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Dispersion and component analysis of the influence of genotype on the formation of performance traits in fattening pigs

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Abstract. The relevance of the work was determined by the need to find effective genetic combinations to increase productivity and ensure the stability of growth processes in animals of modern "commercial genotypes". The aim of the study was to determine the role of genotype as a determining factor in the growth and development of pigs using one-factor dispersion analysis and principal component analysis. The experiment involved 120 fattening pigs, and the test animals were divided into three groups. Group I: a combination of Large White and Landrace sows with Duroc boars of Canadian selection (Genesus) Group II: a combination of Large White and Landrace sows with Pietrain boars of French selection (Axiom) and Group III: a combination of Large White and Landrace sows with boars of the terminal line "Maxter" selected by the company "France Hybrides". The assessment was based on the live weight of pigs of different genotypes at the age of 77-203 days, absolute and average daily gains in separate age periods, as well as the age at which they reached a pre-slaughter live weight of 80, 100, 120 and 140 kg. The results of the variance analysis showed a significant influence of genotype on all studied indicators. The greatest effect of the "genotype" factor was observed for live weight at 154 days of age (43.27%), absolute and average daily gains in the period from 182 to 203 days (44.97%), as well as the age at which live weight of 100 kg was reached (44.72%). It was confirmed that pigs in group I were inferior to their peers in other groups in the early stages of life, but in the later stages of fattening, they demonstrated a significant advantage in terms of gains and growth intensity. Animals in groups II and III were characterised by similar growth rates and did not differ statistically significantly from each other. Principal component analysis allowed to identify two stages in the process of live weight formation: the first (130-155 days) and the second (180-205 days), which are determined by different growth mechanisms and are practically independent of each other. The results confirm the key role of genotype in the formation of productive traits in pigs and can be used in the development of breeding programmes and the improvement of fattening systems

Keywords: breeding; breed composition; live weight; gains; principal components

Introduction

Pig farming is one of the leading sectors of animal husbandry, ensuring food security and stability in the agricultural sector, as well as accounting for a significant share of meat products on the world market. Improving the productive qualities of pigs, in particular growth intensity, average daily gains, feed conversion and meat and fat productivity, remains a key task for modern pig farming. One of the main internal factors determining an animal's potential is its genotype, which influences the realisation of hereditary productivity, but its manifestations can vary significantly depending on feeding and housing conditions. Therefore, quantitative determination of the contribution of genotype to the variability of productive traits and identification of key growth stages is an important prerequisite for effective selection and improvement of intensive fattening technologies (Wusheng & Jørgen, 2022).

Researchers S.W. Kim *et al.* (2024) conducted a comprehensive review of the current state of global pig farming, covering production structure, major breeds and regional characteristics. The study also analyses current research trends, including genetics, feeding and animal health management, which allows the identification of key factors affecting pig productivity in different countries. A.O.K. Adesehinwa *et al.* (2024) examined the characteristics of pig production in Africa, including socio-economic and environmental factors. The authors identified the main problems in the industry, such as limited access to quality genetic material and feed, and determined the prospects for development through the introduction of innovative technologies and optimisation of genetic resources to increase herd productivity and sustainability. According to FAO estimates, pork is the most consumed meat in the world, accounting for 34 - 36% of total global meat consumption, ahead of poultry (33%), beef (24%), and goat and sheep meat (5%). Improving the productive traits of pigs: growth rates, average daily gains, live weight, feed conversion, and meat and fat quality are relevant tasks of modern breeding and production and a key feature for virtually all major breeds in countries with developed pig farming (Ritchie *et al.*, 2023).

According to V.V. Voloshinov *et al.* (2024) , the effective use of imported breeding boars increases carcass meat yield, young stock growth rate, and reduces feed costs per unit of production. The heterosis effect stimulates the productivity of first-generation hybrid young stock and is genetically determined, but it is difficult to obtain, especially for fattening traits. Therefore, the authors recommend that in order to increase average daily gains and reduce the age to 100 kg, it is necessary to take into account the compatibility of boars and sows, as well as the influence of the boar's genotype on the realisation of the genetic potential of the productive traits of the offspring. The selection work of O. Mykhalko *et al.* (2022) was aimed at increasing meatiness and growth rate with minimal feed and resource costs, which has always been the main criterion for the main breeds, types and lines in pig breeding. Genotype as an internal factor determines the potential of an animal: it determines the extent to which growth, fattening and meat productivity can be fully realised under favourable conditions. B. Lebret & M. Čandek-Potokar (2021) noted in their review that it is hereditary factors that form the basis of pork production and determine the quality of carcasses and fresh meat, while technological parameters mainly influence the realisation of this potential. However, in practice, the potential of the genotype is often limited by paratypic factors: feeding, housing conditions, microclimate, health, management characteristics in the relevant area, etc. F. Bussiman *et al.* (2025), studying genotype-environment interactions using high-dimensional ecological data, showed that even animals with high genetic potential can demonstrate different growth and meat production rates depending on housing conditions. Therefore, to understand productivity, it is necessary not only to compare individual lines or breeds, but also to apply methods that allow to quantitatively assess the contribution of the genotype to the overall variability of traits and identify the components through which this contribution manifests itself.

