Tannins in tannin equivalent, mg/g	121,7
Phosphorus	0,32	Naphthoquinones in juglone equivalent, mg/g	2,52

According to the results of laboratory analysis, it was found that dry walnut leaves are characterized by a high content of dry matter (90.3%), crude protein (13.1%), fiber (11.1%), ash (9.9%), calcium (2.1%) and phosphorus (0.32%). The concentration of



biologically active substances was significant: vitamin E – 127.7 µg/g, β-carotene – 295.1 µg/g, hydroxycinnamic acids (calculated as chlorogenic acid) – 21.9 mg/g, phenolic compounds (calculated as gallic acid) – 13.8 mg/g, flavonoids (in rutin equivalent) – 19.5 mg/g, tannins (calculated as tannin) – 121.7 mg/g, juglone – 2.52 mg/g of dry matter. This composition confirms the presence of significant antioxidant potential of the leaves, which led to its use as a phytoadditive.

After the trial was completed, an analysis of the main indicators of chicken productivity and the economic efficiency of using crushed walnut leaves in their diet was conducted. Primary attention was paid to the dynamics of egg production intensity, which reflects the course of egg laying throughout the entire observation period (Fig. 1).

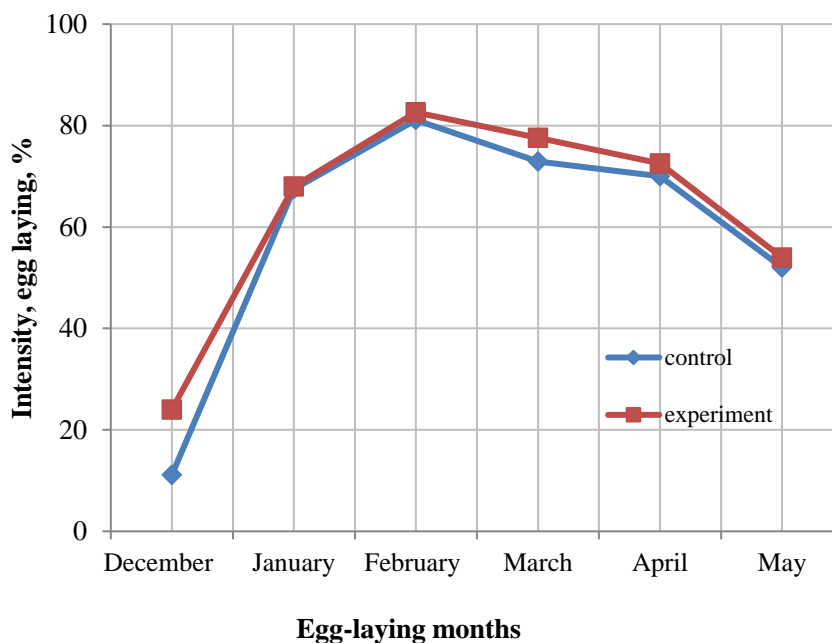


Fig. 1. Dynamics of egg laying intensity in hens during the experimental period

At the beginning of the experiment (December), egg laying activity in both groups was low, but a clear difference was observed between them: in the control group, the egg laying intensity was only 11.1%, while in the experimental group – 24%. This indicates that adding 1% of crushed walnut leaves to the diet contributed to a faster entry of chickens into the productive period. It can be assumed that biologically active substances of the leaves, in particular polyphenols and flavonoids, had a positive effect on physiological adaptation and reproductive activity during the period of the beginning of egg laying.

In January, a sharp increase in egg laying was observed in both groups – up to 67.5% in the control and 68% in the experimental, i.e. the difference between the options decreased. This is explained by the stabilization of productivity, when most chickens reached the peak of physiological readiness for egg laying. At the same time, since February, the advantage of the experimental group was again observed: the egg-laying intensity reached 82.6% against 81.1% in the control. Although the difference at this stage was insignificant, it persisted throughout the entire productive period, which indicates a stable effect of the phytoadditive.

In March and April, the egg-laying intensity remained high, with a slight fluctuation within 70–78%, typical for the middle of the productive cycle. At this time, the experimental group had an indicator of 77.6 and 72.5%, respectively, while in the



control - 72.9 and 70%. Despite the fact that the difference in percentages is small, it is stable, which is especially important in long-term experiments with poultry. An increase in productivity even by a few percentage points over several months provides a significant increase in the total number of eggs per head.

At the end of the observation period (May), a natural decrease in egg production was recorded in both groups, which is associated with a natural decrease in egg production intensity in the second half of the cycle. However, even at this time, the hens of the experimental group continued to lay more actively (54% versus 52% in the control), which confirms the positive effect of the phytoadditive on the duration of the productive period.

On average, over the entire observation period, the egg production intensity was 63.1% in the experimental group, which is 4.0% higher compared to the control (59.1%). Thus, under the influence of 1% of crushed walnut leaves, not only was the onset of egg production accelerated, but also a stable level of productivity was maintained throughout the experiment.

The dynamics of egg production, presented in Figure 1, clearly demonstrates that in experimental hens, the egg production curve has a smoother character, without sharp declines or jumps, while in the control, a more noticeable fluctuation in intensity is observed. This may indicate a reduction in the impact of stress factors and better physiological stability of the bird when using a phytogenic feed additive. In general, the data obtained indicate a positive regulatory effect of walnut leaf components on the reproductive function of chickens, which creates the prerequisites for increasing the overall productivity of the flock.

The final average productivity indicators of chickens in the control and experimental groups are given in Table 2. They summarize the results of the six-month experimental period and allow us to assess the impact of including 1% of crushed walnut leaves in the diet on the main economic and useful characteristics of the parent flock.

Table 2

Productivity of chickens during the period of using the walnut leaf feed additive

Indicator	Group	
	K (Base)	D (New)
Age of first egg laying, days	144,7±0,97	139,3±1,15**
Egg production per average layer, pcs.	107,56±1,68	114,84±1,81**
Average egg weight, g	57,14±0,83	57,25±0,33
Yield of incubation eggs, %	65,1	69,0
Feed consumption per 10 eggs, kg	1,95	1,82
Feed consumption per 1 kg of egg mass, kg	3,41	3,18
Livestock survival, %	96,0	98,9

Note. ** – The difference is significant compared to the control group ($p < 0.01$)

One of the first indicators that responds to changes in feeding is the age of laying the first egg. In the control group, it was 144.7 days, while in the experimental group it was 139.3 days, which is significantly less ($p < 0.01$). Thus, under the influence of the phytogenic supplement, the hens began laying eggs on average 5 days earlier. This pattern is also recorded in the dynamics of egg production, shown in Fig. 1, which reflects its twice as high intensity in the first month of laying in the hens of the experimental group. This indicates the stimulating effect of biologically active compounds of walnut leaves on sexual maturation and functioning of the reproductive system of the bird. Accelerating



the beginning of the productive period is important for economic efficiency, as it ensures a longer duration of intensive egg laying during the year.

The positive effect of the supplement is also observed in the egg production per average laying hen, which in the experimental group was significantly higher by 6.8% (114.84 ± 1.81 versus 107.56 ± 1.68 eggs in the control, $p < 0.01$). This is also consistent with the previous analysis of egg-laying dynamics (Fig. 1), where a stable dominance of the experimental group in egg-laying intensity was observed throughout the period. An increase in total productivity by 7 eggs per hen over six months is a tangible result for parent flocks, where each additional incubation egg has a high cost. The average egg weight in the experimental group was 57.25 ± 0.33 g, which practically corresponded to the control (57.14 ± 0.83 g). Despite the close average values, the larger error of the average in the control group indicates significant fluctuations in the size and morphological parameters of eggs, i.e., less stability of the egg formation process. This is fully consistent with the lower yield of incubation eggs in the control (65.1% versus 69.0% in the experiment). At the same time, the proportion of eggs suitable for incubation is an important criterion for the efficiency of the parent flock and in our experiment the effect of the phytogenic supplement was manifested not only in an increase in the number of laid eggs, but also in a certain stabilization of the physiological processes of egg formation, which ensured a higher yield of products that met incubation standards. The increase in the proportion of incubation eggs in the experimental group can be explained by a more uniform course of the reproductive function of the bird under the influence of biologically active components of walnut leaves. They probably contributed to better absorption of nutrients and reduced the impact of stress factors, which in the complex provided more stable morphological characteristics of eggs without changing their average weight.

Of significant importance for economic calculations is the feed consumption per unit of production. With standardized feeding (115 g per head per day) in the experimental group, feed consumption per 10 eggs was 1.82 kg versus 1.95 kg in the control, i.e. 6.7% less. A similar trend was found for feed consumption per 1 kg of egg mass – 3.18 kg versus 3.41 kg, respectively. Thus, the phytogenic additive not only increased egg production, but also improved the use of feed nutrients, reducing costs per unit of production. This is especially important for production conditions where the efficiency of feed conversion directly affects the cost of incubation eggs.

The survival rate of the flock for the entire period of the experiment in the experimental group was 98.9%, while in the control group it was 96.0%. An increase in this indicator by 2.9% indicates an improvement in the general physiological condition of the chickens and a decrease in the influence of stress factors. This is fully consistent with the antioxidant properties of phenolic compounds inherent in walnut leaves, which are able to maintain the stability of cell membranes and increase the immune reactivity of the body. In general, the analysis of the economic and useful characteristics given in Table 2 shows that the addition of 1% of crushed walnut leaves to the diet had a positive effect on all the main indicators of the productivity of the parent flock. The chickens of the experimental group were characterized by earlier entry into egg laying, higher egg production, higher hatching egg yield, better feed utilization and higher survival rate of the flock. The absence of changes in egg weight confirms that the increase in productivity was not accompanied by a deterioration in this indicator. The combination of these factors creates the prerequisites for increasing the economic efficiency of hatching egg production.

The increase in chicken productivity and hatching egg yield in the experimental group that consumed the walnut leaf supplement contributed to the improvement of the



main economic indicators of production. The economic assessment of the results of the experiment was carried out on the basis of a comparison of productivity, cost and profitability of hatching egg production in the control and experimental groups. The generalized results of the calculations are given in Table 3.

The increase in chicken productivity due to the use of the phytoadditive contributed to the growth of gross egg production from 21.08 to 22.85 thousand pcs. (by 8.4%), including hatching eggs – from 13.70 to 15.77 thousand pcs., i.e. by 15.1%. According to the production structure, the share of hatching eggs in the experimental group was 69%, while in the control group – 65.1%. (Table 2). This difference has significant economic significance, since hatching eggs are the main product of the parent flock. As a result of the increase in sales volumes, income from the sale of eggs in the experimental group increased from 310.96 to 350.80 thousand UAH, or by 12.8%. The main share of this increase is due to the increase in the sale of hatching eggs (from 274.07 to 315.38 thousand UAH), while the sales volume of food eggs remained practically at the same level. Calculations were made based on the average sales prices: hatching eggs - 20 UAH/piece, food eggs - 5 UAH/piece.

Table 3

Economic efficiency of using a phyto-genic supplement from walnut leaves in feeding a parent flock of chickens

Indicator	Group	
	K (base)	D (new)
Initial livestock, heads	200	200
Gross egg production, thousand pcs.	21,08	22,85
of which: - incubation, thousand pcs.	13,70	15,77
- food, thousand pcs.	7,38	7,08
Total income from the sale of eggs, thousand UAH	310,96	350,80
including: - incubation, thousand UAH	274,07	315,38
- market, thousand UAH	36,89	35,42
Feed costs for the trial period, kg	4102,28	4165,07
Need for walnut leaves, kg	–	41,65
Feeding costs, thousand UAH	49,23	49,98
Total costs for keeping poultry, thousand UAH	100,32	101,40
Profit, thousand UAH	210,6	249,4
Cost of 1 incubation egg, UAH	7,32	6,43
Economic effect, thousand UAH	–	14,05

Total costs included the cost of keeping poultry during the experimental period, including the cost of purchasing pullets (at a price of 150 UAH/head) and feed costs, which accounted for about 70% of total costs. In the control group, they reached 100.32 thousand UAH, in the experimental group - 101.40 thousand UAH, i.e. they increased by only 1.1%. The small increase in costs for keeping poultry is explained by the higher survival rate of the livestock in the experimental group (98.9% versus 96% in the control, as shown in Table 1), as a result of which the number of chickens in the productive period increased and, accordingly, the costs for their feeding. The crushed walnut leaves were prepared by the company itself, so additional costs for its purchase were not taken into account, and the technological operations for its preparation (drying, crushing, storage)



did not require additional financial costs. According to the results of the calculations, the profit from the sale of eggs in the experimental group was 249.4 thousand UAH, which is 18.4% more than in the control group (210.6 thousand UAH). The higher financial result is due to the increase in the gross production of eggs, primarily hatching eggs, which have a significantly higher market price. At the same time, the cost of one hatching egg decreased from 7.32 to 6.43 UAH, which indicates a more rational use of feed resources and production capacities. The overall economic effect of using 1% of walnut leaves in the diet was 14.05 thousand UAH. This confirms the feasibility of using the phytoadditive provided that it is prepared on its own, when there are no additional costs, and the profit increases due to increased productivity and safety of the livestock. At the same time, if we consider the alternative option of purchasing leaves from suppliers at an average market price of 230 UAH/kg (the need for this phytomaterial for the period is 41.65 kg), the total costs would increase to 110.98 thousand UAH. In this case, the profit would be 239.8 thousand UAH, and the economic effect would decrease to 4.47 thousand UAH. At the same time, the cost of one incubation egg would increase to 7.04 UAH, but would not come close to the indicator of the control group (7.32 UAH), having a 3.9% lower value. Therefore, even with the purchase of raw materials, the use of phytoadditives remains economically justified, however, the highest efficiency is provided by the farm's own procurement of walnut leaves, which allows reducing the cost of the incubation egg and increasing the profitability of production without additional financial costs.

Discussion. The results obtained indicate that the inclusion of 1% crushed walnut leaves in the diet of parent hens had a positive effect on their productivity, survival and economic performance. An increase in egg production by 6.8% and a reduction in the age of onset of egg laying by 5 days compared to the control confirm the reproductive-stimulating effect of leaf bioactive substances. A similar trend was noted by Bhagwat et al. (2021) and Moyano et al. (2023), who found an increase in egg production and hatching egg yield when phyto-genic supplements were introduced into the diet of laying hens. According to a meta-analysis by Darmawan et al. (2022), phyto-genic extracts on average increase chicken productivity and feed conversion by 3–6%, which fully coincides with our results.

The positive dynamics of productivity in our experiment is likely due to the optimal dosage of the supplement. Popescu et al. (2020) showed that excessive walnut leaf supplementation may not increase performance, while moderate levels improve digestive health and nutrient absorption efficiency. At the same time, Untea et al. (2020) noted the enrichment of yolk with antioxidant compounds without a negative impact on egg production. Thus, our results are consistent with the findings of these authors, but show a more pronounced effect, presumably due to the use of parent stock with a different level of stress and a better balance of the diet. Maintaining stable egg weight while increasing egg production indicates the absence of energy deficit and efficient nutrient use. Similar observations were made by Sharma et al. (2020) and Suresh et al. (2023), where the introduction of phytonutrients did not change egg weight, but contributed to better shell quality. However, some studies have reported a decrease in egg weight with excessive polyphenols (Untea et al., 2020). Therefore, the stability of the indicators in our work confirms the correctness of the selected dose of 1%, which is consistent with the recommendations of Abdelli et al. (2021) and Biswas et al. (2024) on the advisability of using low concentrations of phyto-genic substances to avoid the inhibitory effect of tannins. The high survival of the livestock (98.9% vs. 96.0% in the control) is consistent with numerous works that note the immunomodulatory effect of phyto-genic substances. According to Huang & Lee (2018) and Mahfuz et al. (2021), phenolic compounds and



flavonoids reduce oxidative stress, inhibit the development of pathogens and enhance the nonspecific resistance of the bird's body. Similarly, Popescu et al. (2020) observed improved digestive health in laying hens fed walnut and blueberry leaves. Our data also suggest that antioxidant compounds in the leaves stabilize the physiological state of the bird, which was manifested in lower mortality and more even egg production dynamics.

Improved feed conversion (6.7% reduction in expenditure) reflects more efficient nutrient absorption and less energy loss to overcome stress factors. Similar results were reported by Ren et al. (2025) and Gadde et al. (2017), where phytogetic supplements contributed to the optimization of intestinal microflora and improved feed utilization. Similarly, Ignatovich (2023) reported an increase in feed intake in laying hens of different crosses when using phytobiotics. Thus, our improvement in feed conversion confirms the data of other authors and demonstrates the potential of walnut leaves as a natural stimulator of metabolic processes.

The economic effect recorded in our experiment (an increase in profit by 18.4%) is fully consistent with the results of studies by Ghanem et al. (2021), which showed that the addition of herbal supplements within the range of 0.5–1% increases profitability by 7–12% due to better feed conversion and reduced mortality of laying hens. Similarly, Salihu et al. (2024) and Mincheva et al. (2025) noted that the use of herbal supplements increases the profitability of broiler production. Therefore, the economic feasibility of using walnut leaves is confirmed both by our calculations and by the generalized data of other authors. The biological activity of walnut leaves is due to the high content of polyphenols, juglone and flavonoids, which have antioxidant and antimicrobial properties (Milek et al., 2022; Gaviley et al., 2024). Their complex effect contributes to the normalization of digestion, improvement of immune status and restoration of energy metabolism, which, in turn, ensures a stable increase in productivity without a negative impact on product quality. These properties coincide with the conclusions of Oke et al. (2024) and Oni & Oke (2025), which describe the mechanisms of antioxidant and anti-inflammatory effects of phytogetic additives in poultry farming.

Thus, the results of our study complement current scientific data on the effectiveness of phytogetic feed additives. They confirm that the use of walnut leaves at a dose of 1% is able to improve reproductive performance, survival and economic efficiency of the parent flock of chickens without deteriorating product quality. From the review Based on the natural origin of the raw materials and their compliance with the principles of organic production, such technology can be recommended for integration into environmentally friendly poultry farming systems.

Conclusions

1. It was found that adding 1% of crushed walnut leaves to the diet of parent hens contributed to an increase in their reproductive capacity. The hens of the experimental group began laying eggs 5 days earlier, had a significantly higher egg production (by 6.8%) and a higher yield of incubation eggs (69.0 versus 65.1% in the control). This indicates a positive effect of biologically active substances of the leaves on the physiological state of the bird and the stability of egg formation processes.

2. Under the influence of the phytoadditive, feed utilization and viability of the livestock improved. Feed consumption per 10 eggs and 1 kg of egg mass decreased by 6.7–6.8%, and the survival rate of the bird increased from 96.0 to 98.9%. This confirms the antioxidant and tonic properties of phytogetic components of walnut leaves, which provide better conversion of nutrients and the body's resistance to stress factors.

3. Increasing the productivity of chickens and the survival of the livestock led to an improvement in the economic indicators of the production of hatching eggs. Profit in the experimental group increased by 18.4%, the cost of one hatching egg decreased from



7.32 to 6.43 UAH, and the total economic effect was 14.05 thousand UAH provided that the phytoraw material was procured by the company itself. In the case of purchasing walnut leaves from suppliers, the economic effect decreased to 4.47 thousand UAH, but remained positive.

4. The use of walnut leaves in the diet of parent hens is a promising direction for increasing productivity and profitability of production. Own procurement of raw materials allows realizing the phytogetic potential of the plant without additional costs, which ensures a stable increase in the biological and economic efficiency of poultry farming. Given the natural origin of the raw materials and the absence of synthetic components, such technology can be integrated into organic poultry production systems, contributing to the expansion of the range of safe and environmentally friendly products.

References

- Abdelli, N., Solà-Oriol, D., & Pérez, J. F. (2021). Phytogetic Feed Additives in Poultry: Achievements, Prospective and Challenges. *Animals*, *11*(12), 3471. <https://doi.org/10.3390/ani11123471>
- Aminullah, N., Mostamand, A., Zahir, A., Mahaq, O., & Azizi, M. N. (2025). Phytogetic feed additives as alternatives to antibiotics in poultry production: A review. *Veterinary World*, *18*(1), 141–154. <https://doi.org/10.14202/vetworld.2025.141-154>
- Bhagwat, V., Ellusamy, B., & Paramesh, R. (2021). Evaluation of the effectiveness of phytogetic feed additive on hatchable egg production performance in Cobb 430 Y breeders under field conditions. *Veterinary Research Notes*, *1*(2), 23. <https://doi.org/10.5455/vrn.2021.a5>
- Biswas, S., Ahn, J. M., & Kim, I. H. (2024). Assessing the potential of phytogetic feed additives: A comprehensive review on their effectiveness as a potent dietary enhancement for nonruminant in swine and poultry. *Journal of animal physiology and animal nutrition*, *108*(3), 711–723. <https://doi.org/10.1111/jpn.13922>
- Cobzaru, C., Serban, A. N., & Cernatescu, C. (2019). Identification and analysis of tanins in extracts from walnuts green fruits and leaves. *Smart Energy and Sustainable Environment*, *22*(1), 103-112.
- Darmawan, A., Hermana, W., Suci, D. M., Mutia, R., Sumiati, Jayanegara, A., & Ozturk, E. (2022). Dietary Phytogetic Extracts Favorably Influence Productivity, Egg Quality, Blood Constituents, Antioxidant and Immunological Parameters of Laying Hens: A Meta-Analysis. *Animals*, *12*(17), 2278. <https://doi.org/10.3390/ani12172278>
- Fedosov, A. I., Kyslychenko, V. S., & Novosel, O. M. (2018). Quantitative content of the sum of phenolic compounds determination in artichoke inflorescences, garlic leaves and bulbs. *Medical and Clinical Chemistry*, *20*(1), 100-104. <https://doi.org/10.11603/mcch.2410-681x.2018.v0.i1.8771>
- Gadde, U., Kim, W. H., Oh, S. T., & Lillehoj, H. S. (2017). Alternatives to antibiotics for maximizing growth performance and feed efficiency in poultry: a review. *Animal Health Research Reviews*, *18*(1), 26–45. <https://doi.org/10.1017/s1466252316000207>
- Gaviley, O., Chorna, G., Pankova, S., & Poliakova, L. (2024). Assessment of Phytochemical Characteristics of Walnut (*Juglans regia*) Leaves: Determination of Nutritional Value and Quantitative Content of Phenolic Compounds. *Research in Agricultural Sciences*, *55*(3), 151–157. <https://doi.org/10.17097/agricultureatauni.1556731>



- Ghanem, H.M., Mahmoud, R.E.S., Gadalla, H.E.S., & Ibrahim, S.S. (2021). Egg Productive Performance, Serum Lipid Profile and Economic Efficiency of Laying Hen Fed Different Levels of Cinnamon Oil Supplemented Diet. *Advances in Animal and Veterinary Sciences*, 9(12). <https://doi.org/10.17582/journal.aavs/2021/9.12.2014.2020>
- Huang, C. M., & Lee, T. T. (2018). Immunomodulatory effects of phytochemicals in chickens and pigs – A review. *Asian-Australasian Journal of Animal Sciences*, 31(5), 617–627. <https://doi.org/10.5713/ajas.17.0657>
- Ignatovich, L. S. (2023). Phytobiotics in the diets of laying hens of various crosses, influence of the genotype on the payment of forage. *Siberian Herald of Agricultural Science*, 52(6), 85–93. <https://doi.org/10.26898/0370-8799-2022-6-10>
- Kholif, A. E., Hassan, A. A., El Ashry, G. M., Bakr, M. H., El-Zaiat, H. M., Olafadehan, O. A., & Sallam, S. M. A. (2020). Phytochemical feed additives mixture enhances the lactational performance, feed utilization and ruminal fermentation of Friesian cows. *Animal Biotechnology*, 1–11. <https://doi.org/10.1080/10495398.2020.1746322>
- Kocaçalışkan, İsmail, Turan, E., Ertürk, Ümran, Demir, Y., & Terzi, İrfan. (2020). Varietal and time dependent differences in juglone and total phenolic contents of the walnut (*Juglans regia* L.) leaves. *Progress in Nutrition*, 22(1), 193–198. <https://doi.org/10.23751/pn.v22i1.7949>
- Kostenko, V.M., Panko, V.V., & Syrovatko, K.M. (2008). *Praktykum z hodivli silskohospodarskykh tvaryn. Chastyna I. Khimichni sklad, otsinka pozhyvnosti ta yakosti kormiv* [Workshop on feeding farm animals. Part I. Chemical composition, nutritional assessment and quality of feeds]. Vinnytsia: RVV VDAU (in Ukrainian).
- Mahfuz, S., Shang, Q., & Piao, X. (2021). Phenolic compounds as natural feed additives in poultry and swine diets: a review. *Journal of Animal Science and Biotechnology*, 12(1). <https://doi.org/10.1186/s40104-021-00565-3>
- Martinez, D. A., Ponce-de-Leon, C. L., & Vilchez, C. (2020). Meta-Analysis of Commercial-Scale Trials as a Means to Improve Decision-Making Processes in the Poultry Industry: A Phytochemical Feed Additive Case Study. *International Journal of Poultry Science*, 19(11), 513–523. <https://doi.org/10.3923/ijps.2020.513.523>
- Miłek, M., Ciszakowicz, E., Lecka-Szlachta, K., Miłoś, A., Zaguła, G., Pasternakiewicz, A., & Dżugan, M. (2022). Mineral Composition, Antioxidant, Anti-Urease, and Antibiofilm Potential of *Juglans Regia* Leaves and Unripe Fruits. *Acta Universitatis Cibiniensis. Series E: Food Technology*, 26(1), 69–82. <https://doi.org/10.2478/aucft-2022-0006>
- Mincheva, N., Oblakova, M., Ivanova, I., & Hristakieva, P. (2025). Economic Evaluation of Broiler Diets Supplemented with Either Selected Herbs or Their Associated Essential Oils. *Black Sea Journal of Agriculture*, 8(1), 1–9. <https://doi.org/10.47115/bsagriculture.1564174>
- Moyano, G., Reddy, R., Saravanakumar, M., & D'Souza, P. (2023). Evaluation of phytochemical feed additive on egg production performance in Hy-Line commercial brown layers. *International Journal of Veterinary Sciences and Animal Husbandry*, 8(1), 87–89. <https://doi.org/10.22271/veterinary.2023.v8.i1b.473>
- Oke, O. E., Oyelami, F. O., Ayodele, S. O., & Akinyemi, O. M. (2024). Oxidative stress in poultry production: Potential benefits of herbal supplements in poultry feed –



- A review. *Poultry Science*, 103(9), 5001–5010. <https://doi.org/10.1016/j.psj.2024.102918>
- Oni, A. I., & Oke, O. E. (2025). Gut health modulation through phytochemicals in poultry: mechanisms, benefits, and applications. *Frontiers in Veterinary Science*, 12. <https://doi.org/10.3389/fvets.2025.1616734>
- Popescu, R. G., Voicu, S. N., Pircalabioru, G. G., Ciceu, A., Gharbia, S., Hermenean, A., Georgescu, S. E., Panaite, T. D., & Dinischiotu, A. (2020). Effects of dietary inclusion of bilberry and walnut leaves powder on the digestive performances and health of Tetra SL laying hens. *Animals*, 10(5), 823. <https://doi.org/10.3390/ani10050823>
- Proskurina, K., Yevtifieieva, O., Mala, O., & Mashtaler, V. (2021). Development of the method for standardization of the medicinal plant raw material of *Cichorium intybus* L. herb by the total amount of hydroxycinnamic acid derivatives. *Pharmacia*, 68(1), 167–173. <https://doi.org/10.3897/pharmacia.68.e49273>
- Ren, J., Ren, S., Yang, H., & Ji, P. (2025). Effects of Phytochemical Feed Additive on Production Performance, Slaughtering Performance, Meat Quality, and Intestinal Flora of White-Feathered Broilers. *Veterinary Sciences*, 12(5), 396–396. <https://doi.org/10.3390/vetsci12050396>
- Salihu, E. A., Onimisi, P. A., & Omega, J. J. (2024). Growth Performance and Economic Analysis of Broiler Chickens Fed *Ocimum gratissimum* and *Ocimum canum* Leaves Meals Supplemented Diets as Phytobiotics. *Nigerian Journal of Animal Production*, 1243–1246. <https://doi.org/10.51791/njap.vi.6757>
- Sharma, M. K., Dinh, T., & Adhikari, P. A. (2020). Production performance, egg quality, and small intestine histomorphology of the laying hens supplemented with phytochemical feed additive. *Journal of Applied Poultry Research*, 29(2), 362–371. <https://doi.org/10.1016/j.japr.2019.12.001>
- Suresh, S., D'Souza, P., & Marimuthu, S. (2023). Evaluation of Phytochemical Feed Additive on Egg Production, Egg Quality and Feed Intake in Layer Chicken. *European Journal of Veterinary Medicine*, 3(1), 12–16. <https://doi.org/10.24018/ejvetmed.2023.3.1.58>
- Untea, A. E., Varzaru, I., Panaite, T. D., Gavris, T., Lupu, A., & Ropota, M. (2020). The effects of dietary inclusion of bilberry and walnut leaves in laying hens' diets on the antioxidant properties of eggs. *Animals*, 10(2), 191. <https://doi.org/10.3390/ani10020191>
- Vinus, Dalal, R., Sheoran, N., Maan, N., & Tewatia, B. (2018). Potential benefits of herbal supplements in poultry feed: A review. *The Pharma Innovation Journal*, 7(6), 651–656.
- Vronska L.V., Chubka M.B., & Demyd A.E. (2015). Development of phenolic compounds chromatographic identification in bilberry shoots. *Pharmaceutical Review*, 3, 28–33. <https://doi.org/10.11603/2312-0967.2015.3.4951>



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ECONOMIC ANALYSIS OF EFFICIENCY AND WAYS TO IMPROVE THE PROFITABILITY OF POULTRY GENE POOL MAINTENANCE

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Preservation of animal genetic resources is a key component of food security and economic stability. Genetic diversity provides the foundation for breeding work, allows the production systems to adapt to climate change, and reduces risks associated with epidemics and productivity decline. To assess economic efficiency, it is necessary to conduct specific economic calculations for regions or breeds, taking into account costs, risks, time, market conditions, and climatic factors. The study was carried out at the experimental base of the State Poultry Research Station of the Institute of Animal Science of the National Academy of Agrarian Sciences of Ukraine using genetic resources of chickens of different productivity types (egg – Birky Colored; dual-purpose – Poltava Clay; meat-and-egg – Hercules (Plymouth Rock) White) from the collection of the national poultry gene pool of Ukrainian selection. The article presents the results of scientific research aimed at a systematic analysis of economic efficiency and the identification of ways to improve it in maintaining poultry gene pool populations of various productivity directions. The research established the level of economic efficiency of maintaining gene pool flocks of chickens of different productivity directions and identified the main ways to improve their profitability. The obtained indicators serve as an analytical basis for further calculations aimed at improving technologies for the maintenance and conservation of breeding stock. The profitability level of hatching egg production for 42 weeks of life ranged from -14.08 to 19.75 % (egg-type chickens), -14.28 to 3.5 % (dual-purpose), and -32.56 to 2.6 % (meat-and-egg). For the production and sale of day-old chicks, the profitability indicators were -7.03 to 29.57 % (egg-type), -13.50 to 4.4 % (dual-purpose), and -36.35 to -3.15 % (meat-and-egg). Extending the keeping period of birds from 42 to 52 weeks led to an increase in total egg production and profitability indicators. The profitability level of hatching egg production for 52 weeks of life was 30.10 % (egg-type), 36.83 % (dual-purpose), and 4.66 % (meat-and-egg). For day-old chick production and sales, the profitability levels were 40.77 %, 48.89 %, and -1.23 %, respectively.

Keywords: chickens, economic evaluation, genetic resources, productivity, poultry farming, production.



ЕКОНОМІЧНИЙ АНАЛІЗ ЕФЕКТИВНОСТІ ТА ШЛЯХИ ПОКРАЩЕННЯ РЕНТАБЕЛЬНОСТІ УТРИМАННЯ ГЕНОФОНДУ ПТИЦІ

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Збереження генетичних ресурсів тварин є ключовим компонентом продовольчої безпеки та економічної стабільності. Генетичне різноманіття забезпечує основу для селекційної роботи, дозволяє адаптувати системи виробництва до змін клімату та зменшує ризики, пов'язані з епідеміями та зниженням продуктивності. Для оцінки економічної ефективності необхідно провести специфічні економічні розрахунки для регіонів або порід, враховуючи витрати, ризики, час, ринкові умови та кліматичні фактори. Дослідження проведені на експериментальній базі Державної дослідної станції птахівництва Інституту тваринництва Національної академії аграрних наук України з використанням генетичних ресурсів курей різних напрямків продуктивності (яєчний – Бірківська кольорова; м'ясо-яєчний – Полтавська глиняста; м'ясний – Геркулес (Плімутрок) білий) з колекції національного генофонду птиці української селекції. У статті представлено результати наукових досліджень, спрямованих на системний аналіз економічної ефективності та виявлення шляхів її підвищення при утриманні генофондних популяцій птиці різних напрямків продуктивності. Дослідженням встановлено рівень економічної ефективності утримання генофондних стад курей різних напрямків продуктивності та визначено основні шляхи підвищення їх рентабельності. Отримані показники слугують аналітичною основою для подальших розрахунків, спрямованих на вдосконалення технологій утримання та збереження племінного поголів'я. Рівень рентабельності виробництва інкубаційних яєць за 42 тижні життя коливався від -14,08 до 19,75 % (кури яєчного напрямку), від -14,28 до 3,5 % (кури м'ясо-яєчного напрямку) та від -32,56 до 2,6 % (кури м'ясного напрямку). Для виробництва та реалізації добових курчат показники рентабельності становили від -7,03 до 29,57 % (яєчний напрямок), від -13,50 до 4,4 % (м'ясо-яєчний напрямок) та від -36,35 до -3,15 % (м'ясний напрямок). Подовження періоду утримання птиці з 42 до 52 тижнів призвело до збільшення загальної несучості та показників рентабельності. Рівень рентабельності виробництва інкубаційних яєць за 52 тижні життя становив 30,10 % (яєчний напрямок), 36,83 % (м'ясо-яєчний напрямок) та 4,66 % (м'ясний напрямок). Для виробництва та продажу добових курчат рівні рентабельності становили відповідно 40,77 %, 48,89 % та -1,23 %.

Ключові слова: кури, економічна оцінка, генетичні ресурси, продуктивність, птахівництво, виробництво.