One of the key statistical tools for solving these problems is analysis of variance (ANOVA), which enables to determine whether there are statistically significant differences between groups, for example, between different genotypes, and to estimate the proportion (share) of variation attributable to genotype differences. At the same time, for many productive traits, it is important to determine which characteristics have the greatest variation because they correlate with each other. To this end, S. Panda *et al.* (2020) used component methods, in particular Principal Component Analysis (PCA), which allowed to reduce the dimensionality of multidimensional data, identify the main "trait complexes" that form productive orientation, and understand the relationships between them.

There are examples of the use of such approaches in the literature. In particular, in the work of H.E. Green *et al.* (2024), PCA was used to identify biotypes that link growth traits, carcass quality, and body structure, as well as to search for candidate genes associated with these biotypes. This provides a deeper understanding of which traits (or combinations thereof) are most important from a breeding perspective. Another example is the study by P.A. Vashchenko *et al.* (2023), which examined the MC4R genotype in combination with feeding levels in Ukraine. The authors found that the interaction between genotype and feeding significantly affects live weight, average daily gains, and subcutaneous fat thickness. This emphasises that the genotype does not act in isolation, and the realisation of its potential depends on paratype factors.

At the same time, although there are numerous studies devoted to individual genotypes or marker genetic effects, the literature does not always contain studies that comprehensively combine variance analysis (assessment of the strength of the genotype's influence on different age intervals, absolute and average daily gains, age at which a certain weight is reached) and component analysis (derivation of the main components that summarise production traits). This approach allows for a deeper understanding of: during which growth periods the genotype is most active; which traits have the greatest variability; how growth indicators and age at reaching live weight correlate. The aim of the study was to determine the influence of genotype on the productive traits of fattening pigs by applying variance and component analysis.

Materials and Methods

The experiments were conducted throughout 2023 at a commercial pork production enterprise, the Agricultural Production Cooperative Agrofirma "Myh-Servis-Ahro" in the Mykolaiv region. Pork production at the enterprise was carried out according to the principles of industrial technology with the corresponding organisation of production processes. The study involved 120 heads of finishing pig young stock, which were divided into three groups of 40 heads each. The first group comprised young stock obtained from Large White × Landrace (LW × L) sows crossed with Duroc (D) boars of Canadian selection (Genesus). The second group was formed by crossbred young stock from (LW × L) sows and Pietrain (P) boars of French selection (Axiom). The third group was represented by animals obtained from (LW × L) sows combined with "Maxter" (Mx) terminal line boars from the "France Hybrides" company. The assessment of finishing qualities was conducted when the animals reached live weights of 80, 100, 120, and 140 kg.

As part of the scientific and economic experiment, the groups were formed using the pair-analogue method (Ibatulin *et al.,* 2017) taking into account similarities in live weight and the development of the test animals during the rearing period (4-11 weeks), which corresponded to the comparative period, and no significant differences in live weight were observed in the experimental groups. The experimental pigs were evaluated for fattening indicators: age at reaching live weight of 80, 100, 120 and 140 kg, absolute and average daily gain (g), amount of feed consumed and feed conversion ratios (kg) at the stages of reaching the specified conditions in accordance with the methods (Ladyka & Khmelnychiy, 2023).

The conditions of keeping the experimental animals complied with the Departmental norms of technological planning (2005) and the recommendations of genetic companies for keeping animals. The rules for handling the experimental animals complied with Ukrainian legislation (Order of the Ministry for Development of Economy, Trade and Agriculture of Ukraine No. 224, 2012). The fattening piglets were divided into two fattening stages. The first stage ("Grower") included animals with a live weight of 30-60 kg, which received 2.4-2.6 kg of compound feed per head per day; they were kept in pens of 30 heads on a concrete slatted floor with an area of 0.65 m^2 per head. The second stage ("Finisher") included animals weighing 61-140 kg, which were fed compound feed at a rate of 2.8-3.2 kg per head per day; they were kept on a concrete slatted floor with an area of 0.85-1.2 m^2 per head.

Young animals of different ages and weights were fed with three types of specialised compound feed: "Grower", "Finisher" and "Final Finisher", produced in the farm's own compound feed workshop in accordance with the feeding strategies developed on the farm (Provoratorov, 2007; Voloshchuk, 2014). To balance the diets of fattening young animals, protein, mineral and vitamin supplements and premixes produced by "Koudijs Ukraine" LLC were used. The animals were watered through nipple drinkers located at levels appropriate to their age. The premises were ventilated using exhaust shaft fans and aerodynamic supply valves to create negative pressure. Manure was removed using a periodic vacuum-gravity system from tubs located under the slatted floor. Veterinary treatments in the experimental and control groups were carried out identically in accordance with the scheme adopted on the farm.

The results obtained were processed using statistical methods with the use of computer technologies and the STATISTICA v. 7.0 software package in accordance with generally accepted methods (Feinstein, 1996; Kramarenko *et al.*, 2019).

Results and Discussion

The data obtained indicate that genotype significantly influences the formation of productive traits in pigs, in particular the dynamics of live weight and growth intensity at different ages. Already at the initial stages of fattening, statistically significant differences between the studied groups can be observed, which change in severity over time. The most pronounced effect of genotype is observed in the middle age periods, while in the final stages of fattening, some of the differences are levelled out. A one-factor analysis of variance showed that genotype is a statistically significant factor determining the live weight of fattening pigs at all studied age periods (in all cases $p \leqslant 0.001$), which emphasises its key role in the formation of productive qualities of animals (Table 1).

Table 1. *Influence of pig genotype on their live weight during fattening (one-factor analysis of variance)*

Characteristic (age, days)	*SS* Effect	*df* Effect	*MS* Effect	*SS* Error	*df* Error	*MS* Error	*F*	*P*	η^2 (%)
LWe –77	111.05	2	55.53	215.45	117	1.84	30.15	<0.001	34.01
LWe –133	205.40	2	102.70	449.40	117	3.84	26.74	<0.001	31.37
LWe –154	449.20	2	224.60	589.03	102	5.77	38.89	<0.001	43.27
LWe –182	38.82	2	19.41	240.17	87	2.76	7.03	<0.001	13.92
LWe –203	72.83	2	36.41	271.12	72	3.77	9.67	<0.001	21.17

Note: LWe – live weight
Source: authors' own work

A characteristic feature of the results obtained is that the influence of the "genotype" factor on the live weight of animals gradually increased and reached its maximum level at the age of 154 days (43.27%). At the same time, at 203 days of age, the magnitude of intergroup differences decreased almost twice, which indicates a certain levelling of indicators in the later stages of fattening. A generalised analysis of the average live weights of pigs of different genotypes showed that animals of Group I (♀(LW×L)×♂D) lagged behind their contemporaries from other groups at the early stages of development (77, 133, and 154 days), but at 182 and 203 days they significantly surpassed them. Pigs of Groups II (♀(LW×L)×♂P) and III (♀(LW×L)×♂Mk) showed no statistically significant differences in live weight during most of the studied periods, which indicates the similarity of their growth rates. The results of one-factor analysis of variance confirm the significant influence of genotype on absolute live weight gains at different age intervals of fattening (in all cases $p < 0.001$) (Table 2).

***Table 2.** Influence of pig genotype on absolute live weight gains during fattening (one-factor analysis of variance)*

Characteristic (age, days)	*SS* Effect	*df* Effect	*MS* Effect	*SS* Error	*df* Error	*MS* Error	*F*	*P*	η^2 (%)
AG (77-133)	42.45	2	21.22	206.85	117	1.77	12.01	<0.001	17.03
AG (133-154)	212.93	2	106.47	428.06	102	4.20	25.37	<0.001	33.22
AG (154-182)	196.47	2	98.23	307.93	87	3.54	27.75	<0.001	38.95
AG (182-203)	267.55	2	133.77	327.44	72	4.55	29.42	<0.001	44.97

Note: AG – absolute gain
Source: authors' own work

Unlike live weight indicators, the influence of the "genotype" factor on absolute gains tended to gradually increase: from 17.03% between 77 and 133 days to a maximum of 44.97% between 182 and 203 days. This indicates that the genetic characteristics of animals are more pronounced in the later stages of fattening, when the body reaches high growth rates and tissue formation intensity.