Introduction With the development of industrial poultry farming, where several highly competitive lines, breeds, or crosses displace all others, the issue of preserving the entire diversity of poultry breeds and developing methods for their rational use has become increasingly urgent. Currently, much attention worldwide is paid to the conservation of the gene pool of rare breeds and populations of agricultural poultry; therefore, each country strives to preserve the available poultry gene pool and



resynthesize populations lost during decades of intensive industrialization. This is due to the fact that indigenous poultry are carriers of valuable genes that ensure high adaptability of offspring and excellent taste qualities of poultry products. Consequently, the preservation and restoration of such carriers of valuable genes are of great national economic importance (Melnyk V.O. et al., 2015; Hladii M.V. et al., 2018; Hadzalo Ya.V. et al., 2017; Groeneveld et al., 2016; Hiemstra et al., 2010). At present, there is a sharp narrowing of the genetic base of agricultural poultry worldwide due to the spread of a few breeds that serve as the foundation for final industrial hybrids. Out of 737 breeds of chickens recorded worldwide at the beginning of the 20th century, only 6–7 are now used for producing commercial hybrids: three for egg production and two for meat production (Ladyka V.I. et al., 2023; Katerynych O. et al., 2023; Tixier-Boichard et al., 2011; Muir et al., 2008). Apart from industrial crosses, there are several breeds and populations suitable for small-scale and household farming. These birds have increased body weight, good egg-laying capacity, and are well adapted to extensive rearing conditions (Pokhyl V.I. et al., 2017). Such breeds include Poltava Clay, Kuchyn Jubilee, Adler Silver, Californian Gray, Rhode Island Red, Birky meat-and-egg chickens, among others. These birds demonstrate higher resistance to diseases and temperature stress (Hillel, 2009). At the same time, a number of less common breeds and populations—such as Italian Partridge, Yuriev Loud-voiced, Brahma, Cochin, Padua, Bantam, and others—are also of great value (FAO, 2015; Hladii M.V. et al., 2021). Unfortunately, their population size continues to decline annually due to the absence of a targeted state policy on the conservation of unique genetic resources. In poultry farming, breeding (genetic) resources sold to consumers include hatching eggs, day-old chicks, and reared young stock (Cahaner & Deeb, 2012). Breeding resources are produced in three types of breeding farms: breeding plants, first- and second-order breeding poultry farms. Breeding plants carry out in-depth selection and breeding work with initial cross lines or with individual poultry breeds using individual and family selection methods. These are birds of the highest breeding value and are rarely sold, as they are considered national treasures, and if they are sold, it is at very high prices. First-order breeding poultry farms breed grandparent flocks of crosses, consisting of female birds from maternal lines and male birds from paternal lines. From such flocks, parental forms are obtained, which are sold to second-order breeding poultry producers in certain male-to-female ratios. In the latter, females of the maternal form are crossed with males of the paternal form to obtain final hybrids, which are sold to producers of table eggs and meat. The price of breeding (genetic) resources is determined based on their quality, namely taking into account their superiority in terms of basic productive characteristics over the minimum requirements for breeding resources of each bird species. The minimum requirements are the requirements for assigning the minimum bonitation class, which, according to the “Instructions for the Bonitation of Agricultural Poultry” (2019), is class II. For each species of poultry, and within a species for individual breeds and populations, these requirements are differentiated, especially for the most significant selected traits for each species of poultry. Therefore, calculations of the equivalent price for all types of breeding resources must be carried out separately for each type of farm poultry (egg-laying and meat chickens, turkeys, geese, ducks) (Wolc et al., 2019). To determine the cost of breeding resources of different breeding value, the equivalent price of the product obtained from poultry of the second bonitation class is first determined. For birds of a higher class (I, elite), the price of breeding products is determined by adding a class bonus to the price of class II, which is calculated depending on the level of the bird's advantages over the second class for each trait by which the bird is graded, and the coefficients of inheritance of traits (Plotnikov O., 2022; Chala V., 2023; Petruha N., 2023; Hladii M.V.



et al., 2021; Besbes et al., 2007). Based on the above, it can be argued that studies aimed at assessing economic efficiency and identifying ways to improve the profitability of maintaining a gene pool of purebred poultry are relevant, especially in wartime and during the post-war recovery of the country's economy (FAO, 2021; Groeneveld et al., 2016).

Therefore, the aim of our work was to conduct an economic analysis of the maintenance of gene pool poultry and to model promising ways to improve the overall profitability of maintaining domestically bred chickens.

Materials and methods. The study was conducted at the State Research Station for Poultry Farming of the Institute of Animal Husbandry of the National Academy of Agrarian Sciences, in the Department of Innovative Development of Poultry Farming and at the experimental farm "Preservation of the National Gene Pool of Agricultural Poultry." Domestic chickens of various productivity types were used as genetic material (egg-laying – Birkovska Barvysta, A; egg-meat – Poltavska Hlinyata, 14; meat and egg – Hercules (Plumutrok) white, G2), with which constant work is carried out aimed at preserving the gene pool. Young birds were raised on the floor, and adult birds were kept in two-tier group cage batteries. The chickens were fed a complete feed mixture. The microclimate parameters, feeding and watering fronts, lighting regime, and stocking density of all groups of birds complied with the standards of the "Departmental Standards for Technological Design of Poultry Farms" (VNTP-APK-04.05, 2005).

During the productive period (42–52 weeks of life), the birds were evaluated according to a set of economically useful characteristics: live weight, egg production, and feed consumption.

The profitability of poultry production was calculated using the following formula:

$$Pp = (P/Sp) \times 100\%, \quad (1)$$

where Pp - is the level of profitability, P - is the profit obtained from sales, and Sp - is the cost of production. The results obtained were statistically processed using Microsoft EXCEL software.

Research results. The gene pool has unique properties that can be used both now and in the future. For a complete assessment of the economic efficiency of maintaining gene pool flocks using different technologies, modelling of profitability improvement, we conducted a comprehensive analysis of the main economically useful characteristics and calculated the corresponding indicators by year.

Thus, using productivity data (egg production, reproductive qualities), calculations were made and indicators of the profitability of poultry production were modelled for keeping gene pool breeds of chickens of different productivity directions in cages.

The main indicator used to calculate the quantity of breeding products and the level of profitability of their production is egg production. First of all, we conducted a comparative analysis of egg production over 25 weeks of the productive period over three years (Fig. 1).

During the first year of research, we established a highly probable difference in egg production between Poltava clay 61.0% (egg-meat), Birkovskaya colourful 49.2% (egg) and Hercules white 43.3% (egg-meat). The trend in egg production during the second year of research changed significantly. We established the maximum indicator for egg-laying chickens at 59.7 eggs, compared to 50.6 (egg-meat) and 41.5 (meat-egg), with a highly probable difference between the first and last. In the third year of research, the maximum growth in the indicator was established in all groups of chickens.

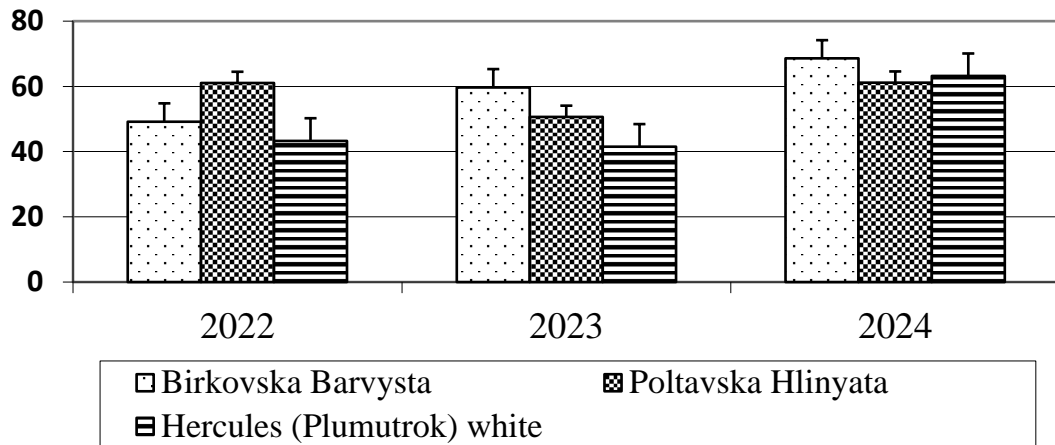


Fig. 1. Dynamics of egg production over 25 weeks of the productive period for chickens of different productivity types

The maximum indicator was established for egg-laying chickens (68.57 eggs) and the minimum for egg-meat chickens (61.10 eggs) with high probability ($p < 0.05$). Taking into account the data obtained, we subsequently performed calculations and a comparative analysis of the economic efficiency of keeping chicken breeds of different productivity types. Table 1 presents data on the productivity of chickens from the gene pool population of the egg-laying type – Birkovskaya Barvysta.

Table 1

Dynamics of economically useful traits and profitability of breeding production of the gene pool of egg-laying chickens over 42 weeks of life (2022-2024)

No	Indicators	Values	Years		
			2022	2023	2024
1	Laying capacity	pcs.	49,20 ^{b***}	59,70 ^{c***}	68,57
2	Average intensity	%	28,11	34,11	39,18
3	Breeding egg yield	%	50,00	50,00	50,00
4	Incubation egg sales	%	70,00	70,00	70,00
5	Incubation eggs sold	pcs.	17,22	20,90	24,00
6	number of day-old chicks	pcs.	12,92	15,67	18,00
7	number of commercial eggs	pcs.	31,98	38,81	44,57
8	cost of incubation egg	UAH	20,00	20,00	20,00
9	cost of day-old chicks	UAH	35,00	35,00	35,00
10	cost of commercial eggs	UAH	4,00	4,00	4,00
11	revenue from the sale of incubation eggs	UAH	472,32	573,12	658,27
12	profit from the sale of hatching eggs	UAH	-77,40	23,40	108,55
13	profitability level from the sale of hatching eggs	%	-14,08	4,26	19,75
14	Revenue from the sale of day-old chicks	UAH	511,07	620,13	712,27
15	Profit from the sale of day-old chicks	UAH	-38,66	70,41	162,55
16	Profitability from the sale of day-old chicks	%	-7,03	12,81	29,57

Notes. a – statistical significance of the difference between 2022 and 2023; b – statistical significance of the difference between 2022 and 2024; c – statistical significance of the difference between 2023 and 2024; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ – level of statistical difference



Based on the results of the egg production indicator, a highly probable ($p < 0.001$) difference was established between the years of the study. The minimum egg production index was established in 2022 at 49.2 eggs. In subsequent years, a highly probable increase in the value to 59.70 (2023) and 68.57 (2024) eggs was established. The average laying intensity for the productive period (25 weeks) ranged from 28.11 to 34.11 and 39.18%, respectively, by year.

Taking into account the breeding egg yield of 70% and their sales of about 70%, the production of this main product ranged from 17.22 (2022) to 20.9 (2023) and 24.0 (2024) eggs. The average number of commercial eggs per year was 31.98–38.81–44.57 eggs per head. With the cost of an incubation egg at 20.0 UAH/unit and a commercial egg at 4.0 UAH/unit, the proceeds after sale were 472.32 (2022), 537.12 (2023) and 658.27 (2024) UAH per head, respectively. Thus, taking into account the costs, the profit per head of the gene pool flock ranged from -77.40 (2022) to 23.40 (2023) to 108.55 (2024) UAH per head. The profitability level we calculated in this case was -14.08 (2022) - 4.26 (2023) - 19.75 (2024) %.

At the same time, we calculated the profit and profitability indicators if day-old chicks were sold instead of hatching eggs. The cost of incubation is 4.0 UAH per egg. Thus, it would be possible to obtain a reliable ($p < 0.001$) higher revenue from sales, at the level of 511.07 (2022) - 620.13 (2023) and 712.27 (2024) UAH per head. In this case, the profit would be -38.66 (2022) - 70.41 (2023) and 162.55 (2024) UAH per head. The profitability level was -7.03 (2022) - 12.81 (2023) and 29.57 (2024) %, which is significantly higher than the sale of hatching eggs.

Thus, the data we obtained allow us to evaluate, adjust and propose ways to improve the economic efficiency of keeping purebred poultry as a gene pool in the future.

The next typical representative of gene pool breeds of chickens for egg and meat production is the Poltava clay breed.

Taking into account the productivity indicators, we calculated the profitability of poultry production for cage rearing of this breed over three years using the proposed model (Table 2).

Over three years of research, we have established a highly probable ($p < 0.001$) decrease and increase in egg production, from 61.0 to 50.6 and 61.1 eggs, respectively. At the same time, the general trend in the dynamics of egg production is different from that of egg-laying poultry.

The average productivity and egg production intensity (25 weeks) throughout the entire period was 34.86 (2022) - 28.91 (2023) - 34.91 (2024) %.

Taking into account the yield of breeding eggs at 70% and their sale at about 60%, the production of hatching eggs by year was about 25.62 (2022) - 21.25 (2023) and 25.66 (2024) eggs.

The average number of commercial eggs per year was 35.28–29.38–35.44 eggs per head. With the cost of an incubation egg at 20.0 UAH/piece and a marketable egg at 4.0 UAH/piece, the proceeds after sale were 705.16 (2022), 584.94 (2023) and 706.32 (2024) UAH per head, respectively. Taking into account the costs presented above, the profit per head of the parent flock of egg-meat chickens ranged from 22.77 (2022) - -97.45 (2023) to 23.93 (2024) UAH per head.

The level of profitability calculated by us is set at - 3.34 (2022) - -14.28 (2023) - 3.51 (2024) %.

Along with this, we have presented calculations, as for laying hens, of the profitability of selling day-old chicks, taking into account incubation at 4.0 UAH per egg. As a result of our calculations, the level of revenue from product sales ranges from 711.57 (2022) to 590.25 (2023) and 712.73 (2024) UAH per head.



Table 2

Dynamics by year of economic and useful characteristics and profitability of breeding production of the gene pool of egg-meat chickens over 42 weeks of life (2022-2024)

No	Indicators	Values	Years		
			2022	2023	2024
1	Laying capacity	pcs.	61,00 ^{a***}	50,60 ^{b***}	61,10
2	Average intensity	%	34,86	28,91	34,91
3	Breeding egg yield	%	70,00	70,00	70,00
4	Incubation egg sales	%	60,00	60,00	60,00
5	Incubation eggs sold	pcs.	25,62	21,25	25,66
6	number of day-old chicks	pcs.	19,22	15,94	19,25
7	number of commercial eggs	pcs.	35,38	29,35	35,44
8	cost of incubation egg	UAH	22,00	22,00	22,00
9	cost of day-old chicks	UAH	35,00	35,00	35,00
10	cost of commercial eggs	UAH	4,00	4,00	4,00
11	revenue from the sale of incubation eggs	UAH	705,16	584,94	706,32
12	profit from the sale of hatching eggs	UAH	22,77	-97,45	23,93
13	profitability level from the sale of hatching eggs	%	3,34	-14,28	3,51
14	Revenue from the sale of day-old chicks	UAH	711,57	590,25	712,73
15	Profit from the sale of day-old chicks	UAH	29,18	-92,14	30,34
16	Profitability from the sale of day-old chicks	%	4,28	-13,50	4,45

Notes: a – statistical significance of the difference between 2022 and 2023; b – statistical significance of the difference between 2023 and 2024; *** $p < 0.001$ – level of statistical difference

In this case, the profit would be 29.18 (2022) – -92.14 (2023) and 30.34 (2024) UAH per head.

The profitability level was 4.28 (2022), 13.50 (2023) and 4.45 (2024) %, which is not significantly higher than the sale of hatching eggs.

An analysis of the results of maintaining a population of meat-and-egg chickens, namely White Hercules, is presented in Table 3.

Based on the results of a comparative analysis of egg production, a highly probable ($p < 0.001$) increase in this indicator was established in 2024 (63.15) compared to 2022 (43.3) and 2023 (41.5) eggs.

The average egg production intensity for the productive period (22 weeks) was established at 28.12 to 26.95 and 41.01%, respectively, by year. At the same time, for 2024, the maximum productivity for meat-and-egg chickens was set at 41.01% compared to other poultry groups (39.18% and 34.91%).

Taking into account the breeding egg yield of 60% and their sales of about 60%, the total production of hatching eggs was 15.59 (2022), 14.94 (2023) and 22.73 (2024) eggs. The production of commercial eggs per year was at the level of 27.71–26.56–40.42 eggs per layer. With the cost of an incubation egg at 24.0 UAH/piece and a commercial egg at 4.0 UAH/piece, after sale, 484 (2022), 464.80 (2023) and 707.28 (2024) UAH per head were received, respectively.



Table 3

Dynamics by year of economic and useful characteristics and profitability of breeding production of the gene pool of meat-and-egg chickens over 42 weeks of life (2022-2024)

No	Indicators	Values	Years		
			2022	2023	2024
1	Laying capacity	pcs.	43,30 ^{a***}	41,50 ^{b***}	63,15
2	Average intensity	%	28,12	26,95	41,01
3	Breeding egg yield	%	60,00	60,00	60,00
4	Incubation egg sales	%	60,00	60,00	60,00
5	Incubation eggs sold	pcs.	15,59	14,94	22,73
6	number of day-old chicks	pcs.	11,69	11,21	17,05
7	number of commercial eggs	pcs.	27,71	26,56	40,42
8	cost of incubation egg	UAH	24,00	24,00	24,00
9	cost of day-old chicks	UAH	35,00	35,00	35,00
10	cost of commercial eggs	UAH	4,00	4,00	4,00
11	revenue from the sale of incubation eggs	UAH	484,96	464,80	707,28
12	profit from the sale of hatching eggs	UAH	-204,22	-224,38	18,10
13	profitability level from the sale of hatching eggs	%	-29,63	-32,56	2,63
14	Revenue from the sale of day-old chicks	UAH	457,68	438,66	667,50
15	Profit from the sale of day-old chicks	UAH	-231,49	-250,52	-21,68
16	Profitability from the sale of day-old chicks	%	-33,59	-36,35	-3,15

Notes: a – statistical significance of the difference between 2022 and 2024; b – statistical significance of the difference between 2023 and 2024; *** $p < 0.001$ – level of statistical difference

Taking into account the amount of expenses, the profit per head of experimental poultry calculated by us was from -204.22 (2022) – -224.38 (2023) – 18.10 (2024) UAH per head. The profitability level calculated by us in this case was -29.63 (2022) – -32.56 (2023) – 2.63 (2024) %.

At the same time, we calculated the amount of profit and profitability from the sale of day-old chicks at a price of 35.0 UAH per head. The cost of incubation is 4.0 UAH per egg. In this case, based on our data, the revenue from sales could amount to – 457.68 (2022) – 438.66 (2023) and 667.50 (2024) UAH per head. In this case, the profit would be -231.49 (2022) - -250.52 (2023) and -21.68 (2024) UAH per head. The profitability level was -33.59 (2022) – -36.35 (2023) and -3.15 (2024) %, which is the lowest among chickens of different productivity types.

Thus, the data we have obtained is the basis for calculations to improve or refine the technology for maintaining and preserving the gene pool, possible subsidies from the state to improve the economic efficiency of keeping purebred poultry as a gene pool.

Purebred poultry, which is the object and unit of gene pool preservation, has many positive qualities, but not always high indicators of economically useful traits, which is why the economic efficiency of genetic resource preservation may be low. In our work, we modelled and tracked a number of economic and technological solutions that can improve the economic indicators for maintaining the gene pool. The main one is the extension of the productive period. Unfortunately, in Ukraine, the breeding season to



meet the needs of private and commercial farms falls in March–June, which significantly reduces (almost 2.5 times) the use of breeding products. At the same time, in our case, it is micro, small and medium-sized poultry farms that are consumers of purebred poultry. Therefore, in our research, we increased the use of poultry from the Ukrainian gene pool by 10 weeks (70 days) from 42 weeks of age to 52 weeks of age and made a comparative analysis of chickens of different productivity types. The results of productivity and economic efficiency when keeping chickens up to 52 weeks of age are shown in Table 4.

According to our data obtained from keeping chickens of different productivity types in cages, the maximum egg production over 52 weeks of life (87.1 eggs) was established for chickens of the Poltava clay breed (egg-meat). The minimum values (64.4 eggs) were obtained for white Hercules (meat and egg). Egg-laying chickens (Birkovskaya Barvysta) had an intermediate value (74.5 eggs). The difference between the maximum and minimum values is highly significant ($p < 0.001$).

Table 4

Comparative analysis of economic traits and profitability of breeding production of the gene pool of chickens of different productivity types at 52 weeks of age (2023)

No	Indicators	Values	Performance direction, analogues		
			egg-laying, Birkovskaya colourful	egg-laying, Birkovskaya colourful	egg-laying, Birkovskaya colourful
1	Laying capacity	pcs.	74,50 ^{a,b***}	87,10 ^{c***}	64,40
2	Average intensity	%	30,41	35,55	26,29
3	Breeding egg yield	%	50,00	70,00	60,00
4	Incubation egg sales	%	70,00	60,00	60,00
5	Incubation eggs sold	pcs.	26,08 ^{a***}	36,58 ^{c***}	23,18
6	number of day-old chicks	pcs.	19,56 ^{a***}	27,44 ^{c***}	17,39
7	number of commercial eggs	pcs.	48,43	50,52	41,22
8	cost of incubation egg	UAH	20,00	20,00	24,00
9	cost of day-old chicks	UAH	35,00	35,00	35,00
10	cost of commercial eggs	UAH	4,00	4,00	4,00
11	revenue from the sale of incubation eggs	UAH	715,20	933,71	721,28
12	profit from the sale of hatching eggs	UAH	165,48	251,33	32,10
13	profitability level from the sale of hatching eggs	%	30,10	36,83	4,66
14	Revenue from the sale of day-old chicks	UAH	773,87	1016,02	680,71
15	Profit from the sale of day-old chicks	UAH	224,14	333,63	-8,47
16	Profitability from the sale of day-old chicks	%	40,77	48,89	-1,23

Notes. a – statistical significance of the difference between egg-laying hens and egg-meat hens; b – statistical significance of the difference between egg-laying hens and meat-egg hens; c – statistical significance of the difference between egg-meat hens and meat-egg hens. *** $p < 0.001$ – level of statistical difference



The average laying intensity of the experimental birds during the productive period was set at 30.41% (egg-laying), 35.55% (egg-meat) and 26.29% (meat-egg) chickens.

According to our own data, the maximum yield of breeding eggs was established for the Poltava clay breed (egg-meat), followed by Hercules white (meat-egg) and Birkovska colourful (egg), respectively 70.0 – 60.0 – 50.0%.

Taking into account the seasonality of production and sales of breeding products, the sales rate for hatching eggs is set at 60.0 (egg-meat, meat-egg) – 70.0 (egg) %.

With the price of hatching eggs at 20.0 (egg-laying) – 22.0 (egg-meat) – 24.0 (meat-egg) UAH per piece and commercial eggs at 4 UAH the total sales revenue was, respectively, from 715.20 (egg) to 721.28 (meat-egg) and 933.71 (egg-meat) UAH per head.

Taking into account the cost of raising and maintaining chickens, the profit was set at 165.48 (egg-laying) – 251.33 (egg-meat) – 32.10 (meat-egg) UAH per head.

The level of profitability of breeding production for cage-reared gene pool flocks of chickens of different productivity types per year of life (52 weeks) is set at 30.10 (egg-laying) – 36.83 (egg-meat) – 4.66 (meat-egg) UAH per head. According to the results of a comparative analysis of the profitability of keeping chickens for 42 and 52 weeks, an average increase of 37.07–0.53% was established for egg-laying chickens; 33.32–51.11% for egg-meat chickens; 2.03–37.22% for meat-egg chickens.

Discussion Thus, extending the period of poultry rearing allows for an increase in productivity and improves the profitability of preserving the gene pool. Increasing the yield of breeding eggs to the minimum standard level (VNTP-APK-04.05) – 75%, and their sale at 100%, with the above-mentioned productivity indicators will increase the level of profitability by 116.84 (egg) – 104.22 (egg-meat) – 77.55 (meat-egg) %. An additional potential for increasing profitability is the growth in the price of breeding resources, but this is currently not possible for the domestic market of Ukraine.

Another additional area for increasing profitability is the incubation and sale of day-old chicks. In this case, sales revenue could increase by 8.0–8.8% for egg and egg-meat poultry. Unfortunately, for meat-and-egg chickens, at such a price for day-old chicks, it may decrease by 6%. The level of profitability may increase by 10.67% and 12.06% for egg-laying and egg-and-meat poultry. For meat-and-egg poultry, it will be -1.23%.

Conclusions

1. Based on the results of the economic analysis, the level of efficiency was established and ways to improve the profitability of maintaining the gene pool of chickens of different productivity directions were determined. The data obtained are the basis for further calculations to improve or refine the technology for maintaining and preserving the gene pool of agricultural poultry.

2. A reliable difference has been established between the gene pool populations of chickens of domestic selection in terms of egg production, the value of which determines the direction of productivity and affects the economic indicators of the profitability of poultry maintenance. Based on the results of a systematic analysis, the profit and profitability of chickens of different productivity directions were calculated for the sale of breeding products in the form of hatching eggs and day-old chicks. The level of profitability of hatching egg production (by year, for 42 weeks of life) for chickens of different productivity directions was set at the following levels, respectively -14.08 – 19.75 % (egg-laying chickens); -14.28–3.5% (egg-meat); -32.56–2.6% (meat-egg). For the production and sale of day-old chicks, the profitability level is, respectively: -7.03–29.57% (laying hens); -13.50–4.4% (egg-meat); -36.35–3.15% (meat-egg).



3. Ways to improve the overall level of profitability while preserving the gene pool have been identified. Increasing the retention period of poultry from 42 to 52 weeks of age leads to an increase in overall egg production and corresponding indicators of profitability in the production of breeding products. The level of profitability of hatching egg production (at 52 weeks of age) for chickens of different productivity types was set at 30.10% (egg-laying chickens); 36.83% (egg-meat chickens); 4.66% (meat-egg chickens). For the production and sale of day-old chicks, the profitability level is 40.77% (egg-laying hens); 48.89% (egg-meat); -1.23% (meat-egg), respectively.

References

- Melnyk, V. O., Tereshchenko, O. V., Zhukorskyi, O. M., et al. (2015). *Resursozberihaiuchi ekolohichno bezpechni tekhnolohii vyroshchuvannia, utrymannia ta hodivli silskohospodarskoi ptytsi: naukovo-praktychnyi posibnyk* [Resource-saving and environmentally safe technologies of rearing, keeping and feeding of poultry: Scientific-practical manual] Kyiv. (in Ukrainian).
- Hladii, M. V., Polupan, Yu. P., Basovskiy, B. M., et al. (2018). *Prohrama zberezhennia henofondu lokalnykh i znykaiuchykh porid silskohospodarskykh tvaryn v Ukraini na 2017–2025 roky* [Program for conservation of the gene pool of local and endangered breeds of farm animals in Ukraine for 2017–2025]. Sumy: Sumskyi NAU. (in Ukrainian).
- Hadzalo, Ya. M., Bashchenko, M. I., Hladii, M. V., et al. (2017). *Tvarynnytstvo Ukrainy: stan, problemy, shliakhy rozvytku* [Animal husbandry of Ukraine: State, problems, development paths] Kyiv. (in Ukrainian).
- Ladyka, V. I., Zhukorskyi, O. M., Hrytsyniak, I. I., et al. (2023). *Henetychni resursy vitchyzniannykh porid silskohospodarskykh tvaryn* [Genetic resources of domestic breeds of farm animals] Odesa: Oldi+. (in Ukrainian).
- Katerynych, O., Pankova, S., & Vasiuko, K. (2023). Preservation and rational use of domestic poultry gene pool in Ukraine. In *Szanse nauk o zwierzętach* (pp. 63–71). Lublin: Wydawnictwo Uniwersytetu Przyrodniczego w Lublinie. <https://doi.org/10.24326/mon.2023.9>
- Pokhyl, V. I., Sanzhara, R. A., Patrieva, L. S., & Katerynych, O. O. (2017). *Porody ta krosy silskohospodarskoi ptytsi* [Breeds and crosses of poultry] Dnipro. (in Ukrainian).
- Ministerstvo aharnoi polityky ta prodovolstva Ukrainy. (2019). *Pro zatverdzhennia Instruksii z bonituvannia silskohospodarskoi ptytsi* [On approval of the Instruction on poultry grading] (in Ukrainian). Retrieved from <https://zakon.rada.gov.ua/laws/show/z0846-01>
- Plotnikov, O. (2022). Povoienne vidnovlennia Ukrainy v konteksti frahmentatsii svitovoi ekonomiky [Post-war recovery of Ukraine in the context of fragmentation of the world economy] *Ekonomika Ukrainy*, 12(733), 3–12. (in Ukrainian). <https://doi.org/10.15407/economyukr.2022.12.003>
- Chala, V. (2023). Povoienna rozbudova v Ukraini zelenoi ekonomiky: osnovni stsenarii [Post-war development of Ukraine's green economy: Main scenarios] *Ekonomika ta pidpriemnytstvo*, 1(127), 12–18. (in Ukrainian). <https://doi.org/10.32782/1814-1161/2023-1-2>
- Petruha, N. (2023). Povoienne vidnovlennia aharnoho sektoru ekonomiky na zasadakh bioekonomiky [Post-war recovery of the agricultural sector of the economy on the principles of bioeconomy] *Ekonomichniy analiz*, 33(4), 49–58. (in Ukrainian). <https://doi.org/10.35774/econa2023.04.049>



- Hladii, M. V., Porkhun, M. H., Kruhljak, O. V., et al. (2021). Ekonomichni zasady prybutkovoho vykorystannia henetychnykh resursiv molochnoho skotarstva Ukrainy [Economic principles of profitable use of genetic resources of dairy cattle in Ukraine] *Rozvedennia i henetyka tvaryn*, 62, 31–36. (in Ukrainian). <https://doi.org/10.31073/abg.62.06>
- Ministerstvo ahrarynoi polityky ta prodovolstva Ukrainy. (2005). *Vydomchi normy tekhnolohichnoho proiektuvannia. Pidpriemstva ptakhivnytstva (VNTP–APK–04.05)* [Departmental standards of technological design. Poultry enterprises (VNTP–APK–04.05)] Kyiv. (in Ukrainian).
- Groeneveld, L. F., et al. (2016). Genetic diversity in farm animals – A review. *Animal Genetics*, 47(6), 528–535. <https://doi.org/10.1111/age.12453>
- Hiemstra, S. J., et al. (2010). *Conservation of animal genetic resources in Europe*. Wageningen Academic Publishers.
- Tixier-Boichard, M., Bed'hom, B., & Rognon, X. (2011). Chicken domestication: From archeology to genomics. *Comptes Rendus Biologies*, 334(3), 197–204. <https://doi.org/10.1016/j.crvi.2010.12.012>
- Muir, W. M., Wong, G. K.-S., et al. (2008). Genome-wide assessment of worldwide chicken diversity. *Proceedings of the National Academy of Sciences*, 105(45), 17312–17317. <https://doi.org/10.1073/pnas.0806569105>
- Hillel, J. (2009). Molecular markers in animal breeding and genetics. *Poultry Science*, 88(5), 881–887. <https://doi.org/10.3382/ps.2008-00247>
- Cahaner, A., & Deeb, N. (2012). Breeding for adaptation to hot climates. In *Poultry breeding and genetics* (pp. 347–363).
- Wolc, A., et al. (2019). Advances in genomic selection in poultry. *Genetics Selection Evolution*, 51(60), 1–10. <https://doi.org/10.1186/s12711-019-0495-9>
- Besbes, B., et al. (2007). Economic aspects of poultry genetic resources. *World's Poultry Science Journal*, 63(1), 25–42. <https://doi.org/10.1017/S0043933907001250>
- FAO. (2021). *Domestic Animal Diversity Information System (DAD-IS)*. Rome: FAO. <https://www.fao.org/dad-is>
- Groeneveld, E., et al. (2016). Monitoring and conservation of poultry genetic resources. *Animal Genetics*, 47(6), 537–547. <https://doi.org/10.1111/age.12454>
- Weigend, S., & Romanov, M. N. (2001). Current strategies for poultry biodiversity. *World's Poultry Science Journal*, 57(4), 435–448. <https://doi.org/10.1079/WPS20010031>
- Hocking, P. M. (2010). Developments in poultry breeding. *World's Poultry Science Journal*, 66(1), 5–13. <https://doi.org/10.1017/S0043933910000028>
- Ekarius, C. (2007). *Storey's illustrated guide to poultry breeds*. Storey Publishing.
- Crawshaw, R. (2012). *Poultry breeds and breeding*. Elsevier.
- Nandi, S., et al. (2018). Genetic conservation in poultry. *Indian Journal of Poultry Science*, 53(3), 305–312.
- Padhi, M. K. (2016). Importance of indigenous breeds of chicken in India. *World's Poultry Science Journal*, 72(2), 259–267. <https://doi.org/10.1017/S0043933916000017>



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A NEW APPROACH TO MINIMIZING THE IMPACT OF TECHNOLOGICAL STRESS FACTORS ON THE CLINICAL AND PHYSIOLOGICAL STATE OF PIGGLES

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Stress in farm animals is interpreted as a complex adaptive response of the body to unusual or extreme conditions caused by intense stimuli that can potentially disrupt its normal functioning. Among them, technological stresses, which are most common in modern pig breeding, are of particular importance. In such circumstances, the use of anti-stress drugs is considered as an effective tool for reducing their negative consequences.

The article presents the results of experimental studies aimed at scientific substantiation of effective approaches to reducing the effect of technological stress factors on the clinical and physiological state of young pigs by using a new anti-stress drug, in comparison with traditional means. Based on laboratory data, it was established that the introduction of the experimental drug from the very beginning of the development of the stress reaction activates hematopoietic processes in the body of young animals of Group III, causing an increase in the blood content of red blood cells by 8.4% ($p < 0.05$) and 3.5%, white blood cells-by 3.4 and 0.9%, hemoglobin concentrations – by 5.7 and 4.3% and Total Protein – by 10.5% ($p < 0.001$) and 5.2% ($p < 0.001$), compared with analogues control and II experimental groups, maintaining the general trend of increasing these indicators at the end of the fattening period. In addition, the results of the studies clearly demonstrate the positive effect of the applied anti-stress drugs on the functional state of young pigs, while the studied indicators remained within the physiological norm, regardless of the group. At the initial stage of the experiment, piglets of Group I showed a slight increase in the respiratory rate, compared with peers of groups II and III by 0.4 and 0.8 movements/min or 1.1 and 2.2%, acceleration of the heart rate by 2.8 and 4.2 beats/min or 2.6 and 3.9% against the background of stable body temperature parameters, the difference in which was respectively 0.24 and 0.30 °C or 0.6 and 0.8% greater in young animals of the control group. At the final stage of the study, a similar dynamics of changes in clinical and physiological parameters was noted.

Keywords: pigs, young animals, stress resistance, blood, body temperature, pulse rate and respiration.



НОВИЙ ПІДХІД ЩОДО МІНІМІЗАЦІЇ ВПЛИВУ ТЕХНОЛОГІЧНИХ СТРЕС-ЧИННИКІВ НА КЛІНІКО- ФІЗІОЛОГІЧНИЙ СТАН ПОРОСЯТ

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Стреси у сільськогосподарських тварин трактують як комплексну адаптаційну реакцію організму на незвичні або екстремальні умови, спричинені дією інтенсивних подразників, що потенційно можуть порушувати його нормальне функціонування. Серед них особливе значення мають технологічні стреси, які найбільш поширені в сучасному свинарстві. За таких обставин, використання антистресових препаратів розглядається як ефективний інструментарій для зниження негативних їх наслідків.