Summarising the results of the analysis of absolute live weight gains of pigs depending on their genotype, it should be noted that animals of group I (♀(LW×L)×♂D) in the periods 77-133 and 133-154 days were inferior to their peers in other groups in terms of growth intensity. At the same time, in the following age intervals (154-182 and 184-203 days), they already had a significant advantage in terms of growth. During most of the study periods, the fattening young animals of groups II and III did not show statistically significant differences between each other in terms of absolute live weight gains, which indicates a similar level of their growth capacity. The data obtained indicate that animals in group I are characterised by a strategy of "late realisation" of genetic potential: slower initial growth is compensated by intensive growth in the final stages of fattening. This may be due to the peculiarities of physiological development and the formation of muscle tissue at a later stage. Groups II and III show more uniform growth, without sharp peak changes in intensity, which may indicate faster realisation of potential at an early age and stable productivity throughout the fattening period. In practical terms, this means that when planning feeding programmes and the duration of fattening, it is advisable to take the genotype into account: animals in group I may need a longer period to realise their full potential, while groups II and III achieve stable performance faster. This approach will increase feed efficiency and production profitability.

The results of one-factor analysis of variance confirm the presence of a significant influence of genotype on the average daily weight gain of pigs at different ages of fattening (in all cases $p < 0.001$) (Table 3). Similar to absolute gains, the strength of the influence of the "genotype" factor on average daily gains tended to increase gradually, which emphasises the importance of genetic characteristics in determining the growth rate of animals in the later stages of fattening.

***Table 3.** Influence of pig genotype on average daily weight gain during fattening (one-factor analysis of variance)*

Characteristic (age, days)	*SS* Effect	*df* Effect	*MS* Effect	*SS* Error	*df* Error	*MS* Error	*F*	*P*	η^2 (%)
ADG (77-133)	13,536.35	2	6,768.18	65,959.82	117	563.76	12.01	<0.001	17.03

Table 3. *Continued*

Characteristic (age, days)	*SS* Effect	*df* Effect	*MS* Effect	*SS* Error	*df* Error	*MS* Error	*F*	*P*	η^2 (%)
ADG (133-154)	35,913.87	2	17,956.93	72,197.19	102	707.82	25.37	<0.001	33.22
ADG (154-182)	17,820.11	2	8,910.05	27,930.46	87	321.04	27.75	<0.001	38.95
ADG (182-203)	16,852.27	2	8,426.14	20,624.84	72	286.46	29.42	<0.001	44.97

Note: ADG – average daily gain
Source: authors' own work

Summarising the results of the analysis of average daily weight gains of pigs depending on their genotype, it can be noted that in animals of group I (♀(LW×L)×♂D) maintained relatively stable growth rates throughout the observation period, ranging between 900 and 915 g, with no substantial fluctuations between age intervals. In contrast, the young pigs of Groups II (♀(LW×L)×♂P) and III (♀(LW×L)×♂Mk) showed a clear pattern: during the 77-133 and 133-154-day periods, their average daily gains were considerably higher than in the subsequent 154-182 and 182-203-day intervals. Among these, Group III animals (♀(LW×L)×♂Mk) exhibited the most pronounced difference between early and late periods, indicating greater variability in growth intensity compared with the other groups.

The results of the one-way analysis of variance demonstrated a significant effect of genotype on the age at which pigs reached specific live weights (ALW) during fattening ($p < 0.001$ in all cases) (Table 4). The strongest influence of the "genotype" factor was observed for the age at reaching 100 kg live weight (44.72%), while the weakest effect was recorded for the age at reaching 120 kg (9.48%).

Table 4. *Influence of pig genotype on the age at reaching a certain live weight during fattening (one-factor analysis of variance)*

Characteristic (age)	*SS* Effect	*df* Effect	*MS* Effect	*SS* Error	*df* Error	*MS* Error	*F*	*P*	η^2 (%)
ALW –80	250.35	2	125.17	542.80	117	4.64	26.98	<0.001	31.56
ALW –100	575.56	2	287.78	711.49	102	6.98	41.26	<0.001	44.72
ALW – 120	38.25	2	19.13	365.45	87	4.20	4.55	<0.001	9.48
ALW –140	95.18	2	47.59	342.73	72	4.76	10.00	<0.001	21.74

Note: ALW – age at reaching a certain live weight
Source: authors' own work

Overall, analysis of the mean age at reaching specific live weights in pigs during fattening, depending on their genotype, showed that Group I animals (♀(LW×L)×♂D) outperformed the other groups at 80 and 100 kg, but were inferior at 120 and 140 kg live weight. Animals of Groups II (♀(LW×L)×♂P) and III (♀(LW×L)×♂Mk) did not differ significantly from each other across almost all weight categories.