У статті наведено результати експериментальних досліджень, спрямованих на наукове обґрунтування ефективних підходів щодо зниження дії технологічних стрес-чинників на клініко-фізіологічний стан молодняку свиней шляхом застосування нового антистресового препарату, порівняно з традиційними засобами. На основі даних лабораторних досліджень встановлено, що введення експериментального препарату з самого початку розвитку стрес-реакції активує кровотворні процеси в організмі молодняку III групи, зумовлюючи збільшення у крові вмісту еритроцитів на 8,4 % ($p < 0,05$) і 3,5 %, лейкоцитів – на 3,4 і 0,9 %, концентрації гемоглобіну – на 5,7 і 4,3 % і загального білка – на 10,5 % ($p < 0,001$) і 5,2 % ($p < 0,001$), порівняно з аналогами контрольної та II дослідної груп, зберігаючи загальну тенденцію щодо зростання цих показників наприкінці періоду відгодівлі. Окрім того результати досліджень чітко демонструють позитивний вплив застосованих антистресових препаратів на функціональний стан молодняку свиней, при цьому досліджувані показники залишалися в межах фізіологічної норми незалежно від групи. На початковому етапі дослідження в поросят I групи спостерігалось незначне підвищення частоти дихання, порівняно з ровесниками II та III груп на 0,4 і 0,8 рухи/хв або 1,1 і 2,2 %, прискорення серцевого ритму на 2,8 і 4,2 удара/хв або 2,6 і 3,9% на тлі стабільних параметрів температури тіла, різниця за якими була відповідно 0,24 і 0,30 °C або 0,6 і 0,8 % більшою у молодняку контрольної групи. На завершальному етапі дослідження відзначали аналогічну динаміку змін клініко-фізіологічних показників.

Ключові слова: свині, молодняк, стресостійкість, кров, температура тіла, частота пульсу і дихання.

Introduction. During the rearing period from birth to retirement, pigs are exposed to a complex of stressors that negatively affect their physiological state (Suprun I. O., 2012; Lykhach V. Ya. et al., 2021; Koroban M. et al., 2023). Technological stress factors generated in the production process most significantly arise due to changes in traditional conditions of keeping, high density of livestock in a limited area, insufficient feeding front, excessive noise level, violation of requirements for planning solutions of premises (Rossi R. et al., 2008). These stress factors have both direct and indirect negative effects on animals. Their mediated action leads to a significant violation of the usual regime for animals, which causes imperceptible stress reactions. Direct exposure is immediately



noticeable and can be eliminated quickly, while indirect exposure is usually delayed when animals are already showing a decrease in productivity (Minka N. S. O. & Ayo J., 2007; Van de Perre V., 2011; Dovhii Yu. Yu., & Feshchenko D. V., 2018).

Along the way, it should be noted that in the piglet rearing system, due attention should be paid to rational space during maintenance (Nielsen S. S. et al., 2022). Failure to comply with technological standards of the area of maintenance restricts the mobility of animals, makes it impossible or reduces the desire to be near their peers, suppresses social interactions and makes it difficult to move around the machine and freely access to feed and water (Fels M. et al., 2014). Reducing the retention area increases aggressiveness in the group, which, in turn, significantly increases the level of injuries. The problem of crowding is especially aggravated by the growing age of young animals and the increase in the size of the group. In the conditions of Group maintenance of piglets, a potential source of stress is not only the size of the group, but also the density of their maintenance. Violation of the parameters of the content density causes stressful situations, accompanied by an increase in the number of aggressive fights between peers in the group and a reduction in the duration of feed consumption, especially among weak and timid animals (Harris M. J. et al., 2006; Braun Dzh. A., & Seddon Yu. M., 2014; Verdon M. et al., 2015).

According to published data (Gillman C. E. et al., 2008; Temple D. et al., 2012; Van Staaveren N. et al., 2018), the source of stress factors for pigs in the rearing process can be the type of floor and the level of its sanitary condition. Keeping animals on a completely latticed floor without bedding eliminates an important element of the technological process – increased comfort.

Individual researchers (Li Y. Z. & Johnston L. J., 2009). we concluded that the live weight of piglets and the introduction of new individuals into groups can negatively affect their behavior, productivity and physiological state. In this context, it is necessary to highlight the well-founded positions of specialists in the field of pig breeding (Tokarchuk T. S., 2017; Lykhach V. Ya. et al., 2020), which emphasize that among the negative sources of stress factors in industrial pork production, an important place is occupied not only by changes in the conditions of detention, but also by the influence of environmental factors and feeding features. However, in their opinion, a significant stress factor for piglets is the period of re-formation of groups.

Comprehensive research (Schröder-Petersen D. L. & Simonsen H. D., 2001; Martin J. E. et al., 2015) demonstrated that regrouping piglets contributes to the formation of adaptive behavior at the fattening stage, while purposeful Organization of socialization and game interaction between piglets in machines significantly reduces the manifestations of agonistic behavior after weaning, which is important for increasing their stress tolerance and optimizing productivity.

Today, the frequency of manifestations of heat stress is becoming an increasingly urgent problem in the pig industry, which is due to global changes in climatic conditions, in particular, an increase in ambient temperature, a decrease in humidity and air velocity. According to (Trouw Nutrition, 2025), the agricultural sector annually suffers losses due to heat stress in the amount of about 200 billion US dollars. Research by other scientists (Yu J., 2010) indicate that heat stress in pigs leads to an increase in rectal temperature on the body surface and a synchronous increase in serum cortisol levels against the background of a significant increase in the expression of small intestine protein genes as evidence of activation of adaptive mechanisms at the molecular level.

Among the most significant sources of stress in pig farming, which negatively affect the physiological state of animals, transportation is singled out. Its consequences are associated with a decrease in productivity, deterioration of the quality of meat raw



materials, an increase in the incidence of respiratory and digestive pathologies (Urrea V. M. et al., 2021). The researchers found that during transportation, pigs experience a whole range of physiological and behavioral changes as evidence of activation of stress responses. Violation of homeostasis is manifested in the form of tissue hypoxia, dehydration of the body, changes in hematological and biochemical parameters of blood (the level of red blood cells, white blood cells, hemoglobin increases), the concentration of hormones, metabolites, nitrogenous compounds, protein fractions and enzymes (Kushnerenko V. H., 2023). Among the criteria for systematic assessment of the impact of technological stress factors on animals, blood and physiological state indicators are of leading importance, which most fully reflect the functional state of their body. That is why, given the multifaceted nature of the action of stress factors inherent in modern pig breeding, which affect the functional state of the body of young animals, their productivity and level of well-being, the assessment of the stress state caused by weaning piglets from the sow, transferring them to rearing and fattening sites for the use of clinical and physiological indicators, the role of which in this system is still insufficiently justified, becomes particularly relevant. Equally important is the search for innovative and more effective solutions to reduce the negative effects of these stress factors on the body of young pigs. In the context of the study of adaptation processes, such biologically active compounds as the amino acid glycine ($C_2H_5NO_2$), succinic acid ($C_4H_6O_4$) and nutrient medium 199 are of particular scientific interest. Their use contributes to the activation of metabolic processes, the intensification of growth and development of animals, the improvement of reproductive function and the increase in the level of natural resistance of the body. At the same time, today there are not enough comprehensive generalizations that highlight the practical feasibility of combined use of these substances in a single pharmaceutical form and their possible synergistic effect in pig farming. The available scientific publications are mainly devoted to the study of the effects of these agents separately, mainly in sheep, Mink and cattle breeding. This, in turn, highlights the need for scientific justification of the effectiveness of their combined use to increase the adaptive stability of young pigs.

The aim of the research is to develop a new approach to minimize the impact of technological stress factors on the clinical and physiological state of young pigs.

Materials and methods of research. Scientific and economic research was carried out in the production conditions of the complex for the production of pork PE AF "Svitanok" Novovodolazhsky District of Kharkiv region, the experimental part – the laboratory of breeding and Technological Research in small animal husbandry and horse breeding of Livestock farming institute of NAAS of Ukraine.

To organize and conduct the planned work, generally accepted requirements for conducting zootechnical experiments were applied. The experimental pig population was represented by first-generation piglets, which were obtained as a result of reproductive crossing of Landrace boars with Yorkshire sows and were imported from Denmark. To form the experimental population in the conditions of the basic farm, imported sows were inseminated with Duroc boars. As part of the experiment, key technological stress factors included: weaning piglets from the sow, transferring them to rearing and fattening sites.

To conduct the experiment during weaning, three groups of piglets were formed – analogues by genotype, age, gender and live weight, 10 heads each. Piglets of the III (experimental) group were intramuscularly administered an experimental drug at a dose of 1.5 ml/10 kg of live weight per day, animals of the II (experimental) group – a similar dose (1.5 ml/10 kg of live weight per day) of a traditional anti-stress drug, and piglets of the I (control) group were given an equivalent amount of sterile saline solution instead of the studied drugs, in order to level the influence of the very fact of injections as a stress



factor. Injections of drugs were made into the inner surface of the pelvic limb of the animal, on an empty stomach, in the first half of the day two days before and two days after the action of each stress factor.

Clinical studies were performed on the basis of a veterinary laboratory. Biomaterial was obtained in the morning, two hours before feeding, from five animals of each group from the large ear vein. Blood was collected in two dry, sterile test tubes, one of which was pretreated with heparin to prevent clotting. The hemoglobin content was determined by the hemoglobin cyanide method, the number of red blood cells was calculated using the Goryaev chamber, and white blood cells were calculated using the conductometric method. The leukocyte formula was evaluated by microscopy of blood smears previously stained by the Romanovsky-Giemsa method, followed by counting individual types of white blood cells (neutrophils, lymphocytes, monocytes, basophils, eosinophils). The total protein concentration was determined in the blood serum using a biuret reaction on a semi-automatic biochemical analyzer Rayto RT-1904c and the use of certified reagents produced by NPP Filisit-Diagnostics LLC. The content of albumins and globulin fractions (α -, β - and γ -globulins) was studied in accordance with the guidelines of the same manufacturer on an ULAB 102 spectrophotometer. glucose levels were determined by the glucose oxidase method using the rayto RT-1904c analyzer. The albumin-globulin coefficient was calculated as the ratio of the albumin concentration to the total content of globulin fractions.

The presence of stress in the body of piglets was also concluded on the basis of changes in clinical indicators. The heart rate was determined by palpation of the caudal artery, the frequency of respiratory movements – by visual observation of fluctuations in the abdominal wall with counting the number of respiratory movements per minute, and the body temperature was recorded using a rectal thermometer.

Statistical data analysis was performed using the licensed STATISTICA 10.0 program (StatSoft) for the Windows operating system. The student's t-criterion was used to compare the differences between the groups. The difference was considered statistically significant if $p < 0.05$.

Research results. Generalization of the values of changes in the morphological composition of blood indicates their intensive formation at the initial stage of the study, which coincides with the period of the most active increase in productivity in experimental animals. As the age of young animals increased, ambiguous changes were observed in the blood profile: an increase in some shaped elements or a decrease in others. At the same time, taking into account the stimulating effect of the studied drugs, the blood parameters remained at the level of the physiological norm (Table 1).

The most pronounced increase in blood saturation with shaped elements at the beginning of the experiment is inherent in young animals of Group III, which prevailed over peers of Group I in terms of red blood cell content by 8.4% ($p < 0.05$), white blood cells – by 3.4% and hemoglobin concentration – by 5.7% and individuals of Group II – by 3.5, 0.9 and 4.3%, respectively. This was due to increased hematopoietic function, better adaptive ability of their body to stress due to the use of an experimental drug, and higher growth rate. In animals that were given a standard stress reliever, compared to Group I analogues, the increase in these blood components was less significant: only by 4.8, 2.5 and 1.3%, respectively.

In the leukogram of the blood of young animals of the experimental groups, a decrease in the content of eosinophils by 16.7 and 22.2%, monocytes – by 9.1 and 33.3%, as well as an increase in the level of Rod neutrophils – by 4.8 and 9.5%, lymphocytes – by 8.2 and 5.7%, which indicates an improvement in the immune status of these animals and a decrease in the intensity of the non-specific immune response to stress, while an



increase in the content of eosinophils and monocytes in the structural spectrum of blood leukocytes Group I piglets are a typical response of the body to stress-induced activation of the immune system.

Table 1

Morphological composition of the blood of experimental young animals, (n=5),

$$\bar{x} \pm S_{\bar{x}}$$

Indicator	Group		
	I – control	II – experimental	III – experimental
At the beginning of the experiment			
Red blood cells, 10 ¹² /L	5,46±0,11	5,72±0,19	5,92±0,16*
White blood cells, 10 ⁹ /L	12,92±0,60	13,24±1,12	13,36±0,72
Hemoglobin, G/L	109,20±3,89	110,60±4,99	115,40±5,42
Leukocyte formula, %			
including: eosinophils	3,60±0,51	3,00±0,32	2,80±0,37
basophils	1,40±0,68	1,60±0,81	1,20±0,58
neutrophils: rod-shaped	4,20±0,58	4,40±0,51	4,60±0,51
segmentonuclear devices	39,40±3,19	39,40±4,30	37,80±2,82
lymphocytes	49,00±3,79	49,40±3,33	51,80±3,60
monocytes	2,40±0,51	2,20±0,58	1,80±0,37
At the end of the experiment			
Red blood cells, 10 ¹² /L	5,92±0,31	6,08±0,19	6,36±0,36
White blood cells, 10 ⁹ /L	12,56±0,69	12,68±0,51	12,94±0,65
Hemoglobin, G/L	120,20±5,70	123,20±5,67	127,60±5,52
Leukocyte formula, %			
including: eosinophils	3,20±0,58	2,80±0,37	2,60±0,40
basophils	1,20±0,73	1,80±0,92	1,80±0,80
neutrophils: rod-shaped	3,40±0,60	3,60±0,60	3,80±0,66
segmentonuclear devices	50,40±4,31	50,20±4,34	48,80±2,85
lymphocytes	38,20±3,75	38,40±3,04	40,80±2,85
monocytes	3,60±1,03	3,20±0,86	2,20±0,58

Note. **p*<0.05 – probability of difference relative to Group I

At the final stage of rearing young animals of the experimental groups, an increase in adaptive resistance to technological stress factors was noted, which probably made it impossible to obtain statistically significant differences in the morphological composition of blood between them and their peers of the control group. At the same time, compared with its onset, the content of red blood cells in the blood increased by 6.3–8.4%, and the concentration of hemoglobin – by 10.1–11.4%, and the leukocyte formula also changed in the direction of increasing the specific proportion of segmentonuclear neutrophils – by 27.4–29.1%, against the background of an increase in the content of monocytes – by 22.2–50.0%, which directly depended on the age characteristics of the formation of its cellular composition, but the values of other parameters, on the contrary, decreased.

The use of anti-stress drugs contributed to an additional increase in the number of red blood cells in the blood of animals of the experimental groups by 2.7 and 7.4%, leukocytes – by 1.0 and 3.0%, hemoglobin concentration – by 2.5 and 6.2%, the level of Rod neutrophils – by 11.8% in both cases of comparisons and lymphocytes – by 0.5 and



6.8% compared to analogues of the control group. At the same time, regardless of the group of animals, the content of segmentonuclear neutrophils prevailed over all forms of white blood cells in the leukogram. Less significant and statistically unlikely discrepancies in these indicators were between the analogues of groups III and II in favor of the former.

The content of total protein in the blood serum, the ratio between its fractions and the concentration of glucose became important indicators of the changes that occurred in the body of young animals (Table 2).

Table 2

Formation of biochemical parameters of blood serum, (n=5), $\bar{x} \pm S_{\bar{x}}$

Indicator	Group		
	I – control	II – experimental	III – experimental
At the beginning of the experiment			
Total Protein, G/L	65,20±0,39	68,50±0,29***	72,10±0,26***/aaa
Protein fractions, %:			
albumins	42,90±2,11	42,62±1,06	41,98±0,64
globulins	57,10±2,11	57,38±1,06	58,02±0,64
including: Alpha globulins	13,38±0,38	12,92±0,15	12,58±0,27
beta globulins	13,00±3,20	13,08±1,63	13,30±0,63
gamma globulins	30,72±1,41	31,28±1,20	32,14±1,37
A/G coefficient, units	0,75±0,06	0,74±0,03	0,72±0,02
Glucose, mmol/L	5,08±0,09	4,42±0,19*	4,15±0,22**
At the end of the experiment			
Total Protein, G/L	72,62±2,29	73,40±1,68	76,26±1,13
Protein fractions, %:			
albumins	44,12±0,65	44,06±0,11	43,42±0,30
globulins	55,88±0,65	55,94±0,11	56,58±0,30
including: Alpha globulins	13,10±0,07	12,82±0,09	12,00±0,07
beta globulins	13,74±0,18	13,86±0,05	14,48±0,27
gamma globulins	29,04±0,49	29,26±0,11	30,10±0,35
A/G coefficient, units	0,79±0,01	0,79±0,00	0,77±0,01
Glucose, mmol/L	6,28±0,52	5,74±0,44	5,55±0,68

Note. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ - probability of difference in relation to Group I; aaa $p < 0.001$ – in relation to Group II

Analyzing the obtained data on the content of these components, we also note that the features of their formation in the blood serum of animals of all groups had a similar direction of changes. At the same time, the use of experimental and standard anti-stress drugs already at the beginning of the research provided significant changes in the protein composition of blood serum, characterized by higher indicators of the content of globulins, and above all, the gamma-globulin fraction. Meanwhile, a positive reaction of the body of young animals of the experimental groups to the administration of drugs was also noted for the content of total protein in the blood serum, which was higher than in the peers of the control group by 5.1 and 10.6% ($p < 0.001$ in both cases of comparison).

At the same time, the use of an experimental drug with a distinctive effect on increasing the total protein content was also manifested in the peers of Group II and the



difference in their favor was 5.2% ($p < 0.001$). Similar advantages of experimental animals over control animals, but with insignificant and statistically unlikely fluctuations in values, were observed in the content of globulins by 0.5 and 1.6%, beta-globulin fractions – by 0.6 and 2.3%, and gamma-globulins – by 1.8 and 4.6%.

The use of anti-stress drugs led to a decrease in the concentration of glucose in the blood serum by 6.5% ($p < 0.05$) and 18.3% ($p < 0.01$), which indicates the normalization of carbohydrate metabolism aimed at meeting the needs of the body in conditions of technological stresses. On the other hand, a statistically significant increase in blood glucose levels in Group I young animals is probably a consequence of the body's response to these stress factors.

By the end of the experiment, the total protein content in the blood serum of experimental animals increased by 11.4, 7.2 and 5.8% ($p < 0.05$ in all cases of comparisons), which confirms the long-term positive effect of the drugs not only on reducing stress, but also improving protein metabolism. The protein level of the albumin fraction increased by 2.8, 3.4 and 3.5%, the beta-globulin fraction – by 5.7, 6.0 and 8.9%, and the glucose concentration – by 23.6%, 29.9 and 33.7%, respectively, in groups I, II and III. Despite the increase in glucose concentration during the experiment, its level remained lower in the experimental groups than in the control group, which may be a consequence of more effective assimilation against the background of the use of anti-stress drugs.

With an increase in the duration of the experiment, there was a decrease in the total level of globulins by 2.1, 2.5 and 2.5%, respectively, albumin fractions – by 2.1, 0.8 and 4.6%, gamma globulin fractions-by 5.5, 6.5 and 6.3%. The albumin-globulin coefficient in the blood of animals of all groups remained almost stable during the experiment and its values repeated the direction of albumin fluctuations, although in animals of Group I, its slight increase is due to the high content of the globulin fraction. Due to the nature of the detected changes, representatives of the II and III experimental groups exceeded the analogues of the I control group by 1.1 and 5.0%, the level of globulin fractions – by 0.1 and 1.3%, beta-globulin fractions – by 0.8 and 5.4%, and gamma-globulins – by 0.8 and 3.7%.

The next stage of the study was the determination of clinical indicators in young animals that characterize the functional state of the body's systems and allow us to assess the effectiveness of the use of anti-stress agents (Table. 3).

Table 3

Functional state of the experimental young animal's body, (n=5), $\bar{x} \pm S_{\bar{x}}$

Indicator	Group		
	I – control	II – experimental	III – experimental
At the beginning of the experiment			
Heart rate, beats/min	112,40±2,38	109,60±1,08	108,20±1,50
Respiratory rate, movements/min	37,80±0,86	37,40±0,51	37,00±0,77
Body temperature, °C	39,38±0,09	39,14±0,20	39,08±0,11
At the end of the experiment			
Heart rate, beats/min	107,40±2,04	105,40±1,81	103,80±1,69
Respiratory rate, movements/min	34,80±1,24	33,80±1,24	33,20±0,97
Body temperature, °C	39,15±0,06	39,04±0,22	38,88±0,12



The obtained research results convincingly indicate a positive effect of the anti-stress drugs used on the functional state of experimental animals, however, regardless of the group, it was at the level of the physiological norm. At the same time, at the beginning of the experiment in piglets of Group I, the respiratory rate was slightly accelerated by 0.4 and 0.8 movements/min or 1.1 and 2.2%, and the heart rate was higher – by 2.8 and 4.2 beats/min or 2.6 and 3.9%, compared with peers of groups II and III. At the same time, the body temperature was stable, and the difference between the control and experimental groups was only 0.24 and 0.30 °C or 0.6 and 0.8 %.

At the end of the experiment, a similar dynamics was observed: in piglets of Group I, the respiratory rate remained slightly higher by 1.0 and 1.6 movements/min or 1.8 and 4.5%, respectively, compared to individuals of groups II and III. In addition, there was a tendency to increase the heart rate by an average of 2.0 and 3.6 beats/min, or 1.9 and 3.5%. The lowest variability was characterized by body temperature, for which a clear intergroup difference was not proved, although its higher values are also inherent in young animals of Group I by 0.24 and 0.3 °C or 0.6 and 0.8%, compared to analogues of groups II and III.

As the experiment lengthened, the breathing rhythm in all experimental animals decreased by 3.0–3.8 movements/min or 7.9–10.0%, and the number of pulse beats decreased by 4.2–5.0 beats/min or 3.8–4.4%. The body temperature of experimental animals changed slightly during the experiment, maintaining a general tendency for all groups to decrease by 0.18–0.23 °C or 0.3–0.6%. The results obtained indicate a high level of adaptation of piglets of all groups to the effects of technological stresses.

The stability of the functional state of the body of young animals of experimental groups against the background of the use of anti-stress drugs both at the beginning and at the end of the experiment confirms their effectiveness in increasing the adaptive ability for the manifestation of technological stress factors.

Discussion. In modern conditions of pig breeding development, the problem of reducing the negative consequences of the impact of technological stress factors on the pig body is becoming a priority. Its solution is based on the introduction of a complex of interrelated approaches, among which an important place is occupied by pharmacological correction of the physiological state, optimization of feeding rations, selection on the basis of resistance to stress, as well as technological (improvement of conditions and parameters of maintenance, microclimate parameters, modernization of equipment, improvement of production processes).

The relationship between clinical and physiological parameters and stress resistance in pigs with the use of stress-correcting agents has been the subject of research by many scientists (Babenko S. P., & Cherniavskiy O. O., 2011; Hartnett P. et al., 2020; Martyshuk T. V. et al., 2021; Wang L. et al., 2023). At the same time, from a scientific and practical point of view, the use of our own approach, without reducing the significance of existing theoretical achievements, allowed us to reveal new aspects of the physiological role of these indicators in the formation of the adaptive ability of young pigs to the influence of technological stress factors.

Summarizing the accumulated experimental material, it was found that technological stress factors caused intergroup differences in the formation of the morpho-biochemical composition of blood, although these indicators were at the level of the physiological norm. The use of the experimental drug from the beginning of the experiment weakened the negative impact of stress factors on hematopoiesis function, contributing to an increase in the content of red blood cells by 8.4% ($p < 0.05$), white blood cells by 3.4 %, hemoglobin concentration – by 5.7% and Total Protein – 10.6% ($p < 0.001$), compared with the peers of the control group. In animals of the II experimental



group, which were administered a standard anti-stress drug, these indicators for animals of the III group changed less clearly – respectively by 3.5, 0.9, 4.3 and 5.2% in favor of the latter, which indicates different effectiveness of the studied drugs. At the end of the experiment, there was a tendency to increase the corresponding indicators in the blood of young animals of both experimental groups, which confirms their long-term positive effect on hematopoietic function. However, regardless of the group and time period of the experiment, fluctuations in the leukogram and albumin-globulin composition of the blood were less significant. Similar confirmations regarding the effect of stress-correcting drugs on the indicators of non-specific immunity and antioxidant protection of pigs are highlighted in the works (Stoianovsky V., 2012; Stoianovsky V. H., 2013; Antonenko P. P. et al., 2013; Fotina T. I., & Rebenko H. I., 2015).

At the same time, changes in physiological parameters demonstrate a natural response of young animals to the influence of technological stress factors. In particular, both at the beginning and end of the experiment, they were slightly higher in piglets of the control group with an increase in serum glucose concentration, which indicates a more pronounced stress response of the latter's body to the action of these factors. In addition, a likely increase in total protein content against the background of a likely decrease in serum glucose levels is probably associated with an increase in the intensity of growth of young animals and optimization of metabolic processes occurring against the background of a decrease in stress load. Reducing the action of catecholamines and corticosteroids normalizes the functional state of the liver, stimulating the synthetic activity of hepatocytes and increasing the concentration of protein fractions in blood plasma, mainly globulins. A simultaneous decrease in glucose levels may reflect an increased use of energy substrates for growth needs, i.e. more efficient absorption of glucose by cells with a stable energy supply. But there was no direct evidence of the implementation of this process in the literature available to us.

Conclusion.

The use of anti-stress drugs had a positive effect on the morphological composition of the blood and protein-carbohydrate metabolism. In experimental animals, a significant increase in the content of red blood cells, total protein and individual protein fractions, in particular beta - and gamma-globulins, was noted against the background of a decrease in glucose concentration, which indicates an increased adaptation of the body to technological stresses and stabilization of its functional state. At the same time, the experimental drug turned out to be the best.

References

- Antonenko, P. P., Semonov, O. V., Suslova, N. I., & Khalak, V. I. (2013). Profilaktyka stresiv u svynei ta pidvyshchennia yikh produktyvnosti za vplyvu fitopreparativ [Prevention of stress in pigs and increasing their productivity under the influence of phytopreparations] *Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Seriya: Veterynarna medytsyna*, 9(33), 80–83. Available at: <https://newlibrary.snau.edu.ua/bib/61862> (in Ukrainian).
- Babenko, S. P., & Cherniavskiy, O. O. (2011). Vplyv probiotyku ta fermentnoho preparatu na peretrvnist pozhyvnykh rehovyn u vidhodivelnoho molodniaku svynei [The effect of probiotics and enzyme preparations on nutrient digestibility in fattening young pigs] *Zbirnyk naukovykh prats Podilskoho derzhavnogo ahrarno-tekhnichnoho universytetu*, 19, 3–5. (in Ukrainian).
- Borotba z teplovyim stresom u svynei [Combating heat stress in pigs] *Trouw Nutrition* : veb-sait. 2025. (in Ukrainian). URL: https://www.trouwnutrition.ua/uk-ua/vydy-ta-sektory/svynomatka/heat_stress_pigs/



- Braun, Dzh. A., & Seddon, Yu. M. (2014). Hrupy chy partery: shcho kazhe nauka? [Groups or parties: what does science say?] *Nauka etolohii*, 1, 6. (in Ukrainian).
- Dovhii, Yu. Yu., & Feshchenko, D. V. (2018). Vyznachty stres-status [Determine stress status]. *Zdorovia tvaryn i liky*, 10, 19. (in Ukrainian).
- Fels, M., Hartung, J., & Hoy, S. (2014). Social hierarchy formation in piglets mixed in different group compositions after weaning. *Applied Animal Behaviour Science*, 152, 17–22. <https://doi.org/10.1016/j.applanim.2014.01.003>
- Fotina, T. I., & Rebenko, H. I. (2015). Vplyv preparativ na pokaznyky nespetsyficznego imunitetu ta antyoksydantnoho zakhystu porosiat v umovakh stresu pry vidluchenni [The effect of drugs on indicators of nonspecific immunity and antioxidant protection of piglets under stress conditions at weaning] *Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Serii: Veterynarna medytsyna*, 1(36), 181–186. (in Ukrainian).
- Harris, M. J., Pajor, E. A., Sorrells, A. D., Eicher, S. D., Richert, B. T., & Marchant, J. N. (2006). Effects of stall or small group gestation housing on the production, health and behaviour of gilts. *Livestock Science*, 102(1–2), 171–179. <https://doi.org/10.1016/j.livsci.2005.12.004>
- Hartnett, P., Boyle, L. A., & O'Driscoll, K. (2020). The effect of group composition and mineral supplementation during rearing on the behavior and welfare of replacement gilts. *Translational Animal Science*, 4(2), 1038–1050. <https://doi.org/10.1093/tas/txaa002>
- Koroban, M., Lykhach, V., Lykhach, A., Barkar, Ye., & Chernysh, S. (2023). Increasing the productivity of young pigs in the context of overcoming technological stress. *Animal Science and Food Technology*, 14(3), 47–60. <https://doi.org/10.31548/animal.3.2023.47>
- Kushnerenko, V. H. (2023). Vplyv stres faktoriv na yakist m'iasa tvaryn [The influence of stress factors on the quality of animal meat] *Tavriiskyi naukovyi visnyk. Silskohospodarski nauky. Kherson. derzh. ahrar.-ekon. un-t. Odesa: VD «Helvetyka»*, 31, 290–295. (in Ukrainian). <https://doi.org/10.32782/2226-0099.2023.131.35>
- Li, Y. Z., & Johnston, L. J. (2009). Behavior and performance of pigs previously housed in large groups. *Journal of Animal Science*, 87(4), 1472–1478. <https://doi.org/10.2527/jas.2008-1202>
- Lykhach, V. Ya., Lykhach, A. V., Faustov, R. V., Kucher, O. O. (2021). Suchasnyi stan ta tendentsii rozvytku suchasnoho svynarstva [Current status and development trends of modern pig farming] *Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Serii «Tvarynnytstvo»*, Sumy, 1(44), 69–79. (in Ukrainian). <https://doi.org/10.32845/bsnau.lvst.2021.1.10>
- Lykhach, V. Ya., Lykhach, A. V., Trybrat, R. O., & Faustov, R. V. (2020). Vplyv vidokremnenoho vyroshchuvannya molodniaku svynei z riznoi stresovoiu chutlyvisti na yoho produktyvni yakosti [The effect of separate rearing of young pigs with different stress sensitivity on their productive qualities] *Animal Science and Food Technology*, 11(1), 43–55. (in Ukrainian). <https://doi.org/10.31548/animal2020.01.043>
- Martin, J. E., Ison, S. H., & Baxter, E. M. (2015). The influence of neonatal environment on piglet play behaviour and post-weaning social and cognitive development. *Applied Animal Behaviour Science*, 163, 69–79. <https://doi.org/10.1016/j.applanim.2014.11.022>
- Martyshuk, T. V., Gutyj, B. V., & Khalak, V. I. (2021). System of antioxidant protection of the body of piglets under the action of feed additive “Butaselmavit-plus”.



- Ukrainian Journal of Veterinary and Agricultural Sciences*, 4(2), 38–43. <https://doi.org/10.32718/ujvas4-2.07>
- Minka, N. S., & Ayo, J. O. (2007). Physiological responses of transported goats treated with ascorbic acid during the hot-dry season. *Journal of Animal Science*, 78(2), 164–172. <https://doi.org/10.1111/j.1740-0929.2007.00421.x>
- Nielsen, S. S., Alvarez, J., Bicout, D. J., Calistri, P., Canali, E., Drewe, J. A., Garin-Bastuji, B., Gonzales Rojas, J. L., Gortázar Schmidt, C., Herskin, M., Michel, V., Miranda Chueca, M. A., Padalino, B., Roberts, H. C., Stahl, K., Velarde, A., Viltrop, A., Winckler, C., Edwards, S., Ivanova, S., Leeb, C., Wechsler, B., Fabris, C., Lima, E., Mosbach-Schulz, O., Van der Stede, Y., Vitali, M., & Spooler, H. (2022). Scientific Opinion on the welfare of pigs on farm. *EFSA Journal*, 20(8). Article 7421. <https://doi.org/10.2903/j.efsa.2022.7421>
- Gillman, C. E., Kilbride, A. L., Ossent, P., & Green, L. E. (2008). A cross-sectional study of the prevalence and associated risk factors for bursitis in weaner, grower and finisher pigs from 93 commercial farms in England. *Preventive Veterinary Medicine*, 83(3–4), 308–322. <https://doi.org/10.1016/j.prevetmed.2007.09.001>
- Rossi, R., Costa, A., Guarino, M., Laicini, F., Pastorelli, G., & Corino, C. (2008). Effect of group size-floor space allowance and floor type on growth performance and carcass characteristics of heavy pigs. *Journal of Swine Health and Production*, 16(6), 304–311. <https://doi.org/10.54846/jshap/577>
- Schröder-Petersen, D. L., & Simonsen, H. B. (2001). Tail biting in pigs. *Veterinary Journal*, 162(3), 196–210. <https://doi.org/10.1053/tvj.2001.0605>
- Stoianovskyi, V. (2012). Fiziolohichni stan orhanizmu porosiat za dii stresu u period vidluchky ta pry zastosuvanni probiotychnykh preparativ [Physiological state of piglets under stress during weaning and when using probiotics] *Silskyi hospodar*, 9–10, 5–8. (in Ukrainian).
- Stoianovskyi, V. H. (2013). Stan nespetsyfichnoi rezystentnosti orhanizmu porosiat za vplyvu tekhnolohichnoho stresu ta sposoby yoho korektsii pry vkluchenni v ratsion riznykh probiotychnykh preparativ [The state of nonspecific resistance of the piglet organism under the influence of technological stress and methods of its correction when including various probiotic preparations in the diet] *Naukovo-tekhnichnyi biuleten Derzhavnoho naukovo-doslidnoho instytutu vetpreparativ ta kormovykh dobavok*, 14(1–2), 418–422.
- Suprun, I. O. (2012). Henezys stresu silskohospodarskykh tvaryn. *Biolohiia tvaryn*, 14(1–2), S. 55–63. (in Ukrainian). <https://aminbiol.com.ua/index.php/ua/arkhiv?catid=1:2013-02-15-09-09-13&id=91:2013-03-06-13-43-07>
- Temple, D., Courboulay, V., Manteca, X., Velarde, A., & Dalmau, A. (2012). The welfare of growing pigs in five different production systems: assessment of feeding and housing. *Animal*, 6(4), 656–667. <https://doi.org/10.1017/S1751731111001868>
- Tokarchuk, T. S. (2017). Mekhanizmy zakhystu vid stresiv u porosiat v period vidluchennia [Mechanisms of protection against stress in piglets during weaning] *Teoriia i praktyka suchasnoi nauky : materialy II mizhnar. nauk.-prakt. konf.*, (m. Chernivtsi, 24-25 lyst. 2017 r.). Kherson: VD «Helvetyka». (in Ukrainian).
- Urrea, V. M., Bridi, A. M., Ceballos, M. C., Paranhos da Costa, M. J. R., & Faucitano, L. (2021). Behavior, blood stress indicators, skin lesions, and meat quality in pigs transported to slaughter at different loading densities. *Journal of Animal Science*, 99(6). Article skab119. <https://doi.org/10.1093/jas/skab119>
- Van de Perre, V., Driessen, B., Van Thielen, J., Verbeke, G., & Geers, R. (2011). Comparison of pig behaviour when given a sequence of enrichment objects or a



- chain continuously. *Animal Welfare*, 20(4), 641–649. <https://doi.org/10.1017/S0962728600003286>
- Van Staaveren, N., Calderón Díaz, J. A., Garcia Manzanilla, E., Hanlon, A., & Boyle L. A. (2018). Prevalence of welfare outcomes in the weaner and finisher stages of the production cycle on 31 Irish pig farms. *Irish Veterinary Journal*, 71. Article 9. <https://doi.org/10.1186/s13620-018-0121-5>
- Verdon, M., Hansen, C. F., Rault, J. L., Jongman, E., Hansen, L. U., Plush, K., & Hemsworth, P. H. (2015). Effects of group housing on sow welfare: a review. *Journal of Animal Science*, 93(5), 1999–2017. <https://doi.org/10.2527/jas.2014-8742>
- Wang, L., Wang, Ch., Peng, Y., Zhang, Y., Liu, Y., Liu, Y., & Yin, Y. (2023). Research progress on anti-stress nutrition strategies in swine. *Animal Nutrition*, 13,. P. 342–360. <https://doi.org/10.1016/j.aninu.2023.03.006>
- Yu, J., Yin, P., Liu, F., Cheng, G., Guo, K., Lu, A., Zhu, X., Luan, W., & Xu, J. (2010). Effect of heat stress on the porcine small intestine: A morphological and gene expression study. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 156(1), 119–128. <https://doi.org/10.1016/j.cbpa.2010.01.008>



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APPLICATION OF SUPPORT VECTOR REGRESSION (SVR) FOR IDENTIFICATION AND "REVERSE ENGINEERING" OF HIGH-PRODUCTIVITY ALLELIC COMBINATIONS IN CATTLE

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Traditional selection in cattle heavily relies on linear mixed models (BLUP), which are effective but limited in modeling non-linear genetic interactions (epistasis). Machine learning (ML) algorithms offer an alternative capable of detecting complex dependencies in genetic data. The aim of this work was to test the Support Vector Regression (SVR) methodology for predicting milk productivity and to develop a "reverse engineering" approach to identify optimal allelic combinations based on a limited and heterogeneous set of genetic markers.