Table 5 shows the estimates of the correlation coefficient between the live weight of pigs of modern genotypes at different ages and the age at which they reach different weight conditions. It was found that there is a reliable and relatively high correlation (at the level of +0.600...+0.800) between the live weight of pigs at the ages of 77, 133 and 154 days. In addition, a certain level of relative variability was noted between the live weight of pigs at 182 and 203 days of age (+0.468). On the other hand, the live weight of pigs at 77, 133 and 154 days of age was negatively correlated with the age at which they reached a live weight of 80 and 100 kg. Accordingly, the live weight at 182 and 203 days of age was negatively correlated with the age at which they reached a live weight of 120 and 140 kg. These pairs of traits are also correlated with each other; on the one hand, the age at which live weight of 80 and 100 kg is reached (+0.694), and on the other hand, the age at which live weight of 120 and 140 kg is reached (+0.349).

Table 5. *Estimates of the correlation coefficient between the live weight of pigs of different genotypes at different ages and the age at which different live weights are reached*

Characteristic	1	2	3	4	5	6	7	8	9
1	×	0.792	0.627			-0.788	-0.629		
2		×	0.690			-0.999	-0.691		
3			×			-0.693	-0.993		
4				×	0.468			-0.985	-0.424
5					×			-0.397	-0.993
6						×	0.694		
7							×		
8								×	0.349
9									×

Note: Signs: 1 – LWe 77; 2 – LWe 133; 3 – LWe 154; 4 – LWe 182; 5 – LWe 203; 6 – ALW 80; 7 – ALW 100; 8 – ALW 120; 9 – ALW 140. Only correlation coefficient estimates for which p < 0.05 are given
Source: authors' own work

The availability of statistically significant estimates of correlation between the live weight of pigs of different genotypes at different ages and the age at which the corresponding weight conditions are achieved provides grounds for applying principal component analysis (PCA) to all nine of these traits. Table 6 shows the estimates of factor loadings for the first two principal components, calculated on the basis of the variation-covariance matrix of live weight of pigs of different genotypes at different ages and the age at which different weight conditions are achieved. The first two principal components together described almost ¾ of the total variability of the variance-covariance matrix. At the same time, the first principal component (PC1) described 45.6% of the total variability of the variation-covariance matrix of live weight of pigs of different genotypes at different ages and ages of reaching live weight of different conditions and was characterised by high positive estimates of factor loadings on live weight at the age of 77, 133 and 154 days of age, and, on the other hand, by high negative estimates of factor loads on the age of reaching a live weight of 80 and 100 kg.

Table 6. *Estimates of factor loadings for the first two principal components calculated on the basis of the variance-covariance matrix of live weight of pigs of different genotypes*

Characteristic	Principal component (PC)	
	PC1	PC2
LWe 77	**0.862**	0.007
LWe 133	**0.928**	-0.069
LWe 154	**0.869**	-0.061

Table 6. *Continued*

Characteristic	Principal component (PC)	
	PC1	PC2
LWe 182	0.179	**0.843**
LWe 203	-0.081	**0.865**
ALW 80	**-0.930**	0.063
ALW 100	**-0.867**	0.045
ALW 120	-0.277	**-0.791**
ALW 140	0.108	**-0.841**
Percentage of variance, %	*45.6*	*31.2*

Note: bold font indicates the factor loadings of the features that contribute most to the identification of the corresponding principal component
Source: authors' own work

Thus, this main component can be identified as live weight gain at 130-155 days of age. The second principal component (PC2) described 31.2% of the total variability of the variation-covariance matrix of live weight of pigs of different genotypes at different ages and ages of reaching live weight of different conditions and was characterised by high positive estimates of factor loadings on live weight at 182 and 203 days of age, and, on the other hand, by high negative estimates of factor loads on the age of reaching a live weight of 120 and 140 kg. Thus, this principal component can be identified as reaching a live weight at 180-205 days of age.

It is characteristic that the first two main components indicate the presence of two stages in the process of forming the live weight of pigs for fattening, which are determined by different mechanisms and are almost independent of each other. The first stage covers the period of 130-155 days, and the second – 180-205 days. Thus, the results of the principal component analysis allowed to move from 9 initial features to two complex features (principal components) that describe most of the variability of the initial matrix, but are orthogonal to each other and make it possible to visualise the results obtained (Fig. 1).

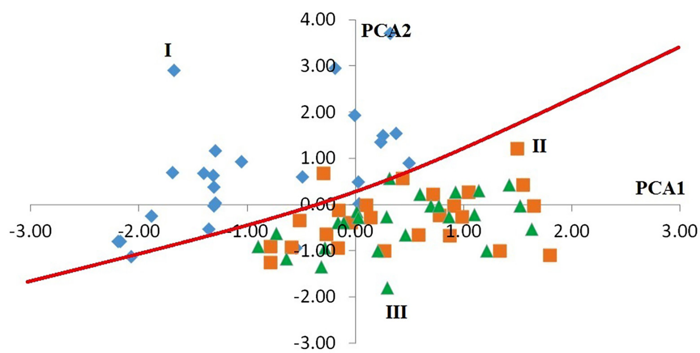

Figure 1. *Ordination of individual animals depending on their genotype in the space of the 1st and 2nd principal components, calculated on the basis of the variance-covariance matrix of live weight at different ages and the age at reaching various live weight stages*
Note: I – ♀(LW×L)×♂D; II – ♀(LW×L)×♂P; III – ♀(LW×L)×♂Mk
Source: authors' own work

Figure 1 presents the ordination of individual animals according to their genotype in the space defined by the first and second principal components, calculated on the basis of the variance–covariance matrix of live weight at different ages and the age at reaching specific live-weight thresholds. A clear intergroup differentiation of pigs depending on genotype is evident. The young animals of Group I (♀(LW×L)×♂D) were clearly separated from those of Groups II (♀(LW×L)×♂P) and III (♀(LW×L)×♂Mk), which formed a single cluster without noticeable differentiation between them. Animals of Group I (♀(LW×L)×♂D) were characterised by high scores on the second principal component but low scores on the first, in contrast to the other two groups. This pattern indicates that pigs of Group I exhibited lower growth rates in live weight during the 130-155-day period but accelerated growth during 180-205 days. Conversely, pigs of Groups II and III showed higher growth intensity at 130-155 days but lower rates in the later finishing period (180-205 days).

The results of the studies confirm the conclusions of M. Mohammadabadi *et al.* (2021) and B.S. Shaferivsky (2021), who also point to the decisive role of genotype in the formation of live weight and growth energy of pigs during ontogenesis. A significant influence of this factor has been established in all age periods, which is consistent with numerous literature data emphasising the role of heredity in the variability of growth indicators, meat productivity and carcass quality. According to researchers A. Antonyk *et al.* (2025), heredity is the main predictor of fattening and slaughter traits in modern pig genotypes, while the influence of housing and feeding conditions is more pronounced only in the case of nutrient deficiency. In particular, the current study clearly demonstrated the role of individual genotype combinations in the formation of live weight, average daily gains and fattening performance. Similar conclusions were made by Z. Pan *et al.* (2022), who, based on transcriptomic and proteomic analysis, identified candidate genes responsible for the deposition of subcutaneous and intramuscular fat in Dingyuan pigs. This once again confirms that the genetic basis of productive traits has a complex polygenic nature, where dozens of genes interact. The current study found that genotype significantly influences the formation of productive traits in fattening pigs, in particular the dynamics of live weight gain and morphofunctional characteristics. Similar results are reported by M. Matsenko (2020), who established the dependence of growth rate and haematological parameters on the duration of embryonic development. The author showed that physiological blood parameters (erythrocytes, haemoglobin, protein) are closely correlated with the growth intensity of animals, which confirms the importance of taking into account not only external factors but also genetically determined characteristics of the organism.

An important aspect is the interaction of the genotype with environmental conditions. The results of the current study indicate that even with the same feeding system, the differences between genotypes remained significant, but the severity of these differences may vary depending on the husbandry technology used. A similar effect was described by J.M. García-Casco *et al.* (2014), who studied Iberian pigs in different free-range systems. The authors showed that the "genotype-environment" interaction affects both carcass morphology and intramuscular fat content. This highlights the need to consider technological factors when interpreting the results of variance analysis. A characteristic pattern identified in the current study is the gradual increase in the influence of the "genotype" factor on the live weight of animals up to 154 days, after which this influence decreased by almost half at 203 days. This dynamic is explained by the processes of physiological equalisation in the herd, when in the final stages of fattening the influence of environmental factors (in particular, the level of feeding and microclimate conditions) begins to play an increasingly important role. Similar results are reported by H. Shao *et al.* (2008), who showed that in later age periods, heritability is weaker than in earlier ones, which leads to a decrease in intergroup differences.