The study was conducted on a sample of 81 Ukrainian Red-and-White dairy cows. Genotypes for 3 QTLs (PRL, LEP, TNF- α) were used, which were transformed into 12 binary features (One-Hot encoding). Milk yield (305 days) and fat content (kg) were used as target variables for building the SVR model. The target variable (milk yield) was standardized using StandardScaler. The model was trained using 5-fold cross-validation with hyperparameter tuning (GridSearchCV), comparing both non-shuffled and shuffled data splits. A synthetic "solution space" (54 combinations) was generated to identify "ideal" genotypes, which was then analyzed by the trained SVR model.

Three-way ANOVA did not reveal a statistically significant ($p < 0.05$) effect of the main factors (PRL, LEP, TNF- α) or their interactions on milk yield, although PRL showed a borderline trend ($p=0.055$). SVR models trained on non-shuffled data failed, yielding negative R^2 values (down to -0.066), indicating overfitting. However, the model using all 3 markers (12 features) combined with 5-fold cross-validation with shuffling (shuffle=True) achieved the best, albeit practically negligible, positive result ($R^2 = 0.0064$) using a non-linear 'rbf' kernel, with an estimated RMSE of ~ 790 kg. The "reverse engineering" approach identified hypothetical complex genotypes (Top 3: CC-CC-AD, CT-CC-AD, CC-CC-AB) with a predicted yield (up to 5173 kg) significantly higher than the herd average (4838 kg).

The study confirmed the methodological suitability of SVR for analyzing heterogeneous genetic data and "reverse engineering" selection goals, even on a critically small sample ($n=81$). The low R^2 values highlight that the primary limitation is the small sample size relative to the number of features, which prevents the model from capturing reliable predictive signals. This approach serves as a powerful analytical complement to traditional BLUP methods, providing a framework for identifying desirable "genetic formulas" for targeted selection once larger datasets become available.

Keywords: machine learning (ML), support vector regression (SVR), prediction, genetic markers, dairy cattle productivity.



ЗАСТОСУВАННЯ МЕТОДУ ОПОРНИХ ВЕКТОРІВ (SVR) ДЛЯ ІДЕНТИФІКАЦІЇ ТА "ЗВОРОТНОГО ІНЖИНІРИНГУ" ВИСОКОПРОДУКТИВНИХ АЛЕЛЬНИХ КОМБІНАЦІЙ У ВРХ

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Традиційна селекція ВРХ спирається на лінійні змішані моделі (BLUP), ефективні, але обмежені у врахуванні нелінійних генетичних взаємодій. Алгоритми машинного навчання (МН) дають змогу виявляти складні залежності у генетичних даних. Мета роботи — апробувати регресію опорних векторів (SVR) для прогнозування молочної продуктивності та розробити підхід «зворотного інжинірингу» для визначення оптимальних алельних комбінацій на основі обмеженого гетерогенного набору маркерів. Дослідження виконано на вибірці з 81 тварини української червоно-рябої молочної породи. Використано генотипи трьох QTL (PRL, LEP, TNF- α), перетворені у 12 бінарних ознак (One-Hot encoding). Цільова змінна — надій за 305 днів. Дані поділено на тренувальний (80%) і тестовий (20%) набори, масштабування проведено за допомогою StandardScaler. Модель SVR навчали з 5-кратною перехресною валідацією та налаштуванням гіперпараметрів (GridSearchCV), порівнюючи перетасовані й неперетасовані дані. Для пошуку оптимальних генотипів створено синтетичний «простір рішень» (54 комбінації), проаналізований навченою моделлю SVR.

Трифакторний ANOVA не виявив статистично значущого впливу факторів (PRL, LEP, TNF- α) або їх взаємодій на надій ($p < 0,05$), хоча для PRL відзначено пограничну тенденцію ($p = 0,055$). Моделі SVR на неперетасованих даних показали від'ємні R^2 (до $-0,066$), що свідчить про перенавчання. Натомість модель з усіма трьома маркерами (12 ознак) і 5-кратною перехресною валідацією з перетасуванням ($shuffle=True$) досягла найкращого, хоч і незначного, результату ($R^2 = 0,0064$; $RMSE \approx 790$ кг) з ядром «rbf». Підхід «зворотного інжинірингу» визначив потенційно оптимальні генотипи (Топ-3: CC-CC-AD, CT-CC-AD, CC-CC-AB) з прогнозованим надоєм до 5173 кг, що перевищує середній рівень по стаду (4838 кг).

Дослідження підтвердило методологічну придатність SVR для аналізу гетерогенних генетичних даних та цілей відбору за допомогою «зворотної інженерії», навіть на критично малій вибірці ($n=81$). Низькі значення R^2 підкреслюють, що основним обмеженням є малий розмір вибірки відносно кількості ознак, що заважає моделі фіксувати надійні прогностичні сигнали. Цей підхід служить потужним аналітичним доповненням до традиційних методів BLUP, забезпечуючи основу для визначення бажаних «генетичних формул» для цілеспрямованого відбору, коли стануть доступними більші набори даних.

Ключові слова: машинне навчання (МН), метод опорних векторів (SVR), прогнозування, генетичні маркери, молочна продуктивність корів

Introduction. The estimation of animal breeding values (EBV) forms the basis of modern selection. For decades, BLUP (Best Linear Unbiased Prediction) models and their genomic modifications (GBLUP, ssGBLUP) have remained the recognized standard in the field (Chafai et al., 2023). These methods are linear mixed models that effectively account for additive genetic variation using relationship (A) or genomic (G) matrices.

However, quantitative traits such as milk productivity are the result of complex biological processes involving non-additive genetic effects, particularly dominance and



epistasis (gene-gene interactions) (Mackay TF, 2014). Linear BLUP models account for epistasis only indirectly, and its explicit inclusion in prediction remains a complex task (Alves K et al., 2023).

In parallel, alternative approaches based on machine learning (ML) algorithms are being developed, such as Support Vector Regression (SVR), Random Forest (RF), Gradient Boosting Machines (GBM), and neural networks (Azodi et al., 2019, Mendoza et al., 2019). The key advantage of these methods is their ability to model complex, non-linear interactions directly from the data (Pérez-Enciso et al., 2019). This is particularly relevant for populations with limited or heterogeneous genomic information (e.g., when using data of different types – immunogenetic, microsatellite, SNP).

Unlike BLUP, ML models can serve as a complementary prediction system that focuses exclusively on the direct "marker → phenotype" relationship, eliminating the need for complex relationship matrices.

Current research extends beyond predicting the phenotype based on a known genotype ($G \rightarrow P$). Rather, of particular interest is the "reverse engineering" of genetic data (Rockman, 2008; Choi et al., 2024). This approach treats a trained machine learning (ML) model as a powerful computational simulator (Liu et al., 2025). It allows for *in silico* resolution of the inverse problem ($P \rightarrow G$): "What allelic combination (G) is necessary to achieve a target productivity level (P)?" (Cavallaro et al., 2024)..

Today, thanks to the development of molecular technologies, a significant amount of data on the polymorphism of key QTL loci and their associations with economically valuable traits has been accumulated. This has become the basis for the active implementation of marker-assisted selection (MAS). For certain cattle breeds, comprehensive model genotypes, so-called "desirable genotype formulas," have already been developed, reflecting optimal allelic combinations for individual candidate genes (e.g., *CSN3*, *DGATI*, *LEP*, *GH*, *PIT-1*, etc.) (Kopylov et al., 2015; Berezovskyi et al., 2015, Kopylov et al., 2016; Hladiy et al., 2018, Ivashchenko, 2023).

However, this approach has a fundamental limitation. In modern domestic and global practice, research mostly focuses on individual loci, while the analysis of complex genotypes (haplotypes) and their combined effect on productivity is almost never carried out. Instead, desirable genotypes of individual loci are usually mechanically combined into "formulas" that are actually based on an additive model—an assumption that the overall effect is a simple sum of the contributions of individual genes.

Such an approach deliberately ignores epistasis—complex non-linear interactions between different genes. Quantitative traits, including milk productivity, are polygenic in nature, and their phenotypic expression is determined not so much by the presence of individual "favorable" alleles as by their harmonious combination. The "optimal" allele of one gene may prove to be ineffective or even unfavorable in combination with a specific allele of another gene.

This is why the use of machine learning (ML) methods in this context is extremely promising. Traditional linear models have limitations, whereas ML algorithms like SVR or Random Forest can detect hidden non-linear relationships in complex datasets. They view the genotype as a comprehensive system, making it possible to account for epistatic effects. This enables a transition from the additive summation of markers to the identification of synergistic allelic combinations (haplotypes) that underlie the highest productivity.

The SVR algorithm is particularly attractive in this context. Unlike, for example, neural networks, which require massive amounts of data, SVR demonstrates high efficiency on relatively small samples (Vapnik, 1995). This is achieved through the "kernel trick," which allows the model to find non-linear dependencies in a high-



dimensional feature space without explicitly computing these complex interactions. Specifically, the Radial Basis Function (RBF) kernel, chosen for this study, is capable of modeling complex epistatic effects, making it an ideal candidate for analyzing polygenic traits on limited datasets (González-Recio et al., 2011).

The aim of this study was (1) to test the Support Vector Regression (SVR) methodology for predicting dairy cattle productivity and (2) to develop and test a "reverse engineering" approach to identify hypothetical high-productivity allelic combinations based on a limited set of heterogeneous genetic data.

Materials and methods. 1. *Sample and Phenotype Characteristics.* The study was conducted on a sample of cows ($n=81$) from the Ukrainian Red-and-White dairy breed population (State Enterprise Experimental Farm "Gontarivka," Kharkiv region). Data on milk yield for the first lactation (305 days) and fat content (kg) were used as the target traits (phenotypes). Descriptive statistics for the milk yield trait were: $X_{\text{Mean}}=4838\pm 91,5$ kg, $X_{\text{Max}}=7093$ kg, $X_{\text{Min}}=2592$ kg.

1. *Genotyping and Data Preparation.* Animals were genotyped using heterogeneous marker systems based on functional QTLs: prolactin (PRL, exon 4, 35106206C>T), leptin (LEP, exon 2, 73C>T), and tumor necrosis factor-alpha (TNF- α , exon 2, SSCP analysis).

To unify the data, the "One-Hot encoding" approach was applied. Each detected genotype (12 variants in total: PRL (3), LEP (3), TNF- α (6)) was converted into a separate binary feature (column), where 1 indicated the animal's possession of the allele and 0 indicated its absence. Thus, an initial feature matrix (X) with dimensions of 81 animals \times 12 features (markers) was formed.

2. *Statistical Analysis (ANOVA).* To preliminarily assess the associative links between individual genotypes (PRL, LEP, TNF) and milk yield ('Milk'), an analysis of variance (ANOVA) was performed. The analysis was carried out in the Python environment using the `ols` (Ordinary Least Squares) function from the `statsmodels.formula.api` library.

Both single-factor models (e.g., Milk \sim C(PRL)) and multi-factor models considering interactions (e.g., Milk \sim C(PRL) * C(LEP) and Milk \sim C(PRL) * C(LEP) * C(TNF)) were evaluated. The statistical significance of the effect of each factor and their interactions was determined using the F-test (using ANOVA Type II).

3. *SVR Modeling.* The Python programming language and the Scikit-learn library were used for the analysis (Pedregosa et al., 2011).

1) *Sample Formation:* The feature matrix (X, 81 \times 12) and the target variable vector (y, 81 \times 1, milk yield) were split into training (80% of data) and testing (20% of data) sets.

2) *Data Scaling:* As SVR is sensitive to scaling, the target variable (Y, milk yield) was standardized (StandardScaler) to a zero mean and unit variance. The feature matrix (X), consisting of binary data (0/1) after encoding, was not scaled.

3) *Model Training:* A Support Vector Regression (SVR) model was used. To find non-linear dependencies, the Radial Basis Function (RBF) kernel (kernel='rbf') was chosen, and the standard linear kernel (kernel='linear') was also tested for comparison.

Model optimization was conducted for two key hyperparameters:

- c (Regularization parameter): Controls the trade-off between minimizing the error on the training data and maximizing the margin. Low c values allow for a larger error (a softer margin), which prevents overfitting, whereas high c values attempt to minimize the error, risking overfitting.



- **epsilon (ϵ -insensitive zone):** Defines the width of the "tube" within which prediction errors are not penalized. This parameter allows the model to ignore minor "noise" in the data.

Optimal hyperparameters (C, epsilon, and kernel type) were automatically selected using an exhaustive Grid Search (`GridSearchCV`) with 5-fold cross-validation on the training set.

4) *Accuracy Assessment:* The predictive ability of the final model was evaluated on the test set (20% of data the model had not seen during training) using the coefficient of determination (R^2) and the Root Mean Squared Error (RMSE).

- **R^2 (Coefficient of Determination):** A metric showing the proportion (from 0 to 1) of the variance in the target variable that the model can explain. It is particularly important that R^2 can be negative ($R^2 < 0$) if the model performs worse than simple data averaging, which is a clear indicator of model non-viability.

- **RMSE (Root Mean Squared Error):** An absolute error measure expressed in the units of the target variable (in our case, kg of milk). It shows how much, on average, the model's predictions deviate from the actual values and is more interpretable than R^2 for assessing the practical magnitude of the error.

5 "Reverse Engineering" Methodology. After training and validation, the SVR model was used for "reverse engineering."

1) *Solution Space Creation:* Based on the 12 selected markers, a complete solution space was generated—a synthetic matrix `X_synth` containing all possible unique combinations of these alleles. The total volume of hypothetical genotypes was 54 ($3 \times 3 \times 6$) combinations.

2) *Hypothesis Prediction:* The trained SVR model (`model.predict(X_synth)`) was applied to each of the 54 hypothetical combinations to predict the *scaled* milk yield.

3) *Inverse Transformation:* The resulting predictions were returned to their original scale (kg) using an inverse transformation (`scaler_y.inverse_transform`), allowing absolute milk yield values to be obtained.

4) *Identification:* The obtained predictions were sorted in descending order to identify the TOP-10 best allelic combinations corresponding to the maximum predicted productivity.

Data processing and machine learning model construction were performed using the Google Colaboratory (Colab) cloud service.

Research results. Prior to building predictive machine learning models, an analysis of variance (ANOVA) was conducted to assess the presence of statistically significant associations between the genotypes of individual loci (PRL, LEP, TNF- α) and the target trait – milk yield for 305 days in the first lactation.

To evaluate not only individual effects but also possible epistatic interactions between loci, a three-way analysis of variance was performed. The analysis results (Table 1) indicate the absence of a statistically significant ($p < 0.05$) effect on milk yield for any of the three markers taken individually, as well as for factor interactions. The prolactin (PRL) locus showed a trend towards an association ($p=0.055$), but it did not reach the established significance level. The absence of strong linear associations indicates the difficulty of predicting this trait and justifies the need to apply more flexible non-linear machine learning methods like SVR.

For building the predictive models, SVR was used. The genotypes were transformed using One-Hot Encoding, resulting in a model with 6 features for 2 markers (PRL+LEP) and 12 features for 3 markers (PRL+LEP+TNF- α).



Table 1

Results of the three-way analysis of variance (ANOVA) of the influence of genotypes (*PRL*, *LEP*, *TNF-α*) on the milk yield of Ukrainian Red-and-White dairy cattle

Source of Variation	df	SS	MS	F	p
C(<i>PRL</i>)	2.0	5.287718e+06	2.64e+06	3.814	0.055
C(<i>LEP</i>)	2.0	2.803068e+05	1.40e+05	0.202	0.654
C(<i>TNF</i>)	5.0	4.461275e+06	8.92e+05	1.038	0.362
C(<i>PRL</i>):C(<i>LEP</i>)	4.0	5.585413e+05	1.40e+05	0.163	0.689
C(<i>PRL</i>):C(<i>TNF</i>)	10.0	3.024966e+06	3.02e+05	0.352	0.878
C(<i>LEP</i>):C(<i>TNF</i>)	10.0	5.055151e+06	5.06e+05	0.588	0.709
C(<i>PRL</i>):C(<i>LEP</i>):C(<i>TNF</i>)	20.0	7.549629e+06	3.77e+05	0.440	0.930
Residual	46.0	3.952052e+07	NaN	NaN	NaN

Notes. Residual - residuals, SS - sum of squares, MS - mean square, F - F-statistic, p - significance level.

Due to the extremely limited sample size (n=81), a 5-fold cross-validation method was used for objective model quality assessment. This method involves dividing the 81 observations into 5 equal parts ("folds"), approx. 16-17 animals each. The process is repeated 5 times: the model is trained on 4 parts (≈65 animals) and checks its accuracy (calculates R² and RMSE) on the 1 part (≈16 animals) it has "not seen." The final R² (or RMSE) score is the averaged value of these 5 separate tests. This provides a much more reliable estimate than a single 80/20 split.

Furthermore, we compared two cross-validation approaches:

1. Without shuffling (`shuffle=False`): Data is split sequentially. This can lead to a biased estimate if the data has a hidden order.
2. With shuffling (`shuffle=True`): Data is randomly permuted before being split into 5 folds. This creates more "truthful" and representative folds.

The impact of the cross-validation method proved critical for correct model evaluation. As shown below, models tested without shuffling (`shuffle=False`) demonstrated worse and less stable R² results than models tested with shuffling (`shuffle=True`), which provided more representative test folds.

Scenario 1: SVR Model (*PRL* + *LEP*)

When using the SVR model with two markers (*PRL* and *LEP*, 6 input features), the cross-validation results were unsatisfactory (Table 2).

Table 2

Comparison of SVR results for Scenario 1 (*PRL*+*LEP*)

Validation Method	Best R ²	RMSE (kg)	Best Hyperparameters
No Shuffle (<code>shuffle=False</code>)	-0.066	≈809	{'C': 0.1, 'epsilon': 0.01, 'kernel': 'rbf'}
With Shuffle (<code>shuffle=True</code>)	0.0037	≈793	{'C': 0.1, 'epsilon': 0.5, 'kernel': 'linear'}

In the first case (no shuffle), the R² is negative, indicating complete model non-viability. This is likely because the sequential data split led to unrepresentative test samples. Applying shuffling (`shuffle=True`) stabilized the evaluation, allowing a weak but positive R² = 0.0037 (0.4% of variance explained) to be obtained. Interestingly,



GridSearchCV selected the `kernel='linear'` as optimal here, suggesting the model could not find useful non-linear dependency and the simple linear combination was slightly more robust against overfitting.

Scenario 2: SVR Model (PRL + LEP + TNF- α)

Adding the third marker (*TNF- α*), which increased the input features to 12, also demonstrated the benefits of shuffling (Table 3).

Table 3

Comparison of SVR results for Scenario 2 (PRL+LEP+TNF- α)

Validation Method	Best R ²	RMSE (kg)	Best Hyperparameters
No Shuffle (shuffle=False)	-0.032	≈795	{'C': 0.1, 'epsilon': 0.01, 'kernel': 'linear'}
With Shuffle (shuffle=True)	0.0064	≈790	{'C': 0.1, 'epsilon': 0.01, 'kernel': 'rbf'}

Similar to scenario 1, the non-shuffled model showed a negative R² (-0.032). However, when applying shuffling, the model achieved the best score of all tested variants: R² = 0.0064.

It is important to note that in this case (with 12 features), GridSearchCV selected the non-linear `kernel='rbf'`. This suggests that adding the *TNF- α* marker allowed the model to capture an extremely weak, but statistically fixed, non-linear interaction between the markers, which neither the 2-factor model nor the classic ANOVA could detect.

Based on this best (though still very weak) SVR model (Scenario 2, shuffled, R²=0.0064), 54 hypothetical genotype combinations (3 *PRL* × 3 *LEP* × 6 *TNF- α*) were generated, and milk yield was predicted for each. The top 10 combinations with the highest predicted yield are presented in Table 4.

Table 4

The best hypothetical complex genotypes according to SVR prediction (R²=0.0064)

№	<i>PRL</i>	<i>LEP</i>	<i>TNF-α</i>	Milk yield (305 days), kg
1	CC	CC	AD	5173.2
2	CT	CC	AD	5139.7
3	CC	CC	AB	5057.8
4	CT	CC	AB	5035.9
5	CC	CT	AD	5022.0
6	CC	CC	AA	5013.6
7	TT	CC	AD	4988.0
8	CC	CT	AB	4964.9
9	CT	CC	AA	4940.0
10	CC	CC	AC	4929.1

The analysis shows that the model favors combinations containing the *PRL*-CC genotype (6 of the top 10), *LEP*-CC (8 of the top 10), and *TNF*-AD (4 of the top 10).

Discussion. The SVR modeling results are fully consistent with the preliminary ANOVA data (Table 1). ANOVA did not reveal a statistically significant linear relationship between the studied markers and milk yield, which explains why the



predictive models built on the same data demonstrated an extremely low coefficient of determination (R^2). In essence, the machine learning models confirmed the ANOVA conclusion: in this sample ($n=81$), there is no strong predictive signal associated with the *PRL*, *LEP*, and *TNF- α* loci.

The study demonstrated the successful application of the SVR algorithm for working with heterogeneous genetic data (QTLs) under small sample size conditions. The key result is not so much the absolute prediction accuracy (which is expectedly low due to the $N=81$ to $p=12$ ratio) but the successful implementation of the "reverse engineering" methodology. Unlike traditional estimation, which provides a forecast for existing animals, our approach allowed us to generate an "ideal genetic formula" – a selection goal that can be pursued through targeted fixation of desired alleles.

The use of the non-linear 'rbf' kernel in SVR potentially allowed the model to account for epistatic interactions between the 12 selected markers. It is likely that the high predicted yield of the TOP genotypes (Table 4) is due precisely to a successful combination of alleles, and not just their additive sum effect, which BLUP would estimate.

The study also highlighted the key challenges of working with small-sample biological data. Although classic ANOVA found no significant associations ($p>0.05$), applying SVR with shuffling (`shuffle=True`) allowed for a minimal positive $R^2 = 0.0064$ (Scenario 2). This indicates that adding the *TNF- α* marker and using the 'rbf' kernel allowed the model to capture an extremely weak non-linear dependency that ANOVA could not detect.

However, an $R^2 = 0.0064$ means the model explains only about 0.6% (not 1%) of the milk yield variance. The calculated RMSE for this model was ~790 kg (with a data standard deviation $\sigma=818$ kg). This indicates that, despite the positive R^2 , the model has no practical predictive value for selection.

The main reason for the low efficiency is the insufficient sample size ($n=81$). When we encode 3 markers, we get 12 input features. Training a model on 12 features with only 81 observations leads to the "curse of dimensionality" and severe overfitting, which we observed as negative R^2 values in most scenarios.

To improve the prediction, it is necessary to:

1. Significantly increase the sample size (to several hundred or thousand animals).
2. Include additional markers that have a proven strong association with the trait.
3. Include non-genetic factors (parity, calving season, feeding level) as additional features in the model.

Furthermore, it is worth noting that although Random Forest is often considered a more powerful algorithm, in parallel experiments (data not shown) on this same sample, it showed significantly worse results ($R^2 \approx -0.10$ to -0.23). This indicates its stronger tendency to overfit on such a feature-to-observation ratio (12 to 81). This underscores the advantage of SVR (especially with regularization-promoting parameters like $C=0.1$) specifically in critically small sample conditions.

This study is primarily an important validation of the methodology for applying machine learning (SVR) for analyzing genetic data in animal husbandry. It clearly demonstrated the importance of correct model evaluation, particularly the use of cross-validation with shuffling (`shuffle=True`), to obtain reliable results on small samples.

It was shown that a negative R^2 (as in the non-shuffled scenario) is just as important a result as a positive one, as it clearly indicates the model's non-viability and prevents false conclusions that could be drawn from an inflated R^2 on the training set.

Although the current models have no practical predictive value, the developed algorithm (feature encoding, hyperparameter tuning, R^2 /RMSE evaluation) provides a



basis for further analysis on expanded datasets. The ML approach should be considered a powerful analytical tool that complements the traditional BLUP system. It provides a new methodological basis for identifying rare but high-productivity allelic combinations and for the operational management of the genetic fund.

Conclusions:

1. The Support Vector Regression (SVR) methodology confirmed its suitability for processing and modeling heterogeneous genetic data.
2. Multi-factor analysis of variance (ANOVA) did not reveal a statistically significant ($p < 0.05$) influence of the genotypes of the *PRL*, *LEP*, *TNF- α* loci, or their interactions, on the milk yield level in the studied sample of 81 animals.
3. Building SVR predictive models on a small number of observations ($n=81$) showed low efficiency. Models tested without data shuffling (`shuffle=False`) demonstrated negative R^2 (down to -0.066), indicating overfitting and lower accuracy than a simple mean model.
4. Applying cross-validation with shuffling (`shuffle=True`) stabilized the SVR model evaluation (*PRL+LEP+TNF- α*), allowing the best (though practically insignificant) result of $R^2 = 0.0064$ to be achieved with a non-linear 'rbf' kernel.
5. The proposed "reverse engineering" approach successfully identified hypothetical genotypes with high predicted productivity; however, the best model's average error (RMSE) is ~ 790 kg, confirming its low predictive value for practical selection.
6. The insufficient sample size ($n=81$) relative to the number of input features ($n=12$) is the main limiting factor for building a reliable predictive model.
7. Further research requires a substantial increase in sample size and the testing of more complex ML algorithms (Random Forest, XGBoost) to improve prediction accuracy.

References

- Alves K, Brito LF, Schenkel FS. (2023). Genomic prediction of fertility and calving traits in Holstein cattle based on models including epistatic genetic effects. *J Anim Breed Genet.* Sep;140(5):568-581. <https://doi.org/10.1111/jbg.12810>.
- Azodi CB, Bolger E, McCarren A, Roantree M, de Los Campos G, Shiu SH. (2019). Benchmarking Parametric and Machine Learning Models for Genomic Prediction of Complex Traits. *G3 (Bethesda).* Nov 5;9(11):3691-3702. <https://doi.org/10.1534/g3.119.400498>.
- Berezovskyi, O. V., Yu. P. Polupan, S. Yu. Ruban, & Kopylov K. V. (2015). Zv'iazok polimorfizmu za henamy κ -CN, TG5, LEP z molochnoiu produktyvnistiu koriv ukrains-kykh molochnykh pored [The connection of polymorphism to the κ -CN, TG5, LEP genes with the milk yield of cows of Ukrainian breeds]. Rozvedennya i henetyka tvaryn: mizhdvidomchyy tematychnyy zbirnyk –Animal Breeding and Genetics: interdepartmental thematic scientific collection. Kyiv, 49:154-164 (in Ukrainian)
- Bergstra J., Komer B., Eliasmith C. et al. (2015). Hyperopt: a Python library for model selection and hyperparameter optimization. *Comput. Sci. Discov.* 8:014008. <https://doi.org/10.1088/1749-4699/8/1/014008>.
- Cavallaro, C Cutello, V, Pavone, M & Zito, F. (2024). Machine Learning and Genetic Algorithms: A case study on image reconstruction. *Knowledge-Based Systems* 284 (111194). <https://doi.org/10.1016/j.knosys.2023.111194>.
- Chafai, N., Hayah, I., Houaga, I., Badaoui, B. (2023). A review of machine learning models applied to genomic prediction in animal breeding. *Frontiers in Genetics*, 14:1150596. <https://doi.org/10.3389/fgene.2023.1150596>.



- González-Recio, O., Forni, S. (2011). Genome-wide prediction of discrete traits using bayesian regressions and machine learning. *Genet Sel Evol*, 43, 7. <https://doi.org/10.1186/1297-9686-43-7>.
- Hladiy, M. V., Polupan, Y. P., Kovtun, S. I., Kuzebnij, S. V., Vyshnevskiy, L. V., Kopylov, K. V., & Shcherbak O. V. (2018). Scientific and organizational aspects of generation, genetics, reproduction biotechnology and protection of the genofonds in livestock breeding. *Animal Breeding and Genetics*, 56, 5-14. <https://doi.org/10.31073/abg.56.01>
- Ivashchenko O. Yu. (2023). Henetychne riznomanittia populiatsii velykoi rohatoi khudoby za asotsiiovanymy z rezystentnistiu DNK-markeramy [Genetic diversity of cattle populations by resistance-associated DNA markers]: avtoreferat dys. ... d.filosof : 204 / O. Yu. Ivashchenko. — B.m., https://nubip.edu.ua/sites/default/files/u145/dis_ivashchenko.pdf (in Ukrainian).
- Junhwa Choi, Sunghyun Cho, Subin Choi, Myunghee Jung, Yu-jin Lim, Eunhae Lee, Jaewon Lim, Han Yong Park & Younhee Shin. (2024). Genotype-Driven Phenotype Prediction in Onion Breeding: Machine Learning Models for Enhanced Bulb Weight Selection. *Agriculture* 14, 2239. <https://doi.org/10.3390/agriculture14122239>.
- Kopylov, K. V., O. D. Biriukova, O. V. Berezovskyi, & Basovskyi D. M. (2015). Henetychnyi monitorynh v stadi ukrainskoi chervono-riaboi molochnoi porody za kompleksom heniv [Genetic monitoring in a herd of Ukrainian red-billed milk breed in a complex of genes]. *Tekhnolohiya vyrobnytstva i pererobky produktsiyi tvarynnytstva - Technology of production and processing of livestock products*. Bila Tserkva. 1(116):28-31 (in Ukrainian).
- Kopylov, K. V., O. I. Metlytska, N. B. Mokhnachova, & Suprovych T. M. (2016). Molekuliarno-henetychnyi monitorynh v systemi zberezhenia henetychnykh resursiv tvaryn [Molecular genetic monitoring in the system of conservation of genetic resources of animals]. *Visnyk aharnoi nauky- Bulletin of Agricultural Science*. 6:43-47 (in Ukrainian)
- Liu, M., Gao, Z., Chang, H., Li, S. Z., Shan, S., & Chen, X. (2025). G2PDiffusion: Cross-Species Genotype-to-Phenotype Prediction via Evolutionary Diffusion. arXiv preprint arXiv:2502.04684.
- Mackay, T. F. (2014). Epistasis and quantitative traits: using model organisms to study gene-gene interactions. *Nat Rev Genet*. Jan; 15(1):22-33. <https://doi.org/10.1038/nrg3627>.
- Mendoza H., Klein A., Feurer M. et al. (2019). Towards automatically tuned deep neural networks. In: Hutter F. et al. (eds) *Automated Machine Learning*. Springer, Cham, pp. 135–149.
- Pedregosa F, Varoquaux G, Gramfort A et al (2011). Scikit-learn: machine learning in python. *J Mach Learn Res* 12:2825–2830.
- Pérez-Enciso, M.; Zingaretti, L.M. (2019). A Guide on Deep Learning for Complex Trait Genomic Prediction. *Genes*, 10, 553. <https://doi.org/10.3390/genes10070553>.
- Rockman, M. (2008). Reverse engineering the genotype–phenotype map with natural genetic variation. *Nature* 456, 738–744. <https://doi.org/10.1038/nature07633>.
- Vapnik, V. N. (1995). *The Nature of Statistical Learning Theory*. Springer, New York. <http://dx.doi.org/10.1007/978-1-4757-2440-0>.
- Wang, X., Shi, S., Wang, G. et al. (2022). Using machine learning to improve the accuracy of genomic prediction of reproduction traits in pigs. *Journal of Animal Science and Biotechnology*, 13:60. <https://doi.org/10.1186/s40104-022-00708-0>.



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ENERGY EFFICIENCY OF PRODUCTION OF CATTLE BREEDING PRODUCTS OF HIGH-CAPACITY ENTERPRISES WITHIN THE FRAMEWORK OF THE SIMULATION MODEL PARAMETER SYSTEM

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The results of generalized data on various technologies of large-scale enterprises with milk production volumes (more than 40 thousand c/year) and a cow population of more than 500 heads are presented. Various milking technologies with milk productivity of cows up to 6000 kg, from 6000 kg to 7000 kg and more than 7000 kg of milk per cow are analyzed, options for using additional technical means for preparing and distributing Feed, distribution of cows according to feeding technologies – the ratio correlates with the system of maintenance, but the type of feeding also depends more on the feed supply sector, on this basis the elements of production technologies (milk, beef from culled cattle, increase in live weight of animals on cultivation, fattening) are justified, which are characteristic of the rational organization of the process.

The created simulation model of production of cattle products within certain parameters of enterprises of large production capacity is applied – with the number of cattle 2500-3200 heads, (600-1000 cows with a capacity of 7000-9000 kg per cow and the fat content of milk 3.8-4.1 %).

The structure of the energy content of products by type is determined and given - milk, live weight of culled animals, growth of raised livestock, obtained offspring, taking into account the energy content of excrement and litter. It is proved that the largest share in the structure of the energy content of products suitable for nutrition belongs to the energy content of produced milk – 76.1–84.4 %, In relation to this most influential factor on the coefficients of energy efficiency of the main and total production, the functional dependences of the energy content of products on fat in milk and the relationship between the coefficients of energy content of products and milk fat are determined. The determination of annual total energy costs for the production of cattle products is carried out taking into account the logistics component of the technological process.

Keywords: energy consumption, energy efficiency, technology parameters, productivity, product quality.



ЕНЕРГОЕФЕКТИВНІСТЬ ВИРОБНИЦТВА ПРОДУКЦІЇ СКОТАРСТВА ПІДПРИЄМСТВ ВЕЛИКОЇ ПОТУЖНОСТІ В МЕЖАХ СИСТЕМИ ПАРАМЕТРІВ ІМІТАЦІЙНОЇ МОДЕЛІ

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Представлені результати узагальнених даних різних технологій великотоварних підприємств з обсягами виробництва молока (більше 40 тис. ц/рік) і поголів'ям корів більше 500 голів. Проаналізовано різні технології доїння із молочною продуктивністю корів до 6000 кг, від 6000 кг до 7000 кг і більше 7000 кг молока на корову, варіанти застосування додаткових технічних засобів з підготовки та роздавання кормів, розподіл корів за технологіями годівлі – співвідношення корелює із системою утримання, але тип годівлі більше залежить також від сектору кормозабезпечення, На цій основі обґрунтовані елементи технологій виробництва продукції (молока, яловичини від вибракуваної худоби, приросту живої маси тварин на вирощуванні, відгодівлі), що властиві раціональній організації процесу.

Застосовано створену імітаційну модель виробництва продукції скотарства в межах визначених параметрів підприємств великої виробничої потужності – з чисельністю поголів'я великої рогатої худоби 2500-3200 голів, (600-1000 корів із продуктивністю 7000-9000 кг на корову і вмістом жиру молока 3,8-4,1 %).

Визначено і наведено структуру енерговмісту продукції за видами - молоко, жива маса вибракуваних тварин, приріст худоби, що вирощуються, отриманого приплоду з урахуванням енерговмісту екскрементів і підстилки. Доведено, що найбільша частка в структурі енерговмісту продукції, придатної для харчування належить енерговмісту виробленого молока – 76,1–84,4 %, Відносно цього найбільш впливового на коефіцієнти енергетичної ефективності основної і загальної продукції чинника визначені функціональні залежності енерговмісту продукції від жиру в молоці та взаємозв'язок коефіцієнтів енерговмісту продукції і жиру молока. Визначення річних загальних затрат сукупної енергії на виробництво продукції скотарства проведено з урахуванням логістичної складової технологічного процесу.

Ключові слова: енерговитрати, енергетична ефективність, параметри технології, продуктивність, якість продукції.

Modern conditions for the functioning of various types of agricultural enterprises require compliance with a clear algorithm for the functioning of all parts of the production process mechanism (Gadzalo et al., 2016; Baschenko et al., 2017; Vedmedenko & Kovalenko, 2020).



At the present stage of development of the cattle breeding industry, an essential point is to ensure optimal production indicators (live weight of young animals, average daily increments, gross production, etc.), in the conditions of break – even production – that is, its corresponding cost and sales price (Rudenko et al., 2008; Pankeev, 2022; Pidpala, 2008; Ruban Y. & Ruban S., 2011).

With increasing capacity to the conditions of large-scale production (due to increased productivity, territorial expansion or application of more effective organizational or technological solutions) compliance with the laws of energy efficiency formation of technological processes for the production of high-quality livestock products in conditions of restriction of various types of resources becomes a determining element of competitiveness and therefore clarification of the features of the formation of a system of parameters and justification of standards of technological and technical solutions when creating enterprises of this type is particularly important and relevant.

Previous studies of milk production technologies for small (with a population of 20-150 cows) and medium (350-450 cows) farms allowed us to justify a systematic approach based on which an algorithm for calculating the main elements of energy consumption of resources of such enterprises was created in the MS Excel environment (Marchenko et al., 2020; Getmanets, 2012).. The implementation of a margin assessment of various options for types of energy consumption within the established technical and production parameters allowed us to quantify the coefficients of energy efficiency of products suitable for nutrition and the coefficients of energy efficiency of total products for cow productivity from 7000 kg to 9000 kg within each standard size, taking into account the qualitative characteristic – milk fat. It is based on pilot projects of enterprises developed on the basis of reasonable organizational and production parameters in conditions of fixed high (8000 kg of milk per cow per year) productivity. It should be noted that in the conditions of martial law and the deterioration of many social conditions in rural areas and under the influence of actual climate changes, the assessment of the effectiveness of technological solutions from an economic point of view becomes limited because it does not take into account the component of energy efficiency of production and especially taking into account the quality of raw materials or finished products. Among the many technological solutions in the conditions of today, the creation and maintenance of an efficient production structure is a difficult but relevant task at any stage, since existing farms mostly do not sufficiently meet the requirements of the market environment – they are moderately competitive in terms of technical equipment, technological processes in production, and not always high – quality products.

Increasing the capacity of enterprises increases the negative pressure on the environment and therefore it is very important to reduce the harmfulness of various types of emissions, preserve soil fertility, which indirectly affect changes in climatic conditions. At the same time, the management of these factors in the technological process as a whole changes the energy efficiency of cattle production. (Rudenko et al., 2008; Rudenko et al., 2017; Marchenko et al., 2020; Marchenko et al., 2023; Busenko, 2005).

Previous developments of milk production technologies for large-scale enterprises (with a population of 1000 cows) made it possible to justify their organizational, production and economic parameters under conditions of fixed high productivity (8000 kg of milk per cow per year) (Getmanets, 2012; Baranovsky et al., 2017).. Prior to this, consumption standards were defined separately and patterns of their changes were established under conditions of different productivity of cows (from 4000 to 9000 kg of milk per year). Modern realities require rationalization of such solutions in terms of energy efficiency of production, including taking into account the quality of raw



materials or finished products (Rudenko et al., 2008; Marchenko et al., 2019; Marchenko et al., 2023; Ibatullin et al., 2016)..

According to statistics, among 1,533 enterprises, only 275 (17.8% of the total number) keep 1,000 or more heads of cattle, and their share in the total structure of the cattle population reaches 61.9 %. Currently, among the total number of 1,440 enterprises with a population of more than 1,000 cows, only 74 enterprises (5.1%), the same share not only accounts for almost a third of the population – 30.3%, but is also characterized by higher animal productivity (Tvarinnitstvo, 2023). However, not all technologies or their individual elements used by such enterprises meet modern requirements and therefore they need to be improved to improve (Kostenko et al., 2010; Kostenko, 2018).

At the same time, within the specified parameters of pilot projects or their feasibility studies, it is impossible without establishing and taking into account the Basic Laws of energy efficiency formation of technological processes of production to create in practice in each specific case an energy-efficient, scientifically justified, innovatively attractive technology for the production of products of the required quality (Rudenko et al., 2008; Getmanets, 2012; DBN V. 2.2-1-95, 1995; Ibatullin et al., 2016; Bogdanov et al., 2012). The conducted research is aimed at establishing exactly such regularities in the formation of energy efficiency of technological processes for the production of high-quality livestock products in the context of climate change. They take into account the directions of savings by types of resources (including labor and material) and, as a result, have a positive environmental impact.

Directions for further improvement and principles of building basic technological processes in the production of cattle breeding products for large-scale enterprises are determined using modeling and margin analysis methods. The regularities of the use of energy resources are aimed at improving or more rational their use by Type (human, material, land), respectively, taking into account the dependence of changes in product quality (Merkurieva, 1980).

The object of the study was selected agricultural enterprises for the production of high-capacity milk with a cow population of at least 500 heads.

The purpose of the research is to find out the specifics of forming a system of parameters and standards of technological and technical solutions when creating large-capacity enterprises

Materials and methods of research. According to various methods (economic-statistical, economic-mathematical, expedition surveys, modeling, etc.) using the methodology of bioenergy assessment of production technologies (Kulik et al., 1997), as well as official reports, monitoring, analysis and generalization of the components of the production process in the conditions of tethered and loose methods of keeping cattle were carried out.

Research results. Systematization and generalization of technological and technical solutions of large-capacity Enterprises made it possible to use reporting forms No. 50 – SG, technological passports for the production of dairy cattle farms, which are classified as large-scale enterprises by the volume of milk production (more than 40 thousand c/year) and the number of cows (more than 500 heads) - SE "DG "Artemida" IC Naas of Ukraine", SE "DG Institute of Agriculture of the north-east of the Naas, SE "DG "Gontareva" it Naas, as well as fragments of the agricultural holding "Astarta". The analysis of the livestock structure in Ukraine is made. which shows that over the past ten years, the share of cows in all types of enterprises relative to the total number of cattle has increased to 58.6% compared to 33.8% in 1990. (Astarta – 53.1%). (Marchenko, 2020; Tvarinnitstvo, 2023). The productivity of cows determined by the method of grouping by types of enterprises allowed us to establish approximate volumes of milk



production in gradations of different standard sizes, and the generalization of statistical reporting data for the last three years showed that they are distributed according to the number of cows and milk production as follows (table. 1).

Table 1

Grouping businesses by the number of cows

Indicators	Dairy Cow Farms		cows		gross milk yield	
	n	%	thousand heads	%	thousand tons	%
Dairy Cow Farms	1440	100,0	394,2	100,0	2606,1	100,0
including heads: up to: 50	403	28,0	8,3	2,1	30,8	1,2
50 – 99	209	14,5	15,7	4,0	73,4	2,8
100 – 499	614	42,7	157,5	40,0	1005,9	38,6
500 – 999	140	9,7	93,1	23,6	612,3	23,5
more than 1000	74	5,1	119,6	30,3	883,7	33,9

So, large-scale enterprises, provided that their share of the total number is only 14.8%, have the potential of cows at the level of 212.7 thousand heads, which is 53.9% of their total number of 394.2 thousand heads, and milk production – at the level of 1496 thousand tons or 57.4%.

It is established that in the farms that were included in the monitoring of the development of a program for technological re-equipment of the dairy cattle industry of state-owned enterprises of experimental farms of the Naas network, the milk productivity of cows largely depends on the cow maintenance system and related technology features. The share of cows that were kept using the advanced technology of loose keeping using boxes and on deep bedding was 22%, and the rest of the livestock is kept on a leash. Among large-scale enterprises, the distribution of cows by keeping systems with innovative elements of technological solutions has new or reconstructed premises for loose maintenance (box, deep bedding). this share increases to 28-30%. Productivity ranges from 4852 kg to 7962 kg (at the moment there are more – 8100-8700 kg).

According to the generalized data, there is an advantage in the productivity of cows in the case of using the system of loose keeping and milking in the milking parlor – up to 1.2–1.4 times). Various milking technologies were analyzed – in stalls (milking buckets) – 27 %, in stalls (milk pipeline) – 51 %, in the milking parlor-22% with milk productivity of cows up to 6000 kg, from 6000 kg to 7000 kg and more than 7000 kg of milk per cow, respectively. The use of additional technical means for the preparation and distribution of feed makes it possible to use the feed mixture feeding system. The distribution of cows by feeding Technologies was 70 % (separate ration by Feed type), and 30 % (for the use of feed mixtures). The ratio correlates with the maintenance system, but this type of feeding also depends more on the feed supply sector, under the conditions of using the services of the feed Center (example of Astarta enterprises) and feeding according to modern requirements of balancing the feed mixture (according to the productivity of cows), the annual yield of different productive technological groups is at the level of at least 7000 kg per cow with an interval of annual productivity of at least 1000 kg. An influential factor in the productivity of cows and their growth is the problem with reproduction using any technology, as indicated by the significant variability in the yield of calves per 100 cows-from 51 to 97%.



Studies have shown that a separate element of the technological process is the logistics component, which in the conditions of a large-scale enterprise requires additional corresponding costs for its functioning. Transportation costs vary depending on the distance of production facilities from each other, and also depend on the sales channel of products. At the same time, such a structural unit has all the advantages within the feed delivery shoulder (no more than 70 km) by providing better feeding of animals. In the developed simulation model of enterprise technology variants, which will be discussed below, all calculations of energy costs are carried out taking into account the logistics component for the sale of products within the delivery shoulder of 50 km.

Thus, the generalization of data of agricultural producers of milk, including information on the DP DG network of the National Academy of Sciences of Kharkiv and other regions of Ukraine, allowed to substantiate the features of the formation of a system of parameters and standards of technological and technical solutions in the creation of enterprises of large production capacity, which showed the best results in milk productivity in conditions of different technologies of maintenance, milking systems, feeding cows, the intensity of young growth (Marchenko, 2020; Tvarinnitstvo, 2023).

Taking into account the high variability of cow productivity indicators in the first approximation to the system of parameters and standards of technological and technical solutions, three variants of the standard size were selected – 600, 800 and 1000 cows with full herd turnover and uniform production of marketable products. Annual productivity in the range of 7000-9000 kg of milk per cow. The marketability of milk is 94 %.

Under these conditions, the calculated volumes of feed supply within the average annual number of cows (600-1000 heads) and their annual productivity (7000-9000 kg/head) make it possible to obtain an annual shaft of milk of 4200-9000 tons. Taking into account its drinking to calves, the size of milk sales will be 3950-8460 tons.

Herd structure – cows-31.3 – 33.8 %; heifers-5.9 – 6.1 %; heifers older than one year-13.8 – 17.7 %; heifers up to one year-17.6 – 18.1%; bitches older than one year-9.7 – 9.9%, bitches up to one year-17.8-18.1%. Rejection and replacement of the main herd – 20-25 % (actual cultivation of repair heifers), full turnover of the herd. The method of keeping livestock is loose, using straw bedding. It provides for the cultivation and fattening of bitches on the farm to a live weight of 430-450 kg (900 g of average daily growth). The age of the first insemination of heifers with a live weight of 1 head is 380-400 kg at 15-16 months. The average daily growth of heifers up to a year is at the level of 760 g, older than a year – 800 g. the care of young animals is 4-6 %.

The calculations take into account the products in live weight from culled and fattened livestock in accordance with the structure and turnover of the herd. The feed supply of the cattle herd is based on a system of the same type of feeding with feed mixtures.

Initial data for determining energy costs for the production of dairy cattle products - costs for a cow with a plume: labor – 60-65 people.- H.; the average annual Head of young animals – 18.0 people.- H., electricity-680-730 kWh. Energy equivalents of other resources-according to certain or known reference values (Rudenko et al., 2008; Kulik, 1997).

According to the standard, to obtain milk yields of 7000-9000 kg of milk, it is necessary to prepare 78-95 centners of feed units (89-110 GJ of exchange energy) per cow per year. At the same time, the type of feeding of cows and young cattle is formed in the direction of increasing the consumption of Grain Group feed in animal diets (50-54%), and their use is only as compound feeds, which are full – fledged in composition, provide a given productivity and meet the needs of the physiological state of cows and other sex and age groups of young animals. In the composition of mixed feeds by weight,



the share of grain accounts for no more than 80% and 20% are additives (annual standards for harvesting and feed structures for different types of animals, depending on their productivity in the zones of Ukraine: normative scientific and production manual, 2008).

Practical experience in the operation of cattle farms proves that the achievement of design indicators of production and productivity of livestock, first of all, is limited by the feed availability and usefulness of animal feeding. In this regard, in practice, there is a need to review the traditional systems of production, harvesting and use of feed, when the production of dairy cattle products should ensure full and uniform feeding of animals throughout the year. It is necessary to take into account the effect of logistics factors of mutual distance between individual links of the technological cycle: cultivation of forage crops by type in crop rotations, places and volumes of storage facilities, as well as resources for feed preparation and delivery of feed mixtures to animals. Thus, in feed production: increasing feed supply, increasing the volume and increasing the efficiency of cattle production contributes to: growing the highest-yielding forage crops; harvesting them in the phases of maximum accumulation of nutrients; preparation of high-quality silage, haylage, hay, which in combination with concentrates form the basis of diets of cows and young animals throughout the year;

Calculations of technology variants made it possible to determine the energy efficiency of cattle production of regulated quality in the conditions of large-capacity enterprises within the parameters of technological solutions. Options are considered for enterprises with an average annual number of cattle of 2500-3200 heads. Annual total energy costs for production (milk, growth, Live weight) are set under conditions of varying annual productivity of cows from 7000 to 9000 kg/head.

According to the structure within the standard size of 600 cows (7000-9000 kg/head), the total total energy costs are as follows: 8.3–7.8 % – for herd reproduction, 1.8–1.6 % – from fixed assets of production, 3.7–3.4 % – from working capital without feed and bedding. The total energy of direct and indirect labor costs is 2.3 – 2.0 %, the total energy converted in feed and litter is 83.9–85.2 %. It was found that for 600 cows with a plume with an increase in productivity from 7000 kg/head to 9000 kg/head. (by 28.6 %) total total energy costs for production increase by only 11.8 % – from 240387 GJ to 268915 GJ (or from 445 GJ to 498 GJ per cow).

According to the structure within the standard size of 800 cows, the total total energy costs are as follows: 8.4–7.8 % – for herd reproduction, 1.6–1.4 % – from fixed assets of production, 3.7–3.3 % – from working capital without feed and bedding. The total energy of direct and indirect labor costs is 1.8 – 1.6 %, the total energy converted in feed and litter is 84.5–85.9 %. With an increase in productivity in this case, the total and specific costs of total energy for production increase by 11.8% from 327960 GJ to 366764 GJ (or from 444 GJ to 497 GJ per cow).

According to the structure, within the standard size of 1000 cows, the total total energy costs are as follows: 8.5–7.9 % – for herd reproduction, 1.3–1.2 % – from fixed assets of production, 3.7–3.3 % – from working capital without feed and bedding. The total energy of direct and indirect labor costs is 1.3 – 1.2 %, the total energy converted in feed and litter is 85.2–86.4 %. For 1,000 cows with a plume with an increase in productivity by the same 28.6%, the total total energy consumption for production increases by 11.9% from 411,807 GJ to 460,886 GJ (or from 440 GJ to 490 GJ per cow).

It is established that the energy content of products produced within reasonable technological parameters and directly suitable for consumption with an increase in productivity from 7000 kg to 9000 kg increases from 15248 GJ to 18563 GJ for 600 cows and from 24889 GJ to 30635 GJ for 1000 cows or by 22-23 %. The largest share in the structure of the energy content of such products is occupied by the energy content of



produced milk 76.1–84.4% in accordance with productivity, which becomes a determining factor, both the coefficient of energy efficiency of products suitable for nutrition and the total product (table. 2).

Table 2

Structure of energy content of products by type, %

Energy Content, GJ:	Cow productivity, kg / year		
	7000	8000	9000
obtained milk (with a fat content of 3.8 %)	76,1–80,8	78,4–82,8	80,4–84,4
live weight of culled animals	10,0	9,0	8,2
received for the year of offspring	0,7–0,8	0,7	0,6
weight gain of farmed animals	13,2–8,4	11,9–7,5	10,8–6,8
food-friendly products	100	100	100

Created in the MS Excel environment, the calculation algorithm, which uses a set of initial conditions for the feasibility study of a large production capacity enterprise such as the turnover and structure of the herd, productivity by gender and age groups, costs by the structure of feed, material and other types of resources, etc., allowed us to conduct a margin analysis by types of energy consumption within the selected variants of technical and production parameters and determine the dependence of changes in the energy efficiency of production, taking into account the energy content of milk and its primary quality characteristics – Giroud (Merkurieva, 1980).

For productivity from 7000 kg to 9000 kg per cow per year with an interval of growth of fat content in milk by 0.1% from 3.8% to 4.2 % (the content corresponds to the regulated quality of natural milk), it was determined that the coefficient of energy efficiency of products suitable for nutrition improves from 5.65–6.93% to 5.87–7.14 % (600 cows) and from 5.39–6.62% to 5.62–6.91 % (1000 cows). The energy efficiency coefficient of total products increases from 26.1–27.1% to 26.4–27.4 % (600 cows) and from 26.2–27.1% to 26.4–27.4% (1000 cows), respectively. Thus, it is proved that both coefficients improve in the case of an increase in productivity and fat content of milk (improvement in quality according to this indicator), which generally gives a positive result within the studied gradations of parameters. Patterns of changes reflect graphical dependencies in figures 1-6.

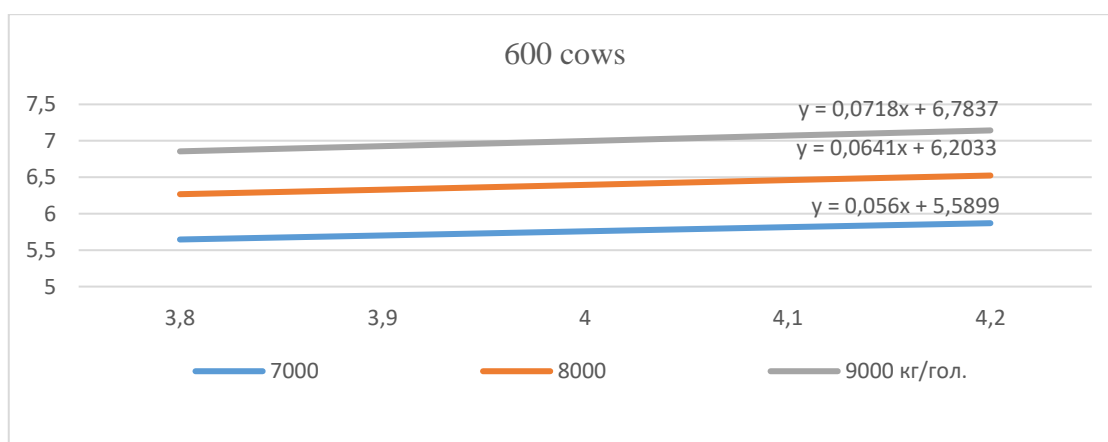


Fig. 1 Dependence of the energy efficiency coefficient of products suitable for nutrition on the fat content in milk and productivity of cows.

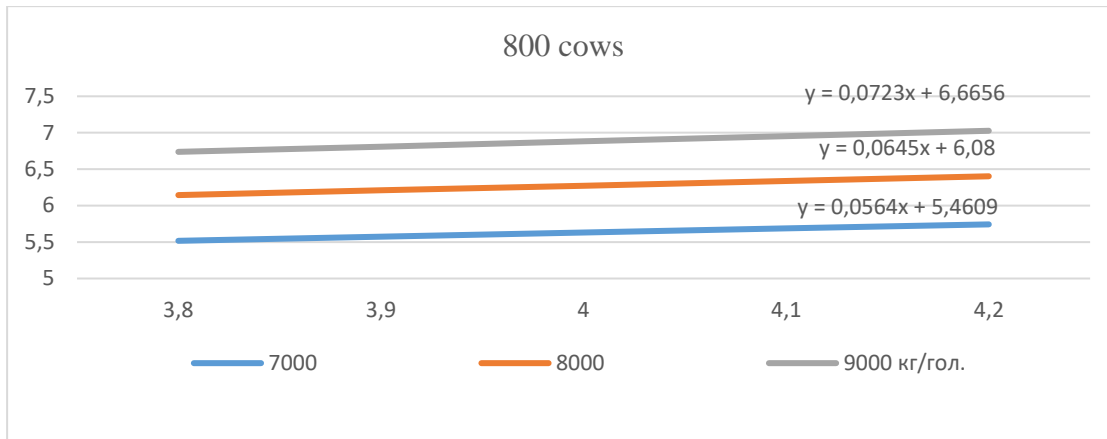


Fig. 2. Dependence of the energy efficiency coefficient of products suitable for nutrition on the fat content in milk and productivity of cows.

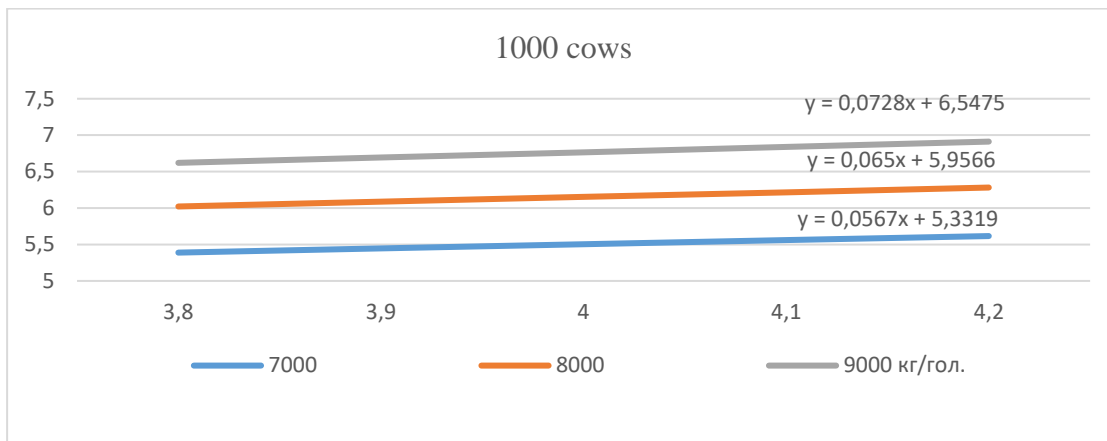


Fig. 3. Dependence of the energy efficiency coefficient of products suitable for nutrition on the fat content in milk and productivity of cows.

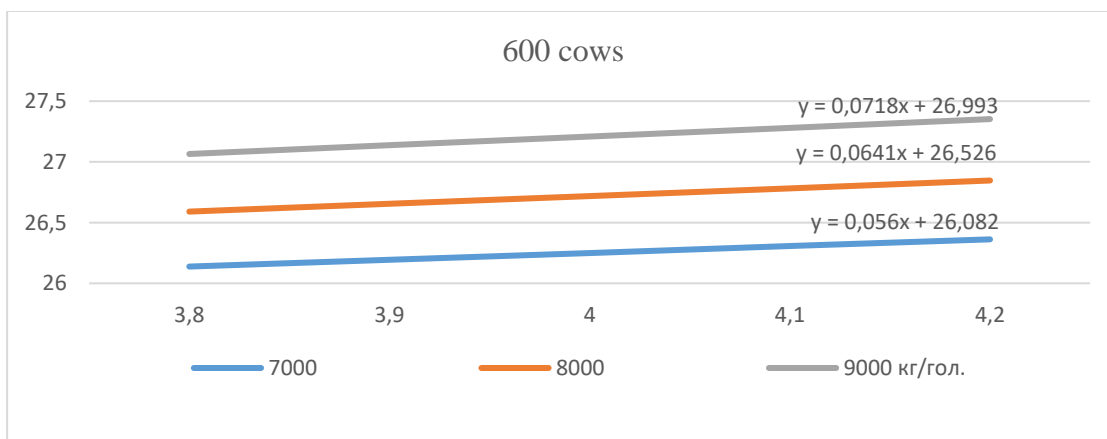


Fig. 4. Dependence of the energy efficiency coefficient of total production on the fat content in milk and productivity of cows.

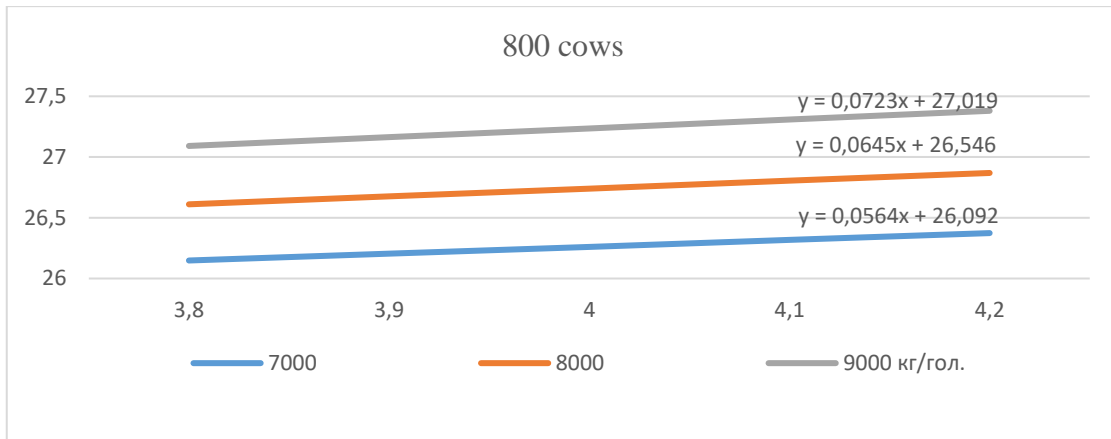


Fig. 5. Dependence of the energy efficiency coefficient of total production on the fat content in milk and productivity of cows.

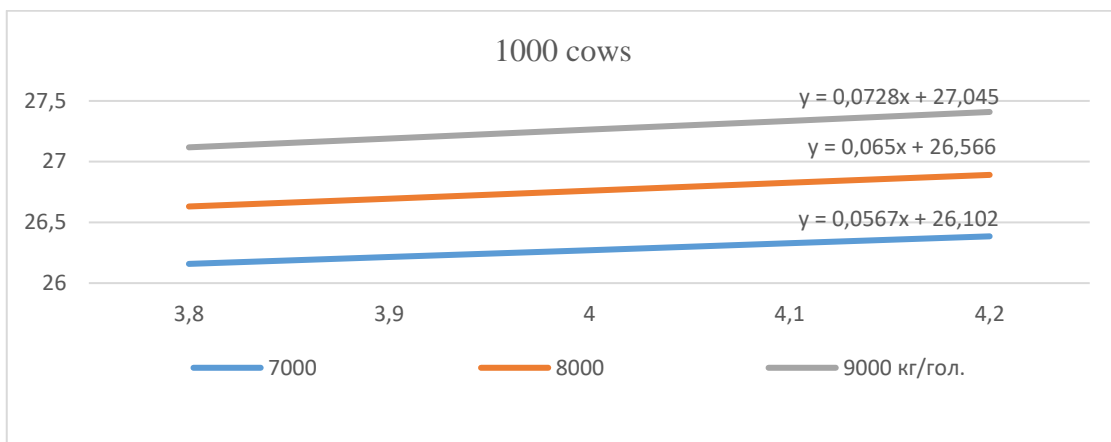


Fig. 6. Dependence of the energy efficiency coefficient of total production on the fat content in milk and productivity of cows.

Under the same conditions, namely, for productivity from 7000 kg to 9000 kg per cow per year with an interval of growth of fat content in milk by 0.1% from 3.8% to 4.2%, regularities of changes in the energy content of products suitable for nutrition and the energy content of all products, taking into account the combined one, are established. The patterns of changes are shown in figures 7-12.

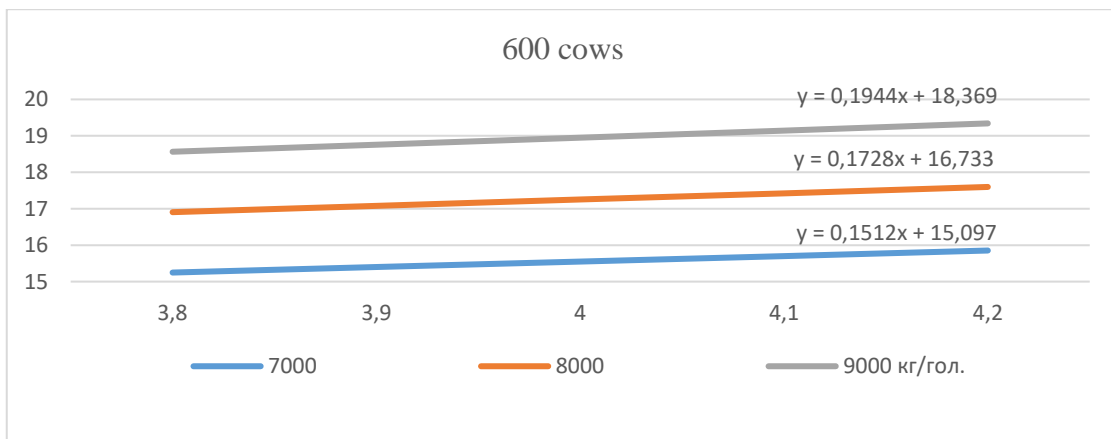


Fig. 7. Dependence of the energy content of products suitable for nutrition (thousand GJ) on the fat content in milk and productivity of cows.

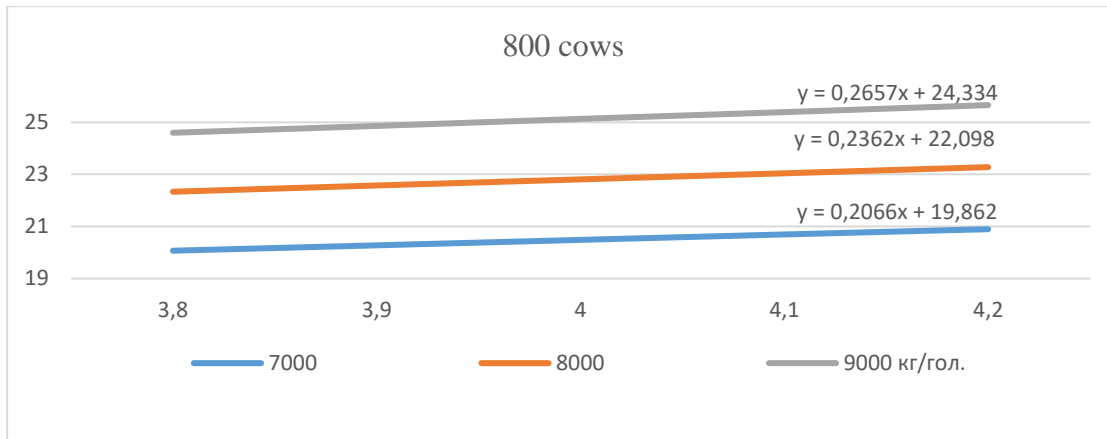


Fig. 8. Dependence of the energy content of products suitable for nutrition (thousand GJ) on the fat content in milk and productivity of cows.

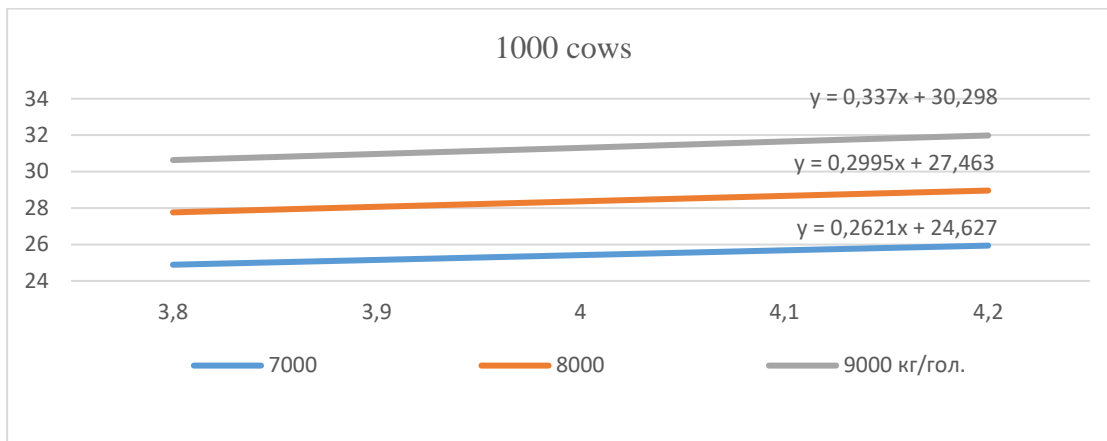


Fig. 9. Dependence of the energy content of products suitable for nutrition (thousand GJ) on the fat content in milk and productivity of cows.