An interesting phenomenon observed in the present study was that animals of Group I (♀(LW×L)×♂D), although initially lagging behind their peers in live weight and gains during the early growth phases (77-154 days), subsequently (182-203 days) demonstrated a significant compensatory advantage. Similar patterns were reported by R.M. Godinho *et al*. (2018), who noted that combining genotypes with different growth intensities may generate a "late-start" effect, whereby animals gradually realise their genetic potential during the final stages of fattening. The correlations established in the current study are also consistent with the literature. The high negative correlation between live weight at an early age (77-154 days) and the age at which 80-100 kg is reached confirms the statements made by R.M. Godinho *et al*. (2018) that more intensive initial growth allows intermediate weight limits to be reached more quickly. On the other hand, the negative correlation between live weight at later ages (182-203 days) and the age at which 120-140 kg is reached confirms that the final periods of fattening are crucial for the formation of final productivity.

The use of principal component analysis made it possible to identify two independent growth stages: 130-155 and 180-205 days. A similar approach was used by N. Gilbert *et al*. (2017), who, based on multidimensional data analysis, identified several "performance windows" in pig development when genetic potential is most strongly manifested. In the current study, animals in group I were characterised by the second scenario with accelerated growth in the late stage, while groups II and III were characterised by the first scenario, confirming the existence of different strategies for realising genetic potential. The results of the current component analysis confirmed that individual latent factors can be identified as genetically determined trait complexes. This coincides with the conclusions of M. Muñoz *et al*. (2018), who studied the diversity of European local pig breeds and showed that candidate genes associated with growth and meat productivity form specific groups that are consistently manifested in the phenotype. Including such factors in breeding programmes can significantly improve the accuracy of animal selection. Additionally, it should be noted that the data from the current study on genotypic variation in fattening performance are consistent with the results of X. Xie *et al*. (2023), who identified key mutations in the PRKAG3 and PHKG1 genes that determine the glycolytic potential of muscle tissue. These genes have a significant impact on slaughter performance. Identifying genotypes with the best productive characteristics makes it possible to increase the efficiency of fattening. As shown by the research of S. Dall'Olio *et al*. (2017), integrating data on genotypes and meat productivity markers into selection schemes provides a significant increase in genetic progress.

Thus, the results of the current study confirm that genotype is one of the key factors determining the level and stability of fattening pig performance. Its influence is realised through polygenic trait complexes and depends on interaction with feeding and housing systems. The current study confirmed the high significance of genotype as a factor in the formation of pig productivity and allowed to identify key age intervals when genetic potential is most strongly manifested. Dispersion and component analysis have proven their effectiveness as tools for quantitative assessment of these factors, as well as for identifying latent structures in the data. The use of these methods opens up new opportunities for the formation of selection strategies aimed at increasing production efficiency and improving the quality of pig products.

Conclusions

Genotype is a determining factor in the formation of performance traits in fattening pigs and significantly affects growth dynamics, growth intensity and age at which live weight is reached. The application of variance analysis showed that the "genotype" factor has a statistically significant effect ($p < 0.001$) on all studied parameters, with its specific weight of variation changing depending on the age period and specific trait. The greatest effect was found in the middle age interval (154 days) for live weight (43.27%) and in the later period (182-203 days) for absolute and average daily gains (44.97%). This indicates an increase in the role of hereditary factors in the final stages of fattening, when the animals' bodies intensively accumulate muscle and fat tissue. An important finding is the different type of genetic potential realisation: pigs in group I (♀(LW×L)×♂D) showed slower initial growth, but compensated for this with intensive growth in the final period, while animals in groups II (♀(LW×L)×♂P)and III (♀(LW×L)×♂Mk) were characterised by more uniform growth rates with a predominance at an early age. Different genotypes require differentiated feeding and fattening management programmes: genotypes with late potential realisation should be kept longer to achieve maximum productivity, while genotypes with rapid realisation ensure early achievement of marketable conditions with shorter fattening periods.

Analysis of the age at which live weight was achieved confirmed that the trait most sensitive to genotype was the age at which a live weight of 100 kg was achieved (44.72%), making this indicator an informative marker for breeding and technological programmes. At the same time, the genotype had a lesser effect on the age at which a live weight of 120 kg was reached (9.48%), which indicates a gradual levelling of growth indicators as the final conditions are approached. The integration of variance and component analysis allows for a deeper understanding of the mechanisms of genotype influence on the performance of fattening pigs, identification of periods of maximum realisation of hereditary potential, and establishment of practical guidelines for selection and technological solutions. This ensures more efficient use of feed, lower production costs and increased competitiveness of the pig industry in industrial production.