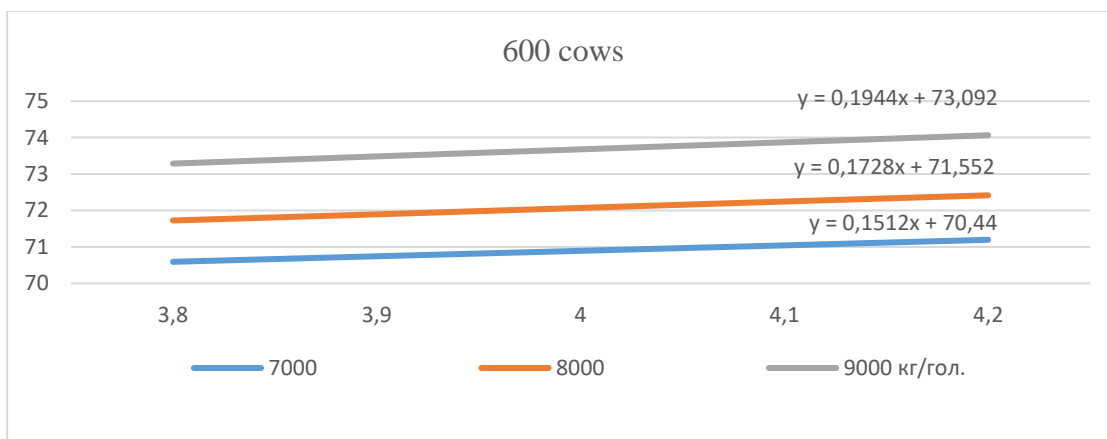


Fig. 10. Dependence of the energy content of all products, taking into account conjugate (thousand GJ), on the fat content in milk and cow productivity.

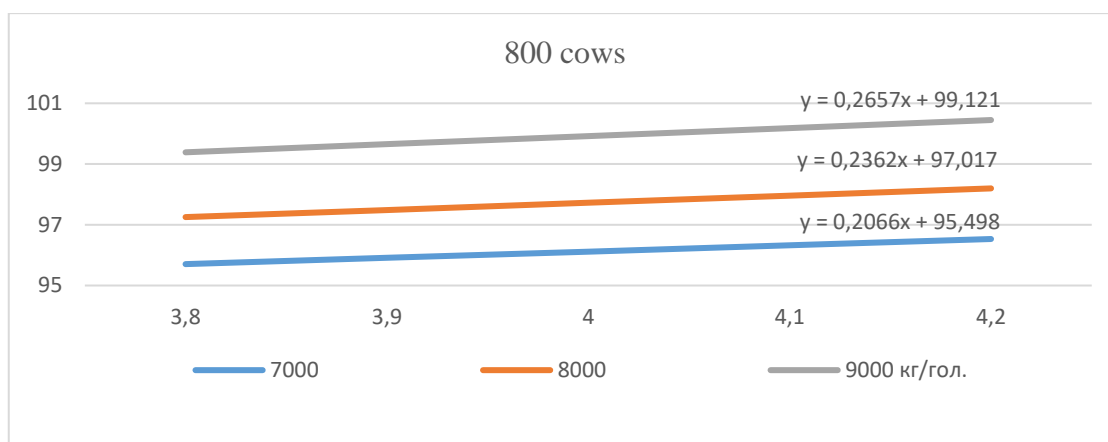


Fig. 11. Dependence of the energy content of all products, taking into account conjugate (thousand GJ), on the fat content in milk and cow productivity.

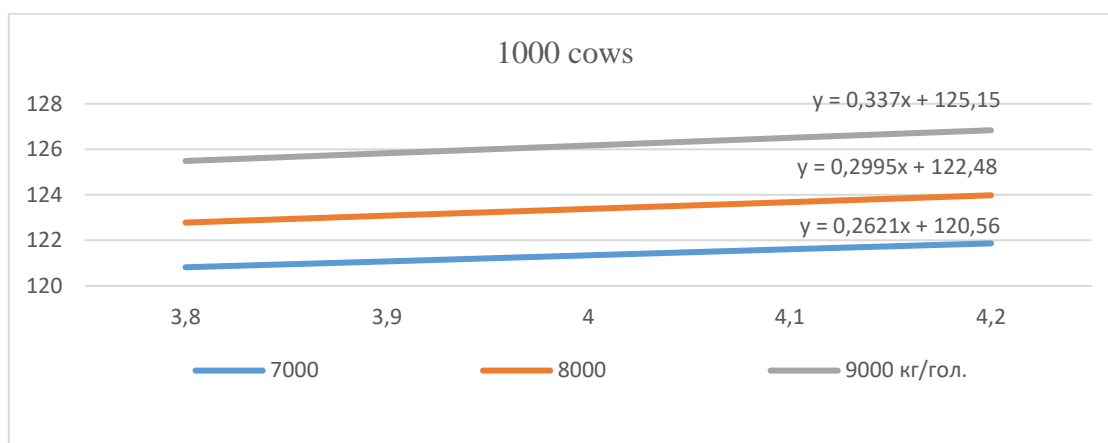


Fig. 12. Dependence of the energy content of all products, taking into account conjugate (thousand GJ), on the fat content in milk and cow productivity.

These dependencies confirm the opinion that regardless of the fat content in milk, with an increase in productivity, both the energy content of products suitable for nutrition and the energy content of all products increase. At the same time, both an increase in the number of cows and their productivity affects the growth of absolute indicators. The result of productivity growth for every 1000 kg of milk is an increase in this energy content by 1658-1744 GJ (600 cows) , 2266-2384 GJ (800 cows), 2873-3023 GJ (1000 cows) or within 5.2% in accordance with the quality of milk in terms of fat content. The increase in the energy content of all products from increasing the productivity of cows (600 heads) from 7000 kg to 8000 kg is 1134-1220 GJ (7.6 %), from 8000 kg to 9000 kg – 1561-1648 GJ (5.6 %).

For 800 cows, there is an increase of 1548-1666 GJ (7.6 %) and 2134-2252 GJ (5.5%), for 1000 cows, the trend continues – 1962-2112 GJ (7.6 %) and 2706-2856 GJ (5.4%), respectively.

The dependences of changes in the energy content of products suitable for nutrition and the energy content of all products on the fat content of milk are shown in Tables 3 and 4.



Table 3

Relationship between the energy content of food-friendly products (Y), % from milk fat content (X), %

Milk fat content (X), %	number of cows, heads		
	600	800	1000
3,8	$y = 1,6577x + 13,59$	$y = 2,2654x + 17,803$	$y = 2,8732x + 22,016$
3,9	$y = 1,6793x + 13,720$	$y = 2,295x + 17,980$	$y = 2,9106x + 22,241$
4,0	$y = 1,7009x + 13,849$	$y = 2,3245x + 18,157$	$y = 2,948x + 22,465$
4,1	$y = 1,7225x + 13,979$	$y = 2,354x + 18,334$	$y = 2,9855x + 22,69$
4,2	$y = 1,7441x + 14,108$	$y = 2,3835x + 18,511$	$y = 3,0229x + 22,915$

Table 4

Relationship of energy content of all products (Y), % from milk fat content (X), %

Milk fat content (X), %	number of cows, heads		
	600	800	1000
3,8	$y = 1,3475x + 69,172$	$y = 1,8408x + 93,767$	$y = 2,3341x + 118,36$
3,9	$y = 1,3691x + 69,302$	$y = 1,8703x + 93,944$	$y = 2,3716x + 118,59$
4,0	$y = 1,3907x + 69,431$	$y = 1,8998x + 94,121$	$y = 2,409x + 118,81$
4,1	$y = 1,4123x + 69,561$	$y = 1,9294x + 94,298$	$y = 2,4464x + 119,03$
4,2	$y = 1,4339x + 69,691$	$y = 1,9589x + 94,475$	$y = 2,4839x + 119,26$

The dependences of changes in the coefficients of energy efficiency of products suitable for nutrition and total products, respectively, the qualitative characteristics of milk in the dynamics of productivity growth of cows (7000-9000 kg/head) within the standard sizes of enterprises (600: 800 and 1000 cows) are illustrated in Tables 5 and 6.

Table 5

Relationship between the energy efficiency ratio of food-friendly products (Y),%, and milk fat (X), %

Milk fat content (X), %	number of cows, heads		
	600	800	1000
3,8	$y = 0,6048x + 5,0467$	$y = 0,6103x + 4,9126$	$y = 0,6158x + 4,7786$
3,9	$y = 0,6127x + 5,0948$	$y = 0,6183x + 4,9611$	$y = 0,6238x + 4,8274$
4,0	$y = 0,6206x + 5,1429$	$y = 0,6262x + 5,0095$	$y = 0,6319x + 4,8761$
4,1	$y = 0,6285x + 5,1911$	$y = 0,6342x + 5,058$	$y = 0,6399x + 4,9249$
4,2	$y = 0,6364x + 5,2392$	$y = 0,6422x + 5,1064$	$y = 0,6479x + 4,9737$



Table 6

Relationship between the energy efficiency ratio of total production (Y),%, and milk fat (X), %

Milk fat content (X), %	Number of cows, heads		
	600	800	1000
3,8	$y = 0,4634x + 25,671$	$y = 0,4715x + 25,674$	$y = 0,4797x + 25,676$
3,9	$y = 0,4713x + 25,719$	$y = 0,4795x + 25,722$	$y = 0,4877x + 25,725$
4,0	$y = 0,4792x + 25,767$	$y = 0,4875x + 25,771$	$y = 0,4958x + 25,774$
4,1	$y = 0,4871x + 25,816$	$y = 0,4954x + 25,819$	$y = 0,5038x + 25,823$
4,2	$y = 0,495x + 25,864$	$y = 0,5034x + 25,868$	$y = 0,5119x + 25,871$

Thus, calculations indicate that both an increase in productivity and an improvement in milk quality have a positive effect on the energy efficiency of production in relative terms. The substantiated dependencies and established regularities make it possible to practically quantify the efficiency of costs from an energy point of view in the conditions of various technologies for the production of cattle products.

Discussion. In today's difficult conditions of limited various types of resources, their effective use for the production of cattle products, and especially in large-scale enterprises with an extensive network of technological elements, becomes of great importance. Many scientists-researchers and practitioners agree with the relevance of this complex problem today. In this sense, the materials of our research are aimed at revealing and deepening options for solving a number of complex problems of rational energy use. The purpose of the work coincides with general challenges caused by complications of production processes, such as a reduction in total production for various reasons, unfavorable climatic conditions, martial law. In the context of these policies, it should be added that ensuring the necessary production indicators in the conditions of break-even production from an economic point of view is aimed at achieving the corresponding cost of production in the conditions of actual sales prices, and this, in turn, in the strategic perspective does not fully (indirectly) describe the characteristics of energy costs of resources. In these circumstances, it is more adequate, in our opinion, to apply energy assessment with the ability to determine and predict resource requirements through natural indicators of parameters and standards of the created or existing production technology.

Our analysis and numerous studies have confirmed the facts that existing technologies do not always meet the requirements of our time, and the quality of milk or raw materials needs to be improved to a level that ensures high competitiveness.

Monitoring and generalization of technological and technical solutions of enterprises of large production capacity allowed to analyze the systems of keeping animals, the relationship of the degree of technical support for the production process of milk production, to establish inhibitory or contributing factors of influence, to create a simulation model, to determine the initial parameters. Within the specified parameters of the complex multi-factor simulation model of a large-scale enterprise, calculations are made and regularities of energy efficiency formation are established, which are illustrated by the presented materials.

The substantiated dependencies and established regularities make it possible, taking into account the qualitative characteristics of products, to form the main technological elements of the cattle production system within the parameters of enterprises of the standard size of 600-1000 cows with full herd turnover. Modeling of



production using equations of dependence of its energy content on qualitative characteristics makes it possible to quantify the energy component of individual technological processes of production by types of resources and take the necessary measures to improve it.

Conclusions:

1. Monitoring and analysis of technological and technical solutions of enterprises of large production capacity, which showed the best results in terms of milk productivity in the conditions of various technologies of keeping, milking systems, feeding cows, the intensity of rearing young animals allowed to justify the initial parameters and standards of technological solutions and on this basis to assess the energy consumption and energy efficiency of cattle production.

2. In the system of parameters of the created complex simulation models, the dependencies of energy consumption formation on the main elements of resource support for the technological process of cattle production within the limits of changes in gradations of quantitative and qualitative characteristics – enterprise capacity, animal productivity, milk fat content-are justified.

3. The tools of simulation models and certain relationships allow you to directly simulate technological conditions, evaluate not only the quantitative energy component in accordance with each type of resources spent, but also, according to their availability, in fact, form the most energy-efficient technological process for the production of cattle products or improve it,

References

- Baranovskiy, D. I., Hetmanets, O. M., Khokhlov, A. M. (2017). *Biometriia v prohramnomu seredovyschi MS Excel: navchalnyi posibnyk [Biometrics in the MS Excel software environment: a training manual]* Kharkiv: SPD FO Brovin O.V., 90 p. (in Ukrainian)
- Bashchenko M. I. (2017). *Tvarynnytstvo Ukrainy: stan, problemy, shliakhy rozvytku (1991-2017-2030 rr.). [Animal husbandry in Ukraine: status, problems, and development paths (1991–2017–2030)].* K.: Ahrarna nauka, 160 p.
- Bohdanov, H. O., Kandyba, V. M. (2012). *Normy i ratsiony povnotsinnoi hodivli vysokoproduktyvnoi velykoi rohatoi khudoby [Standards and rations for complete feeding of high-yielding cattle].* reference book–manual. Kyiv : Ahrar. nauka, 296 p. (in Ukrainian)
- Busenko O. T. (2005). *Tekhnolohiia vyrobnytstva produktsii tvarynnytstva [Livestock production technology].* Kyiv: Vyscha osvita, 496 p. (in Ukrainian)
- DBN V.2.2–1–95 «Budyanky i sporudy dlia tvarynnytstva», Derzhavnyi komitet Ukrainy u spravakh mistobuduvannia i arkhitektury [“Buildings and structures for animal husbandry,” State Committee of Ukraine for Urban Development and Architecture]. Kyiv, 1995. URL: <https://ips.ligazakon.net/document/> (in Ukrainian)
- Hadzala, Ya. M., Bashchenko, M. I., Zhuk, V. M., Lupenko, Yu. O. (2016). *Stratehiia rozvytku silskohospodarskoho vyrobnytstva produktsii v Ukraini na period do 2025 roku [Strategy for the Development of Agricultural Production in Ukraine for the Period until 2025].* K.: Ahrar. nauka, 216 p. (in Ukrainian)
- Ibatullin, I. I., Zhukorskiy, O. M. (edd.) (2016). *Dovidnyk z povnotsinnoi hodivli silskohospodarskykh tvaryn [Reference book on complete feeding of farm animals].* Kyiv: Ahrarna nauka, 336 p. (in Ukrainian)
- Kostenko, V. I., Siratskiy, Y. Z., Ruban, Yu. D. et all. (2010). *Tekhnolohiia vyrobnytstva moloka i yalovychny [Technology of milk and beef production].* K.: Ahrarna



- osvita, 530 p. (in Ukrainian)
- Kostenko, V. I. (2018). *Tekhnolohiia vyrobnytstva moloka i yalovychny* [Technology of milk and beef production]. Textbook. Kyiv: Lira, 672 p. (in Ukrainian)
- Kulyk, M. F. (1997). *Metodyka bioenerhetychnoi otsinky tekhnolohii vyrobnytstva produktsii tvarynnytstva i kormiv* [Methodology for bioenergetic assessment of livestock and feed production technologies]. Vinnytsia. 54 p. (in Ukrainian)
- Marchenko, V. A., Korkh, I. V., Korkh, O. V., Petrash, V. S., Admin, O. Ye., Admina, N. H., Tkachov, A. V. (2020). *Pidvyshchennia efektyvnosti zaluchennia investytsii dlia ferm z riznymy obsiahamy richnoho vyrobnytstva moloka: rekomendatsii* [Improving the effectiveness of attracting investments for farms with different volumes of annual milk production: recommendations]. Kharkiv, Livestock farming institute of NAAS of Ukraine. 45 p. (in Ukrainian)
- Marchenko, V. A., Korkh, I. V., Petrash, V. S., Tkachov, A. V. (2019). *Obgruntuvannia mekhanizmiv optymizatsii tekhnoloho–ekonomichnykh parametriv molochnykh ferm i kompleksiv riznoi vyrobnychoi potuzhnosti* [Justification of mechanisms for optimizing the technological and economic parameters of dairy farms and complexes of various production capacities]. *Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Seriiia «Tvarynnytstvo» - Bulletin of Sumy National Agrarian University. Series “Animal Husbandry.* V. 1–2 (36–37). P. 70–78. <https://doi.org/10.32845/bsnau.lvst.2019.1-2.12> (in Ukrainian)
- Marchenko, V. A., Trishyn, O. K., Chyhrynov, Ye. I., Drozdov, S. Ye., Petrash, V. S., Admina, N. H., Tkachov, A. V., Ponomarova, V. V. (2023). *Osoblyvosti formuvannia systemy parametriv i normatyviv tekhnolohichnykh ta tekhnichnykh rishen pry stvorenni pidpriemstv maloi vyrobnychoi potuzhnosti* [Features of the formation of a system of parameters and standards for technological and technical solutions when creating small-scale production enterprises] *Naukovo-tekhnichnyi biuleten Instytutu tvarynnytstva NAAN.* Kharkiv, № 128. P. 130–140. <https://doi.org/10.32900/2312-8402-2022-128-130-140> (in Ukrainian)
- Marchenko, V. A., Trishyn, O. K., Chyhrynov, Ye. I., Drozdov, S. Ye., Petrash, V. S., Tkachov, A. V., Ponomarova, V. V. (2023). *Enerhoefektyvnist vyrobnytstva produktsii skotarstva nevelykoho pidpriemstva u mezhakh systemy parametriv i normatyviv tekhnolohichnykh ta tekhnichnykh rishen* [Energy efficiency of livestock production in a small enterprise within the system of parameters and standards for technological and technical solutions]. *Scientific Progress & Innovations* <https://journals.pdaa.edu.ua/visnyk> 26 (2) P. 72–78. <https://doi.org/10.31210/spi2023.26.02.13> (in Ukrainian)
- Merkurieva, Ye. K. (1980). *Variatsiina statystyka v doslidzhenniakh produktyvnosti tvaryn* [Variational statistics in animal productivity research]. Kyiv: Vyscha shkola, 216 p. (in Ukrainian)
- Normatyvnyi naukovo-vyrobnychiy posibnyk Instityta tvarynnytstva UAAN (2008). *Richni normatyvy zahotivli ta struktury kormiv dlia riznykh vydiv tvaryn v zalezhnosti vid yikh produktyvnosti po zonakh Ukrainy* [Annual standards for the procurement and structure of feed for different types of animals depending on their productivity by region in Ukraine: normative scientific and production manual]. 3 vyd. dop., Kharkiv, 31 p. (in Ukrainian)
- Pankieiev, S. P. (2022). *Tekhnolohichni osoblyvosti vyrobnytstva yalovychny v umovakh silskohospodarskykh pidpriemstv khersonskoi oblasti* [Technological features of beef production in agricultural enterprises in the Kherson region]. *Tavriiskyi naukovyi visnyk* № 124, P. 174–182. <https://doi.org/10.32851/2226-0099.2022.124.24> (in Ukrainian)



- Pidpala T. V. (2008). Skotarstvo i tekhnolohiia vyrobnytstva moloka ta yalovychyny: navchalnyi posibnyk [Cattle breeding and milk and beef production technology]. Textbook. Mykolaiv: Vydavnychi viddil MDAU, 369 p. (in Ukrainian)
- Ruban, Yu. D., Ruban, S. Yu. (2011). Tekhnolohiia vyrobnytstva moloka i yalovychyny: Pidruchnyk dlia stud. vyshch. ahr. navch. zakl. II–IV rivniv akredytatsii [Technology of milk and beef production: Textbook for students of higher agricultural educational institutions of II–IV levels of accreditation]. Kharkiv : Espada, 800 p. (in Ukrainian)
- Tvarynnytstvo Ukrainy 2022. Derzhavna sluzhba statyky Ukrainy [Livestock Farming in Ukraine 2022. State Statistics Service of Ukraine]. Kyiv. 2023. 158 p. (in Ukrainian)



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**EFFECTIVE STRATEGY FOR CONTROLLING THE NUMBER
OF ECTOPARASITIC MITES VARROA DESTRUCTOR ON
HONEYBEES APIS MELLIFERA L. 1758 FOR APPLYING AN
INTEGRATED APPROACH
(REVIEW)**

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Apis mellifera (honey bee) is one of the economically valuable species, representatives of the Class Insecta. The biggest threat to the bee Apis mellifera remains the ectoparasitic mite Varroa destructor, which causes many health problems, the consequences of which can lead to the collapse of families. The influence of the parasite on swimming may be due to the susceptibility of honeybees to infectious diseases due to their relative proximity and high frequency of social interactions within their family. However, other factors, including environmental conditions related to the parasite's life cycle, as well as the life expectancy and intensity of mite development, can increase its negative impact. Scientists' observations include increased acaricide resistance in the Varroa population and lower treatment thresholds, suggesting that ticks or pathogens they can transmit to bees are becoming increasingly virulent. Weak families with a high prevalence of infestations contribute to the dispersal of ticks and the transmission of diseases in stronger and healthier nests. Harmful effects of parasitization V. destructor and the effects of acaricides on bee colonies have prompted beekeepers to look for sustainable approaches to tick control. To achieve this goal, individual beekeepers sought to breed V. destructor-resistant honeybees using different selection criteria.

The social behavior of insects has led beekeepers to address their intra-specific and interspecific relationships, focusing on internal behavior to reduce the spread of mites. on honeybees. The efforts of many scientists to find means and measures that will help reduce the extent of infestations and control ticks at a safe level for bees were discussed.

Current scientific directions for studying the social behavior of insects and the use of individual signs of bee behavior in the fight against this parasite are outlined.

Keywords: Varroa mite, bees, acaricides, behavioral reactions



ЕФЕКТИВНА СТРАТЕГІЯ КОНТРОЛЮВАННЯ ЧИСЕЛЬНОСТІ ЕКТОПАРАЗИТАРНОГО КЛІЩА *VARROA DESTRUCTOR* НА МЕДОНОСНИХ БДЖОЛАХ *APIS MELLIFERA* L. 1758 ЗА ЗАСТОСУВАННЯ КОМПЛЕКСНОГО ПІДХОДУ (ОГЛЯДОВА)

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Apis mellifera (бджола медоносна) є одним із господарсько цінних видів, представників класу *Insecta*. Найбільшою загрозою для медоносної бджоли *Apis mellifera* залишається ектопаразитичний кліщ *Varroa destructor*, який викликає безліч проблем зі здоров'ям, наслідки не вирішення яких може призвести до колапсу сімей. Вплив пливу, який чинить паразит може бути обумовлений сприйнятливістю медоносних бджіл до інфекційних захворювань через їх відносну близькість і високу частоту соціальних взаємодій в межах їх сім'ї. Однак інші чинники, включно умови довкілля, пов'язані з життєвим циклом паразита, а також тривалість життя та інтенсивність розвитку кліща, можуть збільшити його негативну дію. Спостереження науковців включають підвищення стійкості до акарицидів у популяції *Varroa* та зниження порогів обробки, що свідчить про те, що кліщі або патогени, що вони здатні передавати бджолам стають все більш вірулентними. Слабкі сім'ї з високою екстенсивністю інвазії сприяють розсіюванню кліщів і передаванню хвороб у сильніші і здоровіші гніздах. Згубні наслідки паразитування *V. destructor* та вплив акарицидів на бджолині сім'ї спонукали бджолярів до пошуку стійких підходів для контролю над кліщем. Для досягнення цієї мети окремі бджолярі прагнули розвести стійких до *V. destructor* медоносних бджіл, використовуючи різні критерії відбору.

Соціальна поведінка комах спрямувала увагу бджолярів звернутися до їх внутрішньоспецифічних та міжспецифічних відносин, роблячи акцент на внутрішній поведінці, щоб зменшити поширення кліща на медоносних бджіл. Обговорено зусилля багатьох вчених щодо пошуку засобів і заходів, які сприятимуть зниженню екстенсивності інвазії та контролю кліща на безпечному для бджіл рівні.

Окреслено актуальні наукові напрями дослідження соціальної поведінки комах та використання окремих ознак поведінки бджіл у боротьбі з цим паразитом.

Ключові слова: кліщ *Varroa*, бджоли, акарициди, поведінкові реакції

The honey bee, *Apis mellifera*, plays an important role in modern agriculture. In addition to honey production, insects provide critical ecosystem services, primarily pollination, for a wide range of valuable crops. However, over the past half-century, honeybees have experienced increased stress, which has led to a constant increase in the mortality rate of bee colonies in the world. The factors behind this increased mortality have not yet been fully elucidated. Changes in land use, cultivation and agricultural methods; new pesticides and their larger applications; more intensive beekeeping; exotic parasites and the spread and growth of honeybee pathogens have been suggested as the main factors contributing to their mortality.



The decline in insect numbers seen in previous years has prompted increased awareness and efforts to maintain their survival and the vital role they play in stabilizing the ecological balance of various ecosystems.

Numerous reviews have been published covering the biology of the *Varroa* mite, social immunity *A. mellifera*, history of acaricide use and control, literature on the effectiveness of various treatments available to control mites in honey bee families (Cremer, S. et al., 2007; Mondet, F. et al., 2014; Traynor, K.S. et al., 2020).

Thus, this review focused on:

- study of the harmful effects of *Varroa* mites on European honeybees;
- justification of modern means, methods and methods of mite control and their limitations;
- identifying opportunities for more sustainable methods of controlling ectoparasites.

The aim of the study is to assess the biological significance of the *Varroa* mite in the life of bees, to determine its role as the main factor of increased mortality of bee colonies in the world, as well as to outline promising areas for further scientific research aimed at effectively combating invasion and minimizing harmful effects on bee health.

Materials and methods. The methodological tools included both general scientific methods-logical analysis and synthesis, classification and systematization, generalization, and special ones – problem-chronological and source-scientific and terminological analyses, as well as analysis of literature sources, which was carried out in the form of a systematic review study by searching publications in the databases Scopus, Web of Science, Google Scholar, etc. The review included works in English published mainly in recent years in accordance with certain criteria. The systematization of available scientific data was carried out in order to generalize modern knowledge about existing measures for the treatment of varroasis, effective and safe medicines, which can become the basis for the formation of research methodology in this direction in the conditions of Ukraine, taking into account international experience.

Research results. Scientists and beekeepers are developing approaches to controlling the spread of the mite *V. destructor*, because despite substantial evidence of the need for tick control, no effective solution has been found (Dietemann et al., 2012; Wagoner et al., 2020).

Much attention has been paid to the evolutionary biology of *V. destructor* and the interaction between the host and parasite. It is known that the tick feeds mainly on the fat body, as well as on the hemolymph of honeybees (Ramsey et al., 2019) during the transmission of viral, bacterial and fungal pathogens that affect and lead to the collapse of many commercially managed apiaries, and the immune system *A. mellifera* is constantly weakening due to pathogens. The evolutionary trend of *V. destructor* shows a successful transition from its main host (*A. cerana*) to the current host (*A. mellifera*). It is considered that *A. cerana* has developed host defense mechanisms against mites (Techer et al., 2019).

The history of *V. destructor* can be traced back to 1904, when *V. jacobsoni* was first described in honey bee families *A. cerana* on the island of Java, and later spread to other parts of the world (Traynor et al., 2020). Until 2000, many scientists and beekeepers believed that *V. jacobsoni* was a mite that contributed to the death of honey bee colonies. In the same year, 2000, taxonomic work and the first microsatellites discovered previously unknown *Varroa* species and found out that *V. destructor* is able to reproduce on *A. mellifera* is also to blame for the deaths of the latter. Before Anderson and Truman described the morphological features of tick *V. Destructor* (2000).



Today, the mite's feeding habit is on the fat bodies and hemolymph of honey bees and the reproductive period of *V. destructor* in bee colonies undoubtedly remains the main threat to *A. mellifera* (Han, B. et al., 2024). The distribution of *V. destructor* is shown in detail in Figure 1.

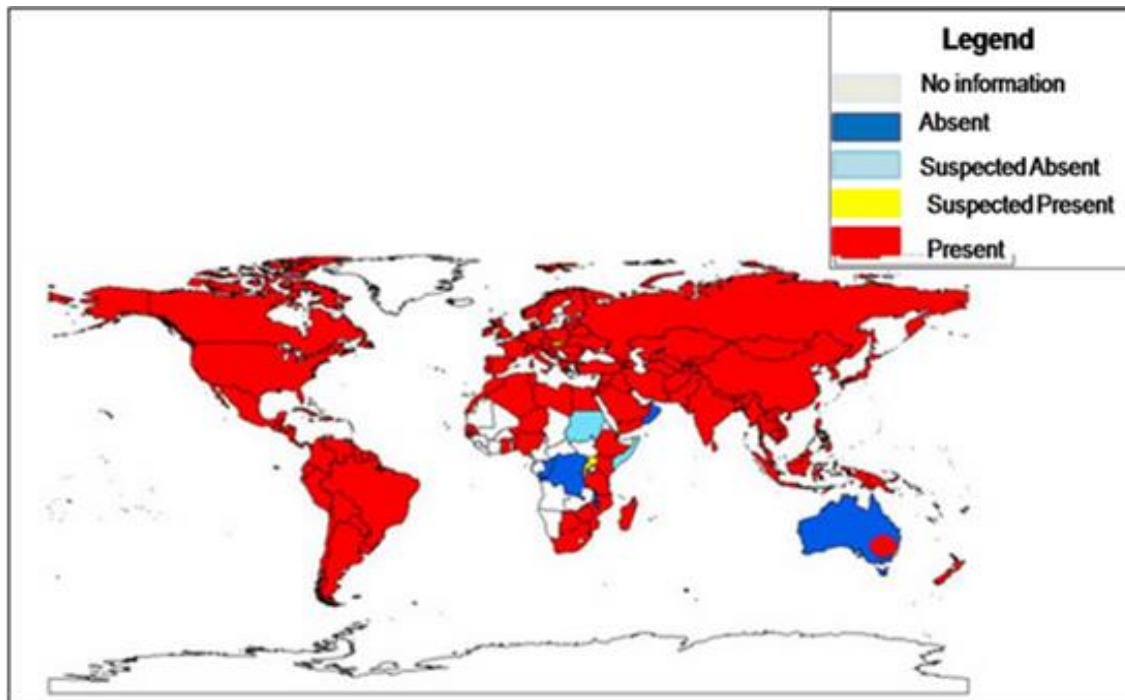


Fig. 1. World distribution of *V. Destructor*. Based on CABI materials. Center for Agriculture and Bioscience International. 2024. Available online: <https://www.cabidigitallibrary.org/doi/10.1079/cabicompndium.107784> (accessed on 9 June 2024).

Evidence suggests that the host change of *V. destructor* took about (50-100) years and became almost Global in mite distribution. In Australia, the first case of *V. destructor* was reported in June 2022 in the port of Newcastle as part of the implementation of the National *Varroa* Mite Management Program.

Rapid, widespread spread of the parasite was carried out through drift, possibly moving to new colonies, when healthy bees used (known as stealing) a resource from unhealthy ones, while strengthening weak families by adding brood from strong ones, transporting from one apiary to another without careful mite testing (Cremer, S. et al., 2007; Mondet, F. et al. 2014; Traynor, K.S. et al. 2020; Peck, D.T. et al., 2019).

The Behavioral Ecology and adaptability of *V. destructor* to its host in various climatic conditions has been complex and difficult to understand. However, several studies have described their physiology, ecology, reproduction, and host-parasite interactions. Adult females are reddish-brown or dark brown, with an oval shape about (1-1.77) mm long and (1.5–1.99) mm wide; meanwhile, adult males are yellowish, with a spherical body shape (0.75–0.98) mm long and (0.70–0.88) mm wide (Nazzi, F et al., .2016). The tick's reproductive cycle begins with oviposition and ends by the adult stage. Their life cycle includes two phases: reproductive, where adult fertile females, once they are in the cells with the brood, produce young and feed on the fat body of bee larvae and pupae, while damaging the tissues of individuals at the stage when they do not feed, while before sealing the brood, The Tick pierces the cuticle, creating a place for feeding. The reproductive success of *V. destructor* depends on their eating habits and the length of the



formation period at different stages of bee development. Need the *V. destructor* in egg-laying energy requires it to extract more nutrients from the host's body, which leads to poorer conditions for adult bees (Li et al., 2019).

In this regard, the development of Natural Methods for controlling ticks through behavioral traits (stable response patterns) of honeybees is a topic for researchers. This is due to the fact that natural methods have shown a more stable and safe effect on insects than the use of synthetic or organic chemicals. The results of the study indicate the effectiveness of behavioral properties associated with the immunity of honeybees, and the potential of the latter in the fight against *V. destructor*. One of these traits – hygienic behavior – in insects originated as a social immune trait that can reduce exposure to *V.* in addition, this behavior of honeybees is stimulated not only by colonies affected by *V. destructor* (Aumeier et al., 2001), but also those affected by pathogens of other diseases (virosis, mycosis, bacteriosis) (Schöning et al., 2012). The predominant threats that contribute to family loss are brood diseases (Seitz, N. et al., 2015; Lee, K.V. et al., 2015). Among all these factors, the parasitic mite *V. destructor* is the central threat (Traynor et al., 2020). Recently, the behavior of honeybees in relation to affected *V. destructor* colony and their ability to remove diseased individuals are of interest to beekeepers for selecting resistant families. The results of a study of the behavior of honeybees in caring for them and their protective behavior in previous years revealed mechanisms of resistance against mites. However, the manifestation of insect behavioral traits can be influenced by many biological and environmental factors. Therefore, the proportion of damaged mites in bottom debris in nests can be used to determine the success of bees in caring for normal field conditions. Studies have shown that seven ticks selected for grooming showed significantly more damaged mites and lower damage rates after several generations of selection. The reliability of honeybee grooming behavior in selecting resistant families against *V. destructor* is poorly understood (Wagoner et al., 2020). Scientists have suggested that combining their natural immune behavior can be used as an approach to combat the effects of tick damage. Another new feature of bee colonies against *V. destructor* is their ability to slow down the reproduction of mites, which depends on the level of damage (Bubnić et al., 2024). As a result, slow growth of the tick population can be considered the main characteristic of *V. destructor*-resistant colonies. The authors also noted that keeping Queens in cages and the technique of traps using honeycombs associated with oxalic acid treatment can be considered effective treatment strategies. This approach proved to be more effective because the number of mites collected from Bee colonies that survived infection *V. destructor* (VSB), was much lower than in the control group (Mondet et al., 2020). The researchers also demonstrated that families selected for behavioral traits against *V. destructor* had significantly more damaged ticks and lower rates of invasion prevalence than those not selected for behavioral traits. Despite the introduction of many approaches to controlling the spread of mites, no effective measures to protect the health of honeybees have been fully implemented.

Many studies have focused on the biology of *V. destructor* and the history of acaricides used to control ticks (Roth, et al., 2020; Deguine et al., 2021). However, knowledge about the effects of combining the natural behavioral traits of bee colonies that are immune to ticks and the use of acaricides is negligible.

The response of honeybees to *V. destructor* is oriented on their behavior related to the immune system, which is considered hereditary. This ability can be altered by some environmental factors depending on the environment. Although environmental pollutants, poor beekeeping practices, climate change, and food stress can reduce bee populations, *V. destructor* remains the leading cause of bee loss (Oddie et al., 2018; Büchler et al. 2020).



Since *A. cerana* has acquired resistance to *V. destructor*, and it is believed that regardless of the degree of parasite damage to their current host, *A. mellifera*, individual subpopulations are still stable. It is important to note that the immune responses of honeybees associated with *V. destructor* are due to their social behavior, which is considered anti-pathogenic and can suppress deadly pathogens caused by mites.

It is believed that the survival of honey bee colonies in *V. destructor* damage is associated with natural tolerance, which can interfere with the mite's reproductive development and reduce the infectious load (Mondet et al., 2020). However, it is unclear exactly which tolerance factor reduces its number in untreated families. Hypotheses related to the immune system are questionable. It is likely that scientists will have to study each phenomenon separately.

Despite substantial knowledge of the biology of the *Varroa* mite (Locke 2016, Noël et al., 2020) beekeepers are still experiencing difficulties in the process of applying specific strategies to effectively manage it. It is noteworthy that various measures have been proposed to control the parasite – from zootechnical to organic and chemical. Some of the reported control measures include the following: physical removal of the mite (Noël et al., 2012), the hygienic behavior of bees (Noël et al., 2020) and chemical treatments (Roth et al., 2020; Deguine et al., 2021). The main organic methods of tick control are described in the literature. Instead of directly destroying the parasite using chemical methods, organic methods aim to limit the rapid reproduction of mites in the bee nest or remove them mechanically.

One of the measures is a temporary cessation of brood cultivation. Biology of the *Varroa* mite suggests that the female stays in a sealed cell with the pupa for 12 days and 5 days on a bee until she enters the next cell before sealing. The breeding cycle of the tick in this way is 17 days. Therefore, the ratio of mites on bees and brood in the nest should be approximately as follows: 30% on bees and 70% in the brood. In reality, the ratio is: 10% in bees and 90% in brood. This is because bees intensively destroy all mites that are not in sealed cells. It can be assumed that during the active period, when there is no brood, bees can more actively destroy the mite. However, mites cause more damage to bees when they can't enter the brood. Therefore, the cessation of brood cultivation cannot be prolonged. In order for all mites to leave the brood, the temporary cessation of its presence should not exceed 21 days, when the last sealed brood will appear. A situation is created when all the mites that were in the brood will pass to bees. At this time, you can apply a combined approach and treat bees with medicines, when their use in the absence of brood will be most effective. A common disadvantage of such methods is that the fruitless period weakens the strength of the family so much that under certain conditions it can die altogether (Ellis et al., 2019; Gornich M., 2024).

Another method that is proposed to be used to control varroasis involves the use of wax with reduced cells. At the beginning of using this method, the results of using wax with a reduced cell were encouraging. However, scientific studies have not shown the effectiveness of this approach. However, data analysis shows that wax with a reduced cell can still be an effective measure against *Varroa*. It is believed that on a wax with a reduced cell, the development at the pupal stage of the bee can go faster. The *Varroa* mite, which is very sensitive to such changes, may not have time to finish development, as a result, the reproduction of the parasite will be disrupted. Another hypothesis suggests that in smaller cells, the pupa is placed more tightly, and this makes it difficult for the tick to move in the cell and feed on it.

Another group of *Varroa* control methods involves mechanically removing mites from the nest by using drone wax and then removing the drone brood. On its natural host, the eastern bee *A. cerana*, the *Varroa* mite breeds exclusively on drone brood, since the



development cycle of the eastern Bee is shorter and the mite does not have time to breed offspring. In families *A. mellifera* the parasite reproduces on both drone and Bee brood, but prefers drone, in which the pupa is larger and its development cycle is longer, which helps to provide the mite with sufficient food for nutrition and time for reproduction. If a drone wax is placed in the bee nest at the time of the appearance of the drone brood, and after sealing it, the brood is removed along with mites, this can prevent an outbreak of an increase in the population of the latter. The disadvantages of this method are obvious: when removing it, it is not always possible to separate the drone brood from the bee brood; bees spend too much food resources on raising drones on drone wax, the presence of which during the swarm period is simply necessary to saturate the area for reliable mating of Queens.

Another approach to mechanical tick removal involves the use of powdered sugar, talcum powder, starch or flour. The mechanism of countering the tick during such an operation is as follows. If the powder gets on the mite's feet, they disrupt the ability of the suckers and hold on to the bee, it falls to the bottom of the hive, from where it is removed by the bees. Another consequence is that bees sprinkled with powder are intensively engaged in self-cleaning (grooming), removing powder and mites from themselves at the same time. This approach can be effective, especially in combination with interrupting brood cultivation and the presence of a sealed bottom in the hive. The obvious disadvantages of the method are that 90% of the mite is in the brood, so in order for topping to be effective, it must be constantly repeated every 5 days. Also, these powders have a negative effect on eggs, open brood and unripe honey.

The next method is to use a sealed bottom, the essence of which is as follows: ticks that live in the bee nest can lose contact with the bee and fall down the Hive, and then switch back to the bees. If the bottom is bounded by a grid with a Cell (3 x 3) mm, then bees cannot touch it. Shedding mites cannot re-pass to bees. The use of a grid can help reduce the tick population in the nest, but this method cannot be used independently in mite control. However, it is effective in the diagnosis of varroasis.

The next approach is hyperthermia, or the thermal method, which is based on the fact that ticks are more sensitive to high temperatures than bees. Comfortable for the mite is the temperature close to +33°C, and for bees – + 36°C. Therefore, the mite prefers the periphery of the nest for its reproduction, where the temperature can be lower. Only after the appearance of varroasis was the method of mite control used using thermal chambers – the bees were shaken into a special cassette, then placed in a container where the temperature (+46 – 48)°C was maintained for a certain time for 12-15 minutes. Mites in such conditions died, and bees survived. The method was time-consuming and complex, but quite effective. Over time, it turned out that prolonged use of the method can lead to the appearance of heat-resistant mites, because the method ceases to be effective.

Another approach is the separation of colonies, which consists in creating a sufficient number of new ones to replace those who died. There are ways to create new families with a small extent of invasion. These are swarms and infertile nuclei (layers). If you create a new family only from flying bees, then for at least two years such a family can have a low extent of invasion, and be productive. But such a strategy can be quite risky. However, when a part of the apiary dies from varroasis, only division can restore the number of bee colonies. (Gornich M., 2024).

Environmentally friendly methods are actively used due to the resistance of *V. destructor* to mild acaricides (thymol, formic and oxalic acids) and the deadly effects of aggressive acaricides (amitraz, fluvalinate and flumethrin) on honeybees (Jack et al., 2021) although mechanical methods (physical removal of ticks, etc.) are less harmful to insects, they have many limitations, in particular: increased labor for beekeepers,



sensitivity to fluctuations in ambient temperature, and minimal differences between lethal concentrations for mites and honeybees (Noël et al., 2020).

Organic methods of controlling *V. destructor* based on behavioral traits associated with the immune system have been actively used. The most important area of such work is the breeding of lines and populations of bees that are resistant to varroasis. Varroa-resistance is the suppression of the reproduction of a mite by bees or the coexistence of bees with a tick so that it does not cause noticeable damage to the latter. The basis of such breeding is the genetics of bees. The goal of such breeding work should be to keep the extent of the invasion constantly low and not increase.

Some of these measures have little proven effectiveness, and they can be harmful to bees. Thus, Rosenkranz et al. (2010) reported that the use of aggressive chemicals (acaricides) to reduce *V. destructor* populations is only temporarily effective precisely because of the emergence of rapidly developing resistant tick individuals. Also Warner et al. (2024) reported the use of thymol, oxalic and formic acids, beta-acids, formamidine, and fluvalinate to control the spread of *V. destructor* was not resistant due to the appearance of resistance in ticks to active substances and the risk to the health of honeybees with an increase in their concentration. The use of chemicals to control the spread of *V. destructor* has shown that the use of synthetic, organic and inorganic chemicals in low doses may be safer for bees. However, their effectiveness is still unknown due to the lack of experimental evidence (Warner et al., 2024). Another study demonstrated that physical tick removal is limited to increasing labor for beekeepers. The ineffectiveness of chemical control measures and the lack of desire to physically remove mites did not leave an opportunity for pest control.

Attempts to create bees that can inhibit the development of the mite or co-exist with it have partially yielded satisfactory results. In particular, mite-resistant bee lines have been bred in the United States. These are the so-called bees with *Varroa* sensitive hygienic behavior (VSH-bees), the essence of which is that bees sense the presence of a tick in cells with sealed brood, open such cells and remove pupae infected with the mite along with the parasite. In this case, the mite's reproductive cycle is interrupted and it dies, even if it remains in the nest. If the cell was printed by mistake, the bees do not remove the pupa, but re-seal it. This behavior of bees is known as re-printing the brood.

There are families where bees are intensively engaged in grooming (cleaning their bodies from mites). At the same time, they bite (do not sting!) mites, separate their legs or damage their shell. Such mites can no longer parasitize bees and are removed from the nest. To assess how effective this behavior of bees is, you need a sealed or sticky bottom of the hive to assess the scree of ticks for two days. Then the crumbling mites need to be examined under a microscope and identify the number of crippled ones. If more than a third (35%) of the crumbled ticks are damaged, then such a family can be considered varroa-resistant. The beekeeper has two options for breeding resistant to *Varroa* mites bees: write out queens of certified lines or breed such insects yourself.

Breeding varroa-resistant bees gives the beekeeper an additional advantage: in this way, he gets rid of the threat of bee damage by a number of other pathogens of bacterial, viral and fungal diseases. Breeding resistant to *Varroa* mites bees is not an easy task, since the mating system of queens creates risks of losing the varroa-resistance trait in subsequent generations of queens. But in the process of breeding bees resistant to ticks, there were also disadvantages. It turns out that parasite-resistant bees in one area, once transported to another, may cease to be so. For example, queens bred in Hawaii, when introduced to continental America, no longer showed signs of resistance. That is, the sign of varroa-resistance is most fully manifested in the local population of bees and ticks. It is also difficult to breed such bees in one, separate apiary. The work can give a positive



result when breeding is performed for all bee colonies of the local population (Gornich M., 2024).

Mechanical and organic methods remain reliable, environmentally friendly and sustainable. Undoubtedly, immune-related behavioral traits of honeybees can provide resistance to mites. Therefore, to limit the spread of the parasite, beekeepers should choose genetically resistant bee colonies created without human intervention. Beekeepers have adopted cultural methods related to the social immunity of honey bees to combat the effects of mite parasitism (Jack et al., 2021; Mondet et al., 2020). For example, some owners of industrial apiaries choose Bee seeds that are resistant to *V. destructor* based on their active hygiene behavior (ability to remove dead brood, identify and remove brood affected by *Varroa*, grooming), (Traynor et al. 2020; Noël et al., 2020; Warner et al., 2024). The population dynamics of *V. destructor* and honeybees show the importance of a break from brood to adult bees. A large time lag in the development of adult bees can disrupt population dynamics and contribute to family death. In this case, a shorter time interval from brood to adult bees will prevent the development of *V. destructor*, and seven years I'll stay strong and healthy. It is also important to note that the *Varroa* mite can die due to seasonal changes (Messan, K., et al., 2020).

Although beekeepers and scientists have developed and tested *V. destructor* control chemicals, they are still not reliable. Chemical controls based on thymol, oxalic and formic acids, formamidine and fluvalinate are not stable. For example, several researchers have reported high mortality in honeybees when using solid acaricides (amitraz, fluvalinate, and flumethrin), even at the recommended doses (Kayode et al., 2014). Although bee mortality is also affected by the outside temperature (below +9 °C), significantly higher mortality of adult bees can be attributed to the methods of using the drug. For example, when using the seepage method, a higher mortality rate of adult bees was recorded than the evaporation method (Coffey et al., 2016). Since mites transmit infectious pathogens, beekeepers believe that the use of chemicals may be the most effective control measure. Mild acaricides (thymol, oxalic and formic acids) are known to be less toxic to adult bees. After long-term evaluation of mild chemicals, they were found to be ineffective due to the rapid development of tick resistance (Truong et al., 2022). However, the rejection of formic, oxalic acids, amitraz, fluvalinate, and other acaricides that control *V. destructor*, especially in summer, does not negate their use and effectiveness (Wu et al., 2024)

Due to the risks associated with synthetic chemical treatments, beekeepers are rapidly shifting their focus to organic chemicals with proven acaricidal efficacy characteristics. Control of *V. destructor* is difficult due to its resistance to widely used acaricides and the lack of recommended methods. However, research continues. Integrating multiple pest control tools and techniques can produce better results than a single strategy (Cremer et al., 2007, Evans et al., 2011).

Sociality in honeybees allowed them to gain properties of social immunity against their enemies, including кліщем *Varroa*. The succession of *V. destructor*-related immune traits prompted beekeepers to evaluate and maintain families with persistent behavioral traits. One of these behavioral signs of honeybees is hygienic behavior.

Many animals exhibit hygienic behavior for a specific purpose. In honeybees, this ability consists of keeping the nest clean, removing dead or diseased brood from the cells, and removing unwanted particles from the body. The hygienic behavior of honeybees was described in the 1930s, when researchers discovered that resistant colonies against American foulbrood rot (AFB) removed diseased larvae (Spivak et al., 2009). After this period, the study of the hygienic behavior of honeybees became much more active. The researchers described hygienic behavior and provided evidence that AFB resistance is the



ability to detect and remove diseased brood before the pathogen reaches the infectious stage of diseased larvae. This reaction of bees is considered common and applicable to all honey families. More recent studies have shown that adult bees from some colonies removed ascospores-infected larvae from their cells within 24 hours, and this made them resistant to the disease (Danka et al., 2013).

Hygiene responses in bee colonies can be complex and sometimes difficult to understand or analyze. The two most important methods, freezing or pinning, are commonly used in analyses to determine the hygienic behavior of honey bee colonies. Similarly, hygienic behavior was used to evaluate honey bee families for resistance to *V. destructor*. Thus, removal of mite-infested brood and removal of frozen larvae are positively correlated ($r = 0.74$). However, Danka et al. (2013) reported a weak correlation. Further research suggested that the variation may be related to individual hygiene behavior in relation to a particular pathogen, rather than just general hygiene. This behavioral specificity led to another form of hygienic behavior known as VSH, whose evolution in honeybees contributed to the selection of resistant insects against *V. destructor*.

Discussion. Discussions among scientists have led to questions such as “what method or strategy can be an effective measure to control *V. destructor*?”. Summarizing the above, we can distinguish four possible ways to deal with a mite *Varroa*:

* Practice safe seven-pit management (good beekeeping practice). In all apiaries, management is a fundamental strategy for successful beekeeping. Management tools and practices are complex because they depend on both individuals and the environment. However, some special rules are implemented in most apiaries. Good management practices at different times of the year are crucial for controlling honeybee ectoparasites. For example, family productivity can be improved by using poor management techniques that can delay *V. destructor* reproduction during spring and summer. It is important to understand the biology of *V. destructor* and assess the level of damage each season of the year to ensure the effectiveness of treatment and prevent possible negative effects of chemical therapy on bees. Therefore, it is necessary to implement a strategic management plan for *V. destructor* and distribute it to beekeepers and scientists. Resolving this situation is not a personal matter for the beekeeper. Rather, it is a daily struggle to limit the spread of the parasite to the entire beekeeping community. In addition to these highlights, key management practices were highlighted to prevent high levels of *V. destructor* damage in seven honeybees at the beginning of the honey harvest season (Rudenko E. V. et al., 2022 Giacobino, A., et al., 2016). The main strategy is to ensure that beekeepers check and report all possible pathologies in families in a timely manner, and apply appropriate control measures to maintain an indicator of the extent of invasion *V. destructor* is below 2%.

* One possible way to preserve the immune properties of honeybees is through selective breeding. The complexity of the " mating " behavior of insects and the difficulties that arise when choosing breeding sites have made it difficult for beekeepers to preserve breeding lines for many generations. For this purpose, suitable breeding sites are proposed to support the genetic resources of honeybees. Recently, Akongte et al. (2024) demonstrated the ability to breed and maintain honey bee families at isolated mating stations.

* To successfully control the parasite, it is necessary to combine several approaches to increase the effectiveness of each of them. As for *V. destructor*, breeding of resistant bee lines is developing rapidly, but chemical treatments should not be forgotten. The ideal situation is to combine stable bee colonies with the recommended mild chemical treatment (thymol and oxalic acid). This can weaken *V. destructor* and



improve the effectiveness of families in slowing down tick reproduction. It is also recommended to apply a mild chemical treatment at an early stage of the honey collection season after selecting resistant strains before the mites multiply rapidly. Mild chemical treatment is expected to interfere with *V. destructor* fertility and create conditions under which resistant honeybee strains can completely neutralize the rest of the population.

Conclusions. Despite the variety of available alternatives for managing the amount of *V. destructor* in bee colonies, a better solution has not yet been made. Based on basic and Applied Research, control measures using mild chemicals (oxalic acid and fluvalinate) were developed and proposed. Today, the combination of zootechnical, mechanical, organic and chemical measures to control the extent of varroasis invasion has confirmed the importance of adopting comprehensive approaches. Researchers should take into account data on geographical location, ecology, damage rates, health impacts of honeybees, and existing management strategies. As a result, organic methods based on the genetic selection of honeybees with immune traits to *V. destructor* and high heredity can be reliable.

References

- Anderson, D. L., Trueman, J. (2000) *Varroa jacobsoni* (Acari: Varroidae) is more than one species. *Experimental & Applied Acarology*, 24, 165–189. <https://doi.org/10.1023/A:1006456720416>
- Aumeier, P., Rosenkranz, P. (2001) Scent or movement of *Varroa destructor* mites does not elicit hygienic behavior by Africanized and Carniolan honey bees. *Apidologie* 32, 253–263. <https://doi.org/10.1051/apido:2001127>
- Bubnič, J., Prešern, J., Pietropaoli, M., Cersini, A., Moškrič, A., Formato, G., Manara, V., Škerl, M. (2024) Integrated pest management strategies to control *Varroa* mites and their effects on viral loads in honey bee colonies. *Insects*, 15, 115. <https://doi.org/10.3390/insects15020115>
- Büchler, R., Kovačić, M., Buchegger, M.; Puškadija, Z., Hoppe, A., Brascamp, E. W. (2020) Evaluation of traits for the selection of *Apis mellifera* for resistance against *Varroa destructor*. *Insects*, 11, 618. <https://doi.org/10.3390/insects11090618>
- Deguine, J. P., Aubertot, J. N., Flor, R. J., Lescourret, F., Wyckhuys, K.A., Ratnadass, A. (2021). Integrated pest management: Good intentions, hard realities. A review. *Agronomy for Sustainable Development*, 41, 38. <https://doi.org/10.1007/s13593-021-00689-w>
- CAB International. (2024) Center for Agriculture and Bioscience. Available online: <https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.107784>
- Coffey, M. F., Breen, J. (2016) The efficacy and tolerability of Api-Bioal as a winter varroacide in a cool temperate climate. *Journal of Apicultural Research*, 55, 65–73. <https://doi.org/10.1080/00218839.2016.1200866>
- Cremer, S., Armitage, S.A., Schmid-Hempel, P. (2007) Social immunity. *Current Biology*, 17, R693–R702. <https://doi.org/10.1016/j.cub.2007.06.008>.
- Danka, R. G., Harris, J. W., Villa, J. D., Dodds, G. E. (2013) Varying congruence of hygienic responses to *Varroa destructor* and freeze-killed brood among different types of honeybees. *Apidologie*, 44, 447–457. <https://doi.org/10.1007/s13592-013-0195-8>
- Dietemann, V.; Pflugfelder, J.; Anderson, D.; Charrière, J.-D.; Chejanovsky, N.; Dainat, B.; de Miranda, J.; Delaplane, K.; Dillier, F.-X.; Fuch, S.; et al. (2012) *Varroa destructor*: Research avenues towards sustainable control. *Journal of Apicultural Research*, 51, 125–132. <https://doi.org/10.3896/IBRA.1.51.1.15>



- Ellis, J. D., Zettel-Nalen, C. M. (2019) Varroa, Varroa Destructor. University of Florida. Available online: https://entnemdept.ufl.edu/creatures/misc/bees/varroa_mite.htm
- Evans, J. D.; Schwarz, R. S. (2011) Bees brought to their knees: Microbes affecting honey bee health. *Trends Microbiology*, 19, 614–620. <https://doi.org/10.1016/j.tim.2011.09.003>
- Giacobino, A., Molineri, A., Cognolo, N. B., Merke, J., Orellano, E.; Bertozzi, E., Masciangelo, G., Pietronave, H., Pacini, A., Salto, C. et al. (2016) Key management practices to prevent high infestation levels of V. destructor in honey bee colonies at the beginning of the honey yield season. *Preventive Veterinary Medicine*, 131, 95–102. <https://doi.org/10.1016/j.prevetmed.2016.07.013>
- Han, B., Wu, J., Wei, Q., Liu, F., Cui, L., Rueppell, O., Xu, S. (2024) Life history stage determines the diet of ecto-parasitic mites on their honey bee hosts. *Nature Communications*, 15, 725. <https://doi.org/10.1038/s41467-024-44915-x>
- Hornich M. (2024) Zootekhnichni i orhanichni metody kontroliu klishcha varroa <https://gornich.com.ua>
- Kayode, L., Lizette, D., Johnson, R.M., Siegfried, B. D., Ellis, M. D. (2014) Effect of amitraz on queen honey bee egg and brood development. *Mellifera*, 14, 33–40.
- Kirrane, M. J., de Guzman, L. I., Holloway, B., Frake, A. M.; Rinderer, T. E., Whelan, P. M. (2014) Phenotypic and genetic analyses of the varroa sensitive hygienic trait in Russian honey bee (Hymenoptera: Apidae) colonies. *PLoS ONE*, 10, e0116672. <https://doi.org/10.1371/journal.pone.0116672>
- Lee, K. V., Steinhauer, N., Rennich, K., Wilson, M. E., Tarpy, D. R., Caron, D. M., Rose, R., Delaplane, K. S.; Baylis, K.; Lengerich, E. J.; et al. (2015) A national survey of managed honey bee 2013–2014 annual colony losses in the USA. *Apidologie*, 46, 292–305. <https://doi.org/10.1007/s13592-015-0356-z>
- Li, A. Y., Cook, S. C., Sonenshine, D. E., Posada-Florez, F., Noble, N., Mowery, J., Gulbranson, C. J., Bauchan, G. R. (2019) Insights into the feeding behaviors and biomechanics of Varroa destructor mites on honey bee pupae using electropenetrography and histology. *Journal of Insect Physiology*, 119, 103950. <https://doi.org/10.1016/j.jinsphys.2019.103950>
- Locke, B. (2016) Natural Varroa mite-surviving *Apis mellifera* honeybee populations. *Apidologie*, 47, 467–482. <https://doi.org/10.1007/s13592-015-0412-8>
- Meisch, C. (1986) Varroa milbe. Geschichte der Ausbreitung, Portrait und Biologie. In *Livre d'or du Centenaire 1886–1986*; Fédération des unions d'apiculteurs du grand-duché de Luxembourg: Luxembourg, pp. 174–177. <https://doi.org/10.3390/agriculture14112094>
- Messan, K., Messan, M. R., Chan, J., DeGrandi-Hoffman, G., Kang, Y. (2020) Population dynamics of Varroa mite and honey bee: Effects of parasitism with age and seasonality. *Ecole Schools*, 440, 109359. <https://doi.org/10.48550/arXiv.2003.12089>
- Mondet, F.; de Miranda, J. R.; Kretzschmar, A.; Le Conte, Y.; Mercer, A.R. (2014) On the front line: Quantitative virus dynamics in honeybee (*Apis mellifera* L.) colonies along a new expansion front of the parasite Varroa destructor. *PLoS Pathogens*, 10, <https://doi.org/10.1371/journal.ppat.1004323>.
- Mondet, F., Beaurepaire, A., McAfee, A., Locke, B., Alaux, C., Blanchard, S., Danka, B., Le Conte, Y. (2020) Honey bee survival mechanisms against the parasite Varroa destructor. A systematic review of phenotypic and genomic research efforts. *International Journal for Parasitology*, 50, 433–447. <https://doi.org/10.1016/j.ijpara.2020.03.005>



- Nazzi, F., Le Conte, Y. (2016) Ecology of *Varroa destructor*. The major ectoparasite of the western honey bee, *Apis mellifera*. *The Annual Review of Entomology*, 61, 417–432. <https://doi.org/10.1146/annurev-ento-010715-023731>
- Noël, A., Le Conte, Y., Mondet, F. (2020) *Varroa destructor*. How does it harm *Apis mellifera* honey bees and what can be done about it? *Emerging Topics in Life Sciences*, 4, 45–57. <https://doi.org/10.1042/ETLS20190125>
- Oddie, M., Büchler, R., Dahle, B., Kovacic, M., Le Conte, Y., Locke, B.; de Miranda, J.R., Mondet, F., Neumann, P. (2018) Rapid parallel evolution overcomes global honey bee parasite. *International Journal of Scientific Reports*, 8, 7704. <https://doi.org/10.1038/s41598-018-26001-7>
- Oddie, M. A. Y., Dahle, B., Neumann, P. (2018) Reduced postcapping period in honey bees surviving *Varroa destructor* by means of natural selection. *Insects*, 9, 149. <https://doi.org/10.3390/insects9040149>
- Peck, D. T., Seeley, T. D. (2019) Mite bombs or robber lures? The roles of drifting and robbing in *Varroa destructor* transmission from collapsing honey bee colonies to their neighbors. *PLoS ONE*, 14, <https://doi.org/10.1371/journal.pone.021839>
- Ramsey, S. D.; Ochoa, R.; Bauchan, G.; Gulbranson, C.; Mowery, J.D.; Cohen, A.; Lim, D.; Joklik, J.; Cicero, J. M.; Ellis, J. D. (2019) *Varroa destructor* feeds primarily on the fat body tissue and not hemolymph. *Proceedings of the National Academy of Sciences*, 116, 1796–1801. <https://doi.org/10.1073/pnas.1818371116>
- Rosenkranz, P., Aumeier, P., Ziegelmann, B. (2010) Biology and control of *Varroa destructor*. *Journal of Invertebrate Pathology*, 103, S96–S119. <https://doi.org/10.1016/j.jip.2009.07.016>
- Roth, M. A., Wilson, J. M., Tignor, K.R., Gross, A. D. (2020) Biology and management of *Varroa destructor* (Mesostigmata: Varroidae) in *Apis mellifera* (Hymenoptera: Apidae) colonies. *Journal of Integrated Pest Management*, 11, 1. <https://doi.org/10.1093/jipm/pmz036>
- Rudenko Ye. V. Maslii I. H (2022) Nalezchna bdzholiarska praktyka v tekhnolohii utrymannia medonosnykh bdzhil. *Naukovo-tekhnichniyi biuleten Instytutu tvarynnytstva NAAN* <https://doi.org/10.32900/2312-8402-2022-128-180-188>
- Schöning, C., Gisder, S., Geiselhardt, S., Kretschmann, I., Bienefeld, K.; Hilker, M.; Genersch, E. (2012) Evidence for damage-dependent hygienic behavior towards *Varroa destructor*-parasitised broods in the western honey bee, *Apis mellifera*. *Journal of Experimental Biology*, 215, 264–271. <https://doi.org/10.1242/jeb.062562>
- Seitz, N., Traynor, K. S., Steinhauer, N., Rennich, K., Wilson, M. E., Ellis, J. D., Rose, R., Tarpy, D. R., Sangili, R. R., Caron, D. M. et al. (2015) A national survey of managed honey bee 2014–2015 annual colony losses in the USA. *Journal of Apicultural Research*, 54, 292–302. <https://doi.org/10.1080/00218839.2016.1153294>
- Spivak, M., Reuter, G. S., Lee, K., Ranum, B. (2009) The future of the MN hygienic stock of bees is in good hands! *American Bee Journal*, 149, 965–967.
- Techer, M. A., Rane, R. V., Grau, M. L., Roberts, J. M. K., Sullivan, S. T., Liachko, I., Childers, A. K., Evans, J. D., Mikheyev, A. S. (2019) Divergent selection following speciation in two ectoparasitic honey bee mites. *Communications Biology*, 2, 357. <https://doi.org/10.1101/512988>
- Traynor, K. S., Mondet, F., De Miranda, J. R., Techer, M., Kowallik, V., Oddie, M. A., Chantawannakul, P., McAfee, A. (2020) *Varroa destructor*: A complex parasite, crippling honey bees worldwide. *Trends in Parasitology*, 36, 592–606. <https://doi.org/10.1016/j.pt.2020.04.004>



- Truong, A. T., Yoo, M. S., Yun, B. R., Kang, J. E., Noh, J., Hwang, T. J., Seo, S. K., Yoon, S. S., Cho, Y. S. (2022) Prevalence and pathogen detection of Varroa and Tropilaelaps mites in Apis mellifera (Hymenoptera, Apidae) apiaries in South Korea. *Journal of Apicultural Research*, 62, 804–812. <https://doi.org/10.1080/00218839.2021.2013425>
- Wagoner, K. M., Millar, J. G., Schal, C., Rueppell, O. (2020) Cuticular pheromones stimulate hygienic behavior in the honey bee (*Apis mellifera*). *International Journal of Scientific Reports*, 10, 7132. <https://doi.org/10.1038/s41598-020-64144-8>
- Warner, S., Pokhrel, L. R., Akula, S. M., Ubah, C. S., Richards, S. L., Jensen, H., Kearney, G.D. (2024) A scoping review on the effects of Varroa mite (*Varroa destructor*) on global honey bee decline. *Science of The Total Environment*, 906, 167492. <https://doi.org/10.1016/j.scitotenv.2023.167492>
- Wu, J.; Liu, F.; Sun, J.; Wei, Q.; Kang, W.; Wang, F.; Zhang, C.; Zhao, M.; Xu, S.; Han, B. (2024) Toxic effects of acaricide fenazaquin on development, hemolymph metabolome, and gut microbiome of honeybee (*Apis mellifera*) larvae. *Chemosphere*, 358, 142207. <https://doi.org/10.1016/j.chemosphere.2024.142207>



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WAYS TO IMPROVE PRODUCTIVE TRAITS IN FINE-FLEECE SHEEP FARMING

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The article presents the results of research aimed at increasing productive traits in fine-fleeced sheep breeding through the use of interbreeding. The aim of the work was to establish the effectiveness of using ram charolais sheep in crossing with ewe of the ascanian fine-fleeced breed of the Tauride type to improve the level of meat productivity and quality of lamb.

In the course of the research, a comparative analysis of the growth and development of young animals was carried out based on the determination of live weight, growth coefficients, absolute and average daily increments in purebred and local peers of different gender and age groups.

It was found that local young animals (F_1) outnumbered purebred peers by live weight by 18.8-40.3% at weaning and 16.9–17.6% at 12 months of age. and it was characterized by higher growth rates and uniform development of the musculoskeletal system.

Local young animals (F_1) are characterized by higher growth rates at weaning by 6.98-8.8%, at 12 months the difference is 4.2-7.6%. according to the average daily growth rates, there is a difference in the range of 20.8 -21.8% at weaning, followed by a decrease to the age of one year, depending on gender..

The intensity of growth and development of young animals can be determined by appropriate indices. Indices of formation intensity, stress and growth uniformity are higher in local young animals

The manifestation of the heterosis effect led to an increase in assimilative activity, which contributed to a more intense accumulation of muscle tissue and the formation of more pronounced meat forms. Balanced feeding and optimal conditions of keeping ensured the realization of the genetic potential of growth and development of crossbreeds, as indicated by the results obtained.

It is proved that the use of ram charole sheep on ascanian fine-fleeced ewe is an effective biotechnological technique that allows obtaining highly productive young meat and wool without compromising the quality of wool raw materials.

The research results confirm the feasibility of introducing systematic interbreeding in the conditions of the Dnieper region to increase the profitability of production and competitiveness of the sheep breeding industry in Ukraine.

Keywords. Ascanian fine-fleeced breed (As), F_1 , local young animals, live weight, growth coefficient. growth intensity indices.



ШЛЯХИ ПОКРАЩЕННЯ ПРОДУКТИВНИХ ОЗНАК В ТОНКОРУННОМУ ВІВЧАРСТВІ

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У статті наведено результати досліджень, спрямованих на підвищення продуктивних ознак у тонкорунному вівчарстві шляхом застосування міжпородного схрещування. Метою роботи було встановлення ефективності використання баранів породи шароле у схрещуванні з матками асканійської тонкорунної породи таврійського типу для покращення рівня м'ясної продуктивності та якості баранини.

У ході досліджень проведено порівняльний аналіз росту та розвитку молодняку на основі встановлення живої маси, коефіцієнтів росту, абсолютних і середньодобових приростів у чистопородних та помісних однолітків різних статевовікових груп.

Встановлено, що помісний молодняк (F_1) переважав чистопородних однолітків за живою масою на на 18.8-40.3% при відлученні та 16.9–17.6 % у 12-місячному віці та характеризувався вищими темпами росту та рівномірним розвитком скелетно-м'язової системи.

Помісний молодняк (F_1) характеризуються вищими коефіцієнтами росту при відлученні на 6.98-8.8%, В 12 місяців різниця становить 4.2-7.6% За показниками середньодобових приростів спостерігається різниця в межах 20.8 - 21.8% при відлученні з подальшим зниженням до річного віку в залежності від статі.

Інтенсивність росту і розвитку молодняку можна визначати відповідними індексами. Індокси інтенсивності формування, напруги та рівномірності росту вище у помісного молодняку

Прояв ефекту гетерозису зумовив підвищення асимілятивної активності, що сприяло інтенсивнішому накопиченню м'язової тканини та формуванню більш виражених м'ясних форм. Збалансована годівля й оптимальні умови утримання забезпечили реалізацію генетичного потенціалу росту і розвитку помісей на що вказують отримані результати.

Доведено, що використання баранів породи шароле на асканійських тонкорунних матках є ефективним біотехнологічним прийомом, який дозволяє отримувати високопродуктивний молодняк м'ясо-вовнового напрямку без погіршення якості вовнової сировини.

Результати досліджень підтверджують доцільність упровадження системного міжпородного схрещування в умовах Придніпровського регіону для підвищення рентабельності виробництва та конкурентоспроможності галузі вівчарства України.

Ключові слова. Асканійська тонкорунна порода (АС), F_1 , помісний молодняк, жива маса, коефіцієнт росту, індекси інтенсивності росту.



Introduction. At all stages of society's development, the main thing is to provide the population with high-quality and complete food products. This problem can be solved only by increasing the production of all types of livestock products. A significant place in this is occupied by purposeful breeding work, taking into account its methods and techniques that are focused on improving the breeding and productive qualities of animals (Poshil, V. I. et al., 2021; Maksym, V et al. 2022).

As an integral part of agro-industrial production in Ukraine, sheep farming remains one of the least intensive industries, the development of which is based mainly on the use of cheap natural pastures and coarse feed with minimal involvement of concentrates. Traditionally, separate zones of specialization have been formed on the territory of the country, differing in the direction of sheep productivity: fine-fleeced, semi-fine-fleeced, semi-coarse-wool and coarse-wool. This division is determined by the climatic, feed and economic conditions of each region (Binkevich, V. Ya., & Yatsenko, I. V., 2015; Ibatullin, I. I. et al., 2014; Pokhyl, V. I., & Mykolajchuk, L. P., 2020).

Different agroecological zones are dominated by local breeds and intra-breed types of sheep, which for a long time were formed under the influence of natural selection and adapted to specific living conditions. Such animal populations remain genetically stable until new requirements for the level of productivity or economic factors determine the needs of society for improving production efficiency (Ibattulin, M., & Svinous, N., 2022).

Using various breeding methods, new types of animals are created that, in accordance with specific agroecological conditions of feeding and keeping, are able to produce competitive high-quality and cheap products. Only under the conditions of scientifically based introduction of new farming methods and breeding approaches is it possible to improve and increase or change the direction of productivity. (Hovhannisyan, V. S., 2018).

Taking into account current trends in the development of World sheep breeding, there is an increase in the economic share of lamb and mutton in the structure of the industry's products. In most countries, revenue from meat sales accounts for more than 90% of the total cost of sheep products, while the share of wool does not exceed 10 %. This leads to a reorientation of production in the direction of meat and meat-wool directions.. At the same time, the share of lamb in the meat balance of the industry is growing, since the population's demand for it is higher than for Lamb obtained from older sheep (Pokhil, V. I. et al., 2021; Owens, F. N. et al., 1993).

According to economic indicators, the most appropriate areas of productive use of sheep in Ukraine are meat and meat-wool, which provide an optimal ratio between the quality of wool and live weight gain. At the same time, increasing the production of lamb and mutton is a way to contribute to the economic activity of the region, ensuring its food security, support sheep farmers, while preserving the environment in this regard, increasing the meat productivity of various breeds, including fine – fleeced ones, characterized by less intensive growth, is one of the priority tasks in breeding work (Iovenko, V. M., & Nezhlukchenko, N. V., 2017; Yefremov, D. V., & Svistula, M. M., 2021).

Improvement of the productive characteristics of domestic sheep breeds of various production directions, especially meat, is carried out by attracting the best global gene pool in this direction. The purpose of its use is to increase the level of meat content in animals of local populations, form a meat type of body structure, and improve its technological qualities (AL-Jaryan, I. L. et al., 2023; Yakovchuk, V. S., & Gorlova, O. D., 2017).



Sheep productivity indicators are important signs for the profitability of any sheep farming, and an increase in their level can be achieved through many methods, such as increasing the percentage of lambs, increasing their weight at weaning, higher quality or more efficient use of feed resources (Alves, Â. G. C. et al., 2018; Zharuk, P. G., & Atanovskaya-Maslyuk, O. I., 2021).

One of the ways to increase the level of sheep productivity is to introduce a crossbreeding system and use the desired characteristics of two or three breeds. The combination of these features improves the maternal or terminal characteristics of the breed, which is improved by the heterosis effect, also known as hybrid energy (strength). (Slavkova, O. P., & Kovaleva, O. M., 2017; Turinsky, V. M. et al., 2020; Behan et al., 2021).

The most effective tool for targeted changes is the use of interbreeding of local sheep with "improving" breeds. This measure helps to increase the level of productivity of native livestock to the indicators of highly productive breeds or create new types of animals that combine the desired properties of the original forms (Sheridan, R. et al., 2003; Zaruba, K. V., & Drozd, S. L., 2018).

The size of an adult is usually considered as the point of maximum muscle mass at which the process of increasing the level of fat deposition begins, and animal growth is defined as an increase in body weight achieved by hypertrophy and hyperplasia to mature size, accompanied by changes in body conformation (Owens et al., 1993; Iovenko, V. M., & Gladiy I. A., 2021).

Although genotype is one of the main factors in assessing the growth and development potential of lambs, its rate can vary under the influence of environmental and feeding factors (Suprun, I. O. et al., 2021).

Heterosis, or hybrid energy, is defined as the increased productivity of the offspring obtained as a result of crossing, compared to the average of the parent forms. Lambs tend to be more resilient at birth, have higher retention rates, and often grow faster. In addition, repair livestock reaches sexual maturity earlier and is more productive. This is especially important for producers who want to breed terminal lambs. All received young animals of the current year of birth are sold (Boyko, N. V. et al., 2022; Herman, Yu. I., & Herman, A. I., 2019).

There are different models of using crossbreeding in sheep breeding. But the practice of interbreeding sheep also has its own regional characteristics. Industrial crossing is a generally recognized effective method for obtaining animals that are genetically and morphologically adapted to a specific complex of ecological and economic conditions. Crossbreeds often have better indicators of viability, growth and productivity compared to purebred animals, especially when moving the latter to other agroecological zones. At the same time, the effectiveness and directions of crossing depend on many factors, including the level of development of the sheep breeding industry itself in a particular region, its resource feed base and breeding policy (Kitaeva, A., & Novichkova, A., 2022; Banks, R., 2022).

Depending on the zonal breeding conditions, the choice of breeds for crossing should be based on scientifically based criteria for the combined ability of the initial genotypes, ensuring further achievement of maximum productivity while maintaining adaptive qualities.

The practice of research in sheep breeding indicates that increasing the profitability of the industry can be directly related to the implementation of programs aimed at increasing the meat productivity of sheep by crossing Queens with producers of intensive meat breeds (Zytvun, I. A. et al., 2018).



During interbreeding, in order to obtain certain desired meat characteristics in crossbreeds, some breeds of sheep are intensively used.. Suffolk, Hampshire, Charolais, Dorper, Southdown and Texel are known for their intensive growth and development, as well as excellent meat characteristics of the carcass. They are generally called Terminal rocks (Yakovchuk, V. S., & Stolbunenko, S. G., 2021; Pokhil V. I. et al., 2022).

The Dnieper region is traditionally dominated by fine-fleeced sheep breeding, which is represented by the ascanian fine-fleeced breed of combined wool and meat productivity. This breed has historically been the basis for the production of merino wool in most farms of the steppe and forest-steppe zones of Ukraine. However, despite its high wool qualities, the level of intensity of morphophysiological processes associated with meat productivity remains insufficient for modern requirements for animal productivity. This, in turn, leads to a gradual reduction in the number of merino-type sheep in farms of various forms of ownership. (Kravchuk, V. et al., 2020; Pokhil V. I. et al., 2021; Bolormaa, S. et al., 2017).

Given this, the actual direction of scientific research is to improve the ascanian fine-fleeced breed by improving its meat qualities without compromising wool productivity. Such studies are conducted on the basis of the Dnipro state agrarian and economic University, where breeding approaches aimed at combining high meat fattening capacity with traditionally good wool quality are developed and tested. The implementation of this direction is important both for restoring the competitiveness of the sheep industry and for increasing its profitability in a market economy.

The aim of the research was to establish the effectiveness of interbreeding ewe of ascanian fine-fleeced sheep and ram charolais sheep producers and to assess the influence of the genotype on the intensity of growth and development of young animals. This area of research has not only an industrial, but also a significant scientific perspective.

Research material and methodology. 100 sheep of the ewe ascanian fine-fleeced breed were selected for research. Sheep were similar in origin, and in groups by age in lambs, live weight were in the same conditions of keeping and feeding. Artificial insemination was performed with sperm with an activity of at least 8 points with their concentration in the ejaculate at the level of 1.9 billion. in 1 ml. and the volume of sperm dose is 0.12 – 0.15 ML.

The object of research was young animals of experimental groups: Group I – purebred ascanian merinos (As), n=20; II – crossbreeds (F₁), n=20.

The study of the growth and development of young animals on the basis of comparative analysis was carried out during key periods of postnatal ontogenesis by periodic individual weighing of animals for 12 months. At the same time, all experimental animals were kept in the same conditions that met the requirements for sheep of this area of productivity. Feeding was carried out according to typical diets, balanced in basic nutrients in accordance with the age and physiological state of the animals.

The relative increase was estimated by the formula proposed by Mayonnaise and improved by S. Brody

$$B = \frac{W_1 - W_0}{0,5 \cdot (W_1 - dW_0)} \cdot 100 \cdot \quad (1)$$

where B is the relative increment, %;
 W₁-final live weight, kg;
 W₀-initial live weight, kg;
 t-Period, days.



In order to select criteria for evaluating the growth patterns of young sheep in early ontogenesis, indicators of the intensity of formation were determined according to the method of Yu. K. Svechin using the formula

$$\Delta t = \frac{W_1 - W_0}{0,5 \cdot (W_2 + W_4)} - \frac{W_6 - W_4}{0,5 \cdot (W_4 + W_6)} \quad (2)$$

where Δt is the intensity of animal formation;

W_2 , W_4 , and W_6 are live weight at 2, 4, and 6 months of age, respectively.

Indicators of growth stress (I_n) and uniformity index (I_r) were studied according to the method of V. P. Kovalenko et al. (Kovalenko, V. P., & Nezhlukchenko, T. I., 2008).

$$I_n = \frac{\Delta t}{VP} \cdot SP \quad (3)$$

$$I_r = \frac{1}{1 + \Delta t} \cdot SP \quad (4)$$

where VP is the relative increment, %;

SP-average daily growth, G.

Biometric data processing was performed using MS Excel software using statistical functions.

Research results. The animal's body is an integral biological system that undergoes a consistent chain of quantitative and qualitative changes in the process of growth and development.

In modern scientific practice, considerable attention is paid to the study of the regularities of these processes under the influence of hereditary factors, conditions of maintenance and the level of feeding. A comprehensive study of such factors makes it possible to carry out early diagnostics of potential productivity, select animals with high reproductive and reproductive qualities, and predict the level of the main breeding characteristics in the livestock.

Postembryonic development of the body is characterized by uneven growth rate of individual tissues and organs in different age periods, as well as constant changes in their morphofunctional ratios. The genetically determined growth program undergoes certain adjustments under the influence of environmental factors, in particular the level of feeding, microclimate and conditions of maintenance.

The productivity potential, which is due to hereditary factors, can be realized only under favorable growing conditions. The influence of paratypical factors during the period of active growth and development of young animals can either stimulate the formation of a highly productive type of animals, or, conversely, inhibit the realization of their hereditary potential.

One of the most informative criteria for assessing growth and development is live weight and the nature of its changes in animals of different gender and age groups. It is this indicator that integrally reflects the intensity of Morphoforming processes that occur in the body at different rates depending on the physiological state. Variations in live weight, in turn, reflect the efficiency of metabolic processes and the ability of the animal to accumulate muscle tissue.

As part of the work, the regularities of growth and development of young sheep of different gender and age groups of the ascanian fine-fleeced breed and crossbreeds of the first generation (F_1) obtained from crossing ewe sheep (As) with sheep-producers of the fertile ram charolais breed were studied. This made it possible to make a comparative



assessment of growth rates, developmental energy, and the influence of genotype on live mass formation.

Table 1

Dynamics of live weight of experimental ram

Age, month	Genotype			
	As		F ₁	
	x±Sx	growth rate	x±Sx	growth rate
At birth	4,3±0,11		4,7±0,13	
1	9,9±0,61	2,23	12,1±0,35	2,57
2	15,8±0,45	3,67	18,9±1,14	4,02
3	20,15±0,65	4,68	24,7±1,25	5,25
4	24,9±0,84	5,79	29,6±1,67	6,30
6	31,6±1,12	7,35	37,9±1,45	8,06
8	37,8±1,71	8,79	44,8±2,15	9,53
12	47,7±2,14	11,09	56,1±2,65	11,94

The results of studies indicate that the live weight of ram ascanian fine-fleeced Lambs is significantly lower compared to local peers for all age periods of development. At birth, there is an advantage of local young animals – the difference is 9.3%, ($p \leq 0.05$) due to the influence of genetic factors of the charolais meat breed.

In the future, the intensity of accumulation of live mass increases more pronounced in cross sheep, which is confirmed by a significant difference in the range of 17.6–22.6%, depending on age. , ($p \leq 0.05$)

An expert assessment of young animals at 12 months of age revealed a 17.6% preference for crossbreeds by live weight ($p \leq 0.05$) relative to purebred peers. This result reflects the increased activity of assimilative processes associated with an increase in live weight. This pattern indicates a pronounced effect of heterosis, which manifests itself during interbreeding.

Local young animals are characterized by increased growth energy and large body measurements, which indicates the harmonious development of the musculoskeletal system. In such animals, there is a more intense and proportional formation of muscle tissue, so that meat forms are more clearly expressed.

To assess the uniformity of development of lambs of experimental groups, the growth coefficient was used, which is an informative indicator of the intensity of growth processes in different age periods and allows you to objectively control the growth rate and the effectiveness of compliance with technological requirements during the cultivation of young animals, which is of great practical importance for improving feeding and breeding methods

Analysis of the dynamics of changes in the growth coefficient Indicator shows that in all age periods of postnatal ontogenesis, a stable dominance of local young animals with the participation of the charole breed over purebred peers of the ascanian fine-fleeced one was observed. By the age of one month, local young animals in this indicator predominate purebred peers by 15.2%, followed by a decrease in the level to 7.6% at the age of 12 months. This indicates a more intensive course of metabolic processes in crossbreeds, which are directly related to the formation of live weight and the overall growth rate of the body. Consequently, the genetic combination of a meat breed with a fine-fleeced one leads to an improvement in metabolic parameters, which is reflected in the increased growth energy of animals.



Full-fledged reproduction of the herd and stable functioning of sheep farms is possible only if there is a high-quality repair reproductive livestock that can ensure the restoration of a productive resource. During interbreeding, there are noticeable differences in the exterior profile of crossbreeds of different age and gender groups. These differences are due to the increased live weight of crossbreeds, which is explained by the heterozygosity of their genotype and more efficient implementation of the hereditary growth potential.

The revealed phenotypic differences between the experimental animals are also due to the manifestation of sexual dimorphism, which manifests itself in more pronounced growth parameters of males and differences in the rate of muscle mass accumulation between the Sexes. This confirms that the genetic combination of different breeds contributes to an increase in the variability of morphological traits, while maintaining the general tendency to improve the level of live weight and subsequent meat productivity.

Based on the results of a study of the dynamics of live weight of experimental yarochni (table. 2) it was found that the use of interbreeding in order to improve meat qualities made it possible to maintain a stable difference in live weight between local and purebred animals in the range of 16.9–22.5%, depending on age. This indicates a positive influence of hereditary factors of producers of improving meat-type breeds on the growth rate and development of young animals obtained from crossing.

The dominance of local ravines over purebred peers was also observed by the growth coefficient, which indicates their higher physiological activity and better intensity of live mass accumulation. The level of preference for this indicator is in the range of 9.25% by the age of 30 days ($p \leq 0.05$). In the future, there is a gradual decline to 4.2% at the annual age. The increased growth rate of local ravines leads to the production of more developed reproductive young animals, which are characterized by a harmonious body structure, balanced measurements and favorable phenotypic characteristics that will be taken into account when forming flocks for further reproduction.

So, summarizing the results obtained, it can be argued that under the same conditions of keeping and feeding, local young animals significantly predominate over purebred peers in terms of the main growth indicators throughout the entire growing period. This confirms the expediency of using interbreeding as an effective tool for increasing the meat productivity of fine-fleeced sheep without significant loss of wool characteristics.

Table 2

Dynamics of live weight of experimental yarochni

Age, month	Genotype			
	As		F ₁	
	x±Sx	growth rate	x±Sx	growth rate
At birth	4,1±0,16		4,6±0,14	
1	9,3±0,46	2,27	11,4±0,44	2,48
2	14,8±0,65	3,61	18,1±1,29	3,93
3	19,1±0,95	4,66	23,2±1,65	5,04
4	23,5±1,25	5,73	28,2±1,72	6,13
6	29,4±1,35	7,17	34,6±1,91	7,52
8	34,8±1,92	8,49	41,2±2,35	8,95
12	44,9±1,75	10,95	52,5±2,54	11,41



Among the main indicators used in zootechnical analysis, the leading place is occupied by the average daily increase in live weight – a relative value that is often considered as a linear function. However, this relationship does not fully reflect the relationship between the age of animals and their growth rates, since it does not take into account fluctuations in the intensity of development in different periods of postembryonic ontogenesis.

For a more objective assessment of the growth intensity of experimental animals based on known live weight indicators, absolute and average daily increments were determined. These parameters are important indicators of growth rates and are used as the main elements of a lifetime assessment of sheep meat productivity. The analysis of these indicators allows us to establish patterns of live mass formation and evaluate the effectiveness of realizing the hereditary growth potential depending on the genotype and conditions of maintenance.

Analysis of the results obtained shows that live weight gains in local young animals (F₁) significantly exceed the indicators of the original ascanian fine-fleeced breed. The average daily growth of crossbreeds in the period (0-4) is in the range of 207.5 G. which is 20.8% higher than their purebred peers. Such features are also observed in terms of the level of absolute increments. In the future, by the age of 12 months, the dominance decreases to the level of 18.3%. These patterns can also be traced in reproductive young animals where local yarks dominate in terms of growth over purebred ones in the period (0-4) in the range of 21.6%, followed by a decrease of 17.3% to 12 months.

The results confirm that merino is a late-maturing breed that is known for its wool productivity, not meat productivity, and therefore shows lower growth and development characteristics compared to crossbreeds.

Assessment of the intensity of growth and development of young sheep, as well as their breed differences, can be carried out by determining the appropriate indices. Indexes help you understand how actively an animal is gaining weight, especially during postnatal ontogenesis. The main ones are: the intensity of formation Δt , the growth Stress Index, I_n , growth uniformity index, I_r (Table 3).

Studies have established that the maximum intensity of formation falls on the age period from birth to four months for all genotypes studied and is in the range of 1.0-1.07.

In the period from birth to 8 months of age, its level increases to a value of 1.33-1.40. during this period, the intensity of forming processes is higher in sheep, with the overall advantage of crossbreeds over purebred peers in this indicator. Crossbreeds are marked by a faster type of formation and have a higher value of this indicator.

Therefore, it can be stated that the intensity of formation is associated with differentiation processes, during which the growth and development of young sheep depends on the genotype of the original breeds.

Table 3

Indices of growth intensity of young animals, age

Indicators	Genotype							
	As				F ₁			
	ram		yarochni		ram		yarochni	
	0-4	0-8	0-4	0-8	0-4	0-8	0-4	0-8
Formation intensity Δt	1,00	1,36	1,01	1,33	1,04	1,40	1,07	1,36
Growth stress index, I_n	1,21	1,19	1,16	1,07	1,48	1,44	1,46	1,29
Growth uniformity index, I_r	0,85	0,59	0,80	0,55	1,01	0,82	0,95	0,65



The growth stress index in agriculture, in particular when raising animals (young sheep), indicates the intensity and intensity of growth of the animal in certain age periods. High values may indicate the maximum use of growth potential, which may be due to various factors, such as the genotype of the animal.

When determining the growth stress index, general patterns were established for all genotypes, where the level of this indicator decreases with age. High indicators of this index are marked by crossbreeds that have an advantage in terms of growth intensity and intensity over their peers (As). It is also noted that the growth stress in any period of ontogenesis depends on the average daily growth.

The growth uniformity index in experimental young animals decreases with increasing age of the animals, which indicates an earlier achievement of puberty in reproductive young animals compared to other farm animals

The proposed analysis of the indices allows us to obtain new data on the patterns of growth and development of young sheep of various origins. It is the growth indices that can be considered as an additional breeding feature.

The results of comprehensive studies confirm that the use of sheep-producers of the fertile ram charolais breed in the system of interbreeding with ewe of the ascanian fine-fleeced breed is an effective method of increasing the productivity of fine-fleeced sheep. This combination of genotypes provides a significant increase in live weight gain in crossbreeds and the formation of more pronounced meat forms.

Discussion. From the point of view of practical breeding of farm animals, forecasting of growth and development parameters is of particular importance, which are closely related to the breeding methods used and the influence of environmental factors, primarily the level and quality of feeding. (Zvidun, I. A. et al. 2018).

In the period from birth to weaning, the highest growth rate is observed, which is due to both the manifestation of the heterosis effect and the high level of milk production of sheep. This stage of development is characterized by the active formation of muscle tissue and the axial and peripheral skeleton, which provides local lambs with an advantage in the rate of accumulation of live mass compared to purebred peers. (Alves, Â. G. C., et al, 2018, Iovenko, V. M., & Gladiy I. A. 2021)

After weaning, under the influence of external factors – in particular, changes in the conditions of detention, a decrease in the level of energy availability of the diet and the transition to independent feed consumption – the growth rate slows down somewhat. However, in the future, this process stabilizes, and the growth of local young animals becomes uniform, physiologically balanced, which indicates the high adaptability of animals and the effective realization of the hereditary potential of meat productivity. (Zharuk, P. G., & Atanovskaya-Maslyuk, O. Y. 2021, AL-Jaryan, I. L at al.,. 2023).

When carrying out interbreeding, the optimal level of feeding of lambs in the period from birth to 12 months of age ensured intensive growth, harmonious development of animals and the formation of pronounced meat productivity in them, which reflects the effectiveness of realizing the genetic potential in local young animals (Owens, F. N., et al., 1993, Pokhil, V. I., and others 2021)

Our studies confirm the literature data on the effectiveness of industrial crossbreeding in sheep breeding. When carrying out such works, it is necessary to constantly monitor the intensity of growth and development of the obtained young animals at different stages of postnatal ontogenesis and, if necessary, influence the level of assimilative processes in the body, while interbreeding in sheep breeding can act not only as an effective breeding tool, but also as an important biotechnological technique that allows simultaneously improving meat productivity and preserving the quality of



wool, increasing the overall profitability of the industry and its competitiveness in modern production conditions.

Conclusions.

1. The use of ram charolais sheep in crossing with ewe of the ascanian fine-fleeced breed provides an increase in the live weight of local young animals by 18.8–40.3% at weaning and 16.9-17.6% at 12 months of age.

2. Local young animals (F₁) are characterized by higher growth rates at weaning by 6.98-8.8%, at 12 months the difference is 4.2-7.6% according to the average daily growth rates, there is a difference in the range of 20.8 -21.8% at weaning, followed by a decrease to the age of one year, depending on gender.

3. The intensity of growth and development of young animals can be determined by appropriate indices. The indices of formation intensity, stress, and growth uniformity are higher in local young animals.

4. The use of sheep-producers of the ram charolais breed in the system of interbreeding with ewe of the ascanian fine-fleeced breed is an effective method of increasing the productivity of fine-fleeced sheep.

References

- Pokhil, V. I., Pokhil, O. M., & Mykolajchuk, L. P. (2021). *Metodolohichni osnovy formuvannia miasnoho vivcharstva Ukrainy* [Methodological foundations of the formation of meat sheep breeding in Ukraine.]. *Rozvytok Prydniprovskoho rehionu : ahroekolohichni aspekt* [Development of the Dnieper region: agroecological aspect] (pp.632-649). Dnipro : Lira. Available at: <https://dspace.dsau.dp.ua/handle/123456789/8125>. (in Ukrainian)
- Maksym, V., Chemerys, V., Dushka, V., & Kuz, M. (2022). Formuvannia kapitalu pidpriemstv z vyrobnytstva produktsii tvarynnytstva v Ukraini [Capital formation of livestock production enterprises in Ukraine] *Naukovyi visnyk Lvivskoho natsionalnoho universytetu veterynarnoi medytsyny ta biotekhnolohii imeni S.Z. Gzhytskoho. Seriiia : Ekonomichni nauky – Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series Economical Sciences*. Lviv, 24(100), 40-46. <https://doi.org/10.32718/nvlvet-e10007> (in Ukrainian)
- Binkevych, V. Ya., & Yatsenko, I. V. (2015). Vivcharstvo Ukrainy: osnovni tendentsii funktsionuvannia haluzi. [Sheep breeding in Ukraine: main trends in the functioning of the industry]. *Naukovyi visnyk Lvivskoho natsionalnoho universytetu veterynarnoi medytsyny ta biotekhnolohii im. Gzhytskoho – Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies*. Lviv, 1(2), 212-220. (in Ukrainian)
- Ibatullin, I. I., Zhukorsky, O. M., Vdovichenko, Yu. V., Zharuk, P. G., Kudryk, N. A., & Zharuk, L. V. (2014). Vivcharstvo Ukrainy v svitli tendentsii svitovoho rozvytku. [Sheep breeding in Ukraine in the light of global development trends]. *Efektivne tvarynnytstvo – Efficient animal husbandry*. Lviv, (2), 12-16. (in Ukrainian).
- Pokhyl, V. I., & Mykolajchuk, L. P. (2020). Miasna produktyvnist molodniaku ovets riznoho pokhodzhennia [Meat productivity of young sheep animals of different origin]. *Theoretical and Applied Veterinary Medicine*, 8(1), 26-30. (in Ukrainian). <https://doi.org/10.32819/2020.81005>
- Ibattulin, M., & Svinous, N. (2022). Udoskonalennia derzhavnoi pidtrymky vyrobnytstva miasa v konteksti prodovolchoho zabezpechennia naseleння Ukrainy [Improving state support for meat production in the context of food security for the population of Ukraine] *Ekonomichni dyskurs – The economic discourse*. Ternopil, (1-2), 23-33. (in Ukrainian). <https://doi.org/doi:10.36742/2410-0919-2022-1-3>



- Hovhannesian, V. S. (2018). *Suchasnyi stan vyrobnytstva produktsii vivcharstva na rynku Ukrainy*. [The modern state of production of sheep breeding in the Ukrainian market]. *Skhidna Yevropa: Ekonomika, Biznes ta Upravlinnia – Eastern Europe: Economy, Business and Management*. Dnipro, 4 (15), 111-117. (in Ukrainian). Available at: https://easterneurope-ebm.in.ua/journal/15_2018/19.pdf
- Iovenko, V. M., & Nezhlukchenko, N. V. (2017). Produktivni ta vidtvorivualni yakosti ovets tavriskoho typu askaniiskoi tonkorunnoi porody. [The productive and reproductive qualities of sheep Tavrian type of the Ascanian fine fleect breed] *Vivcharstvo ta kozivnytstvo – Sheep and goat farming*. Nova Kakhovka, 2, 72-80. (in Ukrainian). Available at: <https://www.ascaniansc.in.ua/images/%202%20-%202017.pdf>
- Efremov, D. V., Svistula, M. M., & Horb, S. V. (2021). *Formuvannia produktyvnykh oznak u remontnykh yarak miasnykh henotypiv za riznykh rivniv yikh enerhetychnoho ta proteinovoho zhyvlennia*. [Formation of productive traits in meat genotypes replacement ewe-lambs according to the different levels of their energy and protein nutrition] *Naukovyi Visnyk «Askaniia-Nova» – Scientific Bulletin «Askania-Nova»*. Nova Kakhovka, 14, 100-110. (in Ukrainian). <https://doi.org/10.33694/2617-0787>
- AL-Jaryan, I. L., AL-Thuwaini, T. M., Merzah, L. H., & Alkhammas, A. H. (2023). Reproductive Physiology and Advanced Technologies in Sheep Reproduction. *Reviews in Agricultural Science*, 11, 171–180. https://doi.org/10.7831/ras.11.0_171
- Yakovchuk, V. S., & Horlova, O. D. (2017). Orhanichne vyrobnytstvo molodoi baranyny na osnovi ekolohichno bezpechnoho utrymanna. [Organic production of young lamb based on environmentally friendly husbandry]. *Vivcharstvo ta kozivnytstvo – Sheep and goat farming*. Nova Kakhovka, 2, 165-177. (in Ukrainian). Available at: <https://www.ascaniansc.in.ua/images/%202%20-%202017.pdf>
- Alves, Â. G. C., Ribeiro, M. N., Arandas, J. K. G., & Alves, R. R. N. (2018). *Animal Domestication and Ethnozootechny*. *Ethnozoology*, 151–165. <https://doi.org/10.1016/b978-0-12-809913-1.00009-0>
- Zharuk, P. G., Atanovska-Masliuk, O. Y., & Masliuk, A. M. (2021). *Produktivnist pomisei, oderzhanykh vid vivtsematok askaniiskoi miaso-vovnovoi porody ta baraniv porody vandeï*. [Productivity of hybrids obtained from Ascanian meat-and-wool breed ewes and vandeï rams]. *Naukovyi Visnyk «Askaniia-Nova» – Scientific Bulletin «Askania-Nova»*. Nova Kakhovka, 14, 54-66. (in Ukrainian). <https://doi.org/10.33694/2617-0787>
- Slavkova, O. P., & Kovaleva, O. M. (2017). Perspektyvy rozvytku vivcharstva [Development of sheep industry perspectives]. *Hlobalni ta natsionalni problemy ekonomiky – Global and national problems of economics*. Odesa, 19, 101-106. (in Ukrainian). Available at: <http://global-national.in.ua/archive/19-2017/22.pdf>
- Turinskyi, V. M., Bogdanova, K. S., & Bogdanova, N. V. (2020). Stan ta tendentsii rozvytku konkurentozdatnoho vivcharstva v Ukraini [State and trends of the development of competitive sheep breeding in Ukraine] *Naukovo-tekhnichnyi biuleten Instytutu tvarynnytstva NAAN – Scientific and Technical Bulletin of the Institute of Animal Science of the National Academy of Agrarian Science of Ukraine*. Kharkiv, 124, 52-61. (in Ukrainian). <https://doi.org/10.32900/2312-8402-2020-124-203-212>
- Behan, A. A., Akhtar, M. T., Loh, T. C., Fakurazi, S., Kaka, U., Muhamad, A., & Samsudin, A. A. (2021). Meat Quality, Fatty Acid Content and NMR Metabolic



- Profile of Dorper Sheep Supplemented with Bypass Fats. *Foods (Basel, Switzerland)*, 10(5), 1133. <https://doi.org/10.3390/foods10051133>
- Sheridan, R., Hoffman, L. C., & Ferreira, A. V. (2003). Meat quality of Boer goat kids and Mutton Merino lambs: Sensory meat evaluation. *Animal Science*, 76(1), 73–79. <https://doi.org/10.1017/S1357729800053339>
- Zaruba, K. V., & Drozd, S. L. (2018). Miasna produktyvnist molodniaku za promysloвого skhreshchuvannia ovets askaniiskoi tonkorunnoi porody z miasnyimi henotypami. [Meat productivity of young animals during industrial crossing of Ascanian fine-wool sheep with meat genotypes] *Vivcharstvo ta kozivnytstvo – Sheep and goat farming*. Nova Kakhovka, 3, 39-47. (in Ukrainian). Available at: <https://ascaniansc.in.ua/images/17%202.pdf>
- Owens, F. N., Dubeski, P., & Hanson, C. F. (1993). Factors that alter growth and development of ruminants. *Journal of Animal Science*, 71(11), 3138–3150. <https://doi.org/10.2527/1993.71113138x>
- Iovenko, V. M., & Gladiy I. A. (2021). Kharakterystyka rostu, rozvytku ta miasnykh yakosti molodniaku ovets riznykh henotypiv. [Characteristics of growth, development and meat qualities of young sheep of different genotypes] *Visnyk ahrarnoi nauky Prychornomia*, 1(109), 69-76. (in Ukrainian). [https://doi.org/10.31521/2313-092X/2021-1\(109\)-9](https://doi.org/10.31521/2313-092X/2021-1(109)-9)
- Suprun, I. O., Getya, A. A., & Fichak, V. M. (2021). Suchasnyi stan ta perspektyvy rozvytku vivcharstva v Ukraini [Current status and prospects for the development of sheep breeding in Ukraine]. *Tekhnolohiia vyrobnytstva i pererobky produktsii tvarynnytstva*, (2), 21-31. (in Ukrainian). <https://doi.org/10.33245/2310-9289-2021-166-2-21-31>
- Boyko, N. V., Korkh, I. V., Pomitun, I. A., Kosova, N. O., & Chyhrynov, Y. I. (2022). Productive traits and feeding behavior of rams under different feeding conditions. *Animal Breeding and Genetics*, 63, 20-28. <https://doi.org/10.31073/abg.63.02>
- Herman, Y. I., & Herman, A. I. (2019). Udoshkonalennia selektsiinykh pryiomiv otsinky ovets romanivskoi porody. [Improving breeding techniques for evaluating Romanov sheep]. *Rozvedennia i henetyka tvaryn*, 57, 45-50. (in Ukrainian). <https://doi.org/10.31073/abg.57.06>
- Kitaeva, A., & Novichkova, A. (2022). Tryvalist vnutrishnoutrobnoho periodu i typ narodzhennia yahniat u vivtsematok riznogo typu konstytutsii [Duration of the intrauterine period and type of lamb birth in ewes of different constitutional types]. *Ahrarnyi visnyk Prychornomia*, (102-103), 87-91. (in Ukrainian). <https://doi.org/10.37000/abbsl.2022.102.14>
- Banks, R. (2022). Long-term Challenges for Animal Breeding. *Animal Breeding and Genetics*, 385–409. https://doi.org/10.1007/978-1-0716-2460-9_1123
- Pomitun, I. A., Korkh, I. V., Kosova, N. O., Boyko, N. V., Pankiv, L. P., & Ryazanov, P. O. (2018). Osoblyvosti formuvannia miasnosti pry vyroshchuvanni barantsiv do riznoi zabiinoi masy. [Features of meat formation when raising rams to different slaughter weights]. *Sheep and goat farming*. Nova Kakhovka, 3, 39-47. (in Ukrainian). Available at: <https://ascaniansc.in.ua/images/17%202.pdf>
- Yakovchuk, V. S., & Stolbunenko, S. G. (2021). Vidhodivelni i miasni yakosti molodniaku ovets pry promyslovomu skhreshchuvanni [Fattening and meat qualities of young sheep during industrial crossbreeding]. *Naukovyi Visnyk «Askaniia-Nova» – Scientific Bulletin «Askania-Nova»*. Nova Kakhovka, 14, 249-263. (in Ukrainian). <https://doi.org/10.33694/2617-0787-2021-1-14-249-263>
- Pokhil, V. I., Turinsky, V. M., Pokhil, O. M. & Pavlenko, R. A. (2022). Promyslove skhreshchuvannia u merynosovomu vivcharstvi Prydniprovia [Industrial



- crossbreeding in Merino sheep breeding in the Dnieper region], Aktualni problemy pidvyshchennia yakosti ta bezpeka vyrobnytstva y pererobky produktsii tvarynnytstva ta akvakultury [Current issues of improving the quality and safety of production and processing of livestock and aquaculture products]. Dnipro. (in Ukrainian). Available at: <https://dspace.dsau.dp.ua/handle/123456789/8646>
- Pokhil, V. I., Turinsky, V. M., Mykolaychuk, L. P., Pokhil, O. M., Bogdanova, N. V., Rozhkov, V. V. & Pavlenko, R. A. (2021) Henetychni aspekty stvorennia zavodskoho typu askaniiskoi tonkorunnoi porody ovets. [Genetic aspects of creating a factory type of the Ascanian fine-wool sheep breed]. *Theory and practice of modern science : I International Scientific and Theoretical Conference*, 91-93. Available at: <http://dspace.dsau.dp.ua/jspui/handle/123456789/5365>
- Kravchuk, V., Babynets, T., Postelha, C., & Smolyar, V. (2020). *Ohliad i systematyzatsiia faktoriv, yaki vplyvaiut na yakist produktsii vivcharstva*. [Overview and systematization of factors that influence the quality of sheep farming products]. *Tekhniko-tehnolohichni aspekty rozvytku ta vyprobuvannia novoi tekhniky i tekhnolohii dlia silskoho gospodarstva Ukrainy*, 26(40), 308-319. [https://doi.org/10.31473/2305-5987-2020-1-26\(40\)-29](https://doi.org/10.31473/2305-5987-2020-1-26(40)-29)
- Bolormaa, S., Brown, D. J., Swan, A. A., van der Werf, J. H. J., Hayes, B. J., & Daetwyler, H. D. (2017). Genomic prediction of reproduction traits for Merino sheep. *Animal Genetics*, 48(3), 338–348. <https://doi.org/10.1111/age.12541>
- Kovalenko, V. P., & Nezhlukchenko, T. I. (2008). *Vplyv liniino-porodnoi hibrydzatsii na intensyvniat rostu svynei*. [The impact of lineal-breed hybridization on the growth rate of pigs]. *Tavriiskyi naukovyi visnyk*, 58(2), 26-29.