Further scientific research should be directed towards a comprehensive study of the influence of genotype, feeding and housing conditions on pig growth using molecular genetic markers, which will allow the optimal feeding parameters to be established, economic efficiency to be assessed and selection and technological strategies for intensive pig farming to be developed.

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Conflict of Interest

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References

[1] Adesehinwa, A.O.K., Boladuro, B.A., Dunmade, A.S., Idowu, A.B., Moreki, J.C., & Wachira, A.M. (2024). Pig production in Africa: Current status, challenges, prospects and opportunities. *Animal Bioscience*, 37(4), 730-741. doi: 10.5713/ab.23.0342.

[2] Antonyk, A., Terman, A., Tyra, M., Żak, G., Polasik, D., Szyndler-Nędza, M., Kulig, H., & Dybus, A. (2025) The effect of rs80860411 polymorphism on fattening, slaughter, and pork quality traits in Polish Large White and Pulawska Breeds. *Animals*, 15(14), article number 2090. doi: 10.3390/ani15142090.

[3] Bussiman, F., Lourenco, D., Hidalgo, J., Chen, C.-Y., Holl, J., Misztal, I., & Vitezica, Z.G. (2025). Genotype-by-environment interaction with high-dimensional environmental data: An example in pigs. *Genetics Selection Evolution,* 57, article number 28. doi: 10.1186/s12711-025-00974-2.

[4] Dall'Olio, S., Scotti, E., Nanni Costa, L., & Fontanesi, L. (2017). Effects of single nucleotide polymorphisms and haplotypes of the protein kinase AMP-activated non-catalytic subunit gamma 3 (*PRKAG3*) gene on production, meat quality and carcass traits in Italian Large White pigs. *Meat Science*, 136, 67-76. doi: 10.1016/j.meatsci.2017.09.012.

[5] Departmental norms of technological planning (2005). *Pig enterprises (complexes, farms, small farms)*. Retrieved from https://lugdpss.gov.ua/images/bezpechnist_veterynariya/Svynarski-pidpryyemstva-VNTP-APK-02.05.pdf.

[6] Feinstein, A.R. (1996). *Multivariable analysis: An introduction*. New Haven: Yale University Press.

[7] García-Casco, J.M., Muñoz, M., Silío, L., & Rodríguez, C. (2014). Genotype by environment interaction for carcass traits and intramuscular fat content in heavy Iberian pigs fattened in two different free-range systems. *Spanish Journal of Agricultural Research*, 12(2), 388-400.

[8] Gilbert, H., *et al.* (2017). Review: Divergent selection for residual feed intake in the growing pig. *Animal*, 11(9), 1427-1439. doi: 10.1017/S175173111600286X.

[9] Godinho, R.M., Bergsma, R., Silva, F.F., Sevillano, C.A., Knol, E.F., Lopes, M.S., Lopes, P.S., Bastiaansen, J.W.M., & Guimarães, S.E.F. (2018). Genetic correlations between feed efficiency traits, and growth performance and carcass traits in purebred and crossbred pigs. *Journal of Animal Science*, 3, 96(3), 817-829. doi: 10.1093/jas/skx011.

[10] Green, H.E., Oliveira, H.R.D., Alvarenga, A.B., Scramlin-Zuelly, S., Grossi, D., Schinckel, A.P., & Brito, L.F. (2024). Genomic background of biotypes related to growth, carcass and meat quality traits in Duroc pigs based on principal component analysis. *Journal of Animal Breeding and Genetics*, 141(2), 163-178. doi: 10.1111/jbg.12831.

[11] Ibatulin, I.I., Zhukorskyi, O.M., & Bashchenko, M.I. (2017). *Methodology and organization of scientific research in animal husbandry*. Kyiv: Agrarian Science.

[12] Kim, S.W., Gormley, A., Jang, K.B., & Duarte, M.E. (2024). Current status of global pig production: An overview and research trends. *Animal Bioscience*, 37(4), 719-729. doi: 10.5713/ab.23.0367.

[13] Kramarenko, S.S., Lugovoy, S.I., Lykhach, A.V., & Kramarenko, O.S. (2019). *Analysis of biometric data in animal breeding and selection*. Mykolaiv: MNAU.

[14] Ladyka, V.I., & Khmelnychiy, L.M. (Eds.). (2023). *Technology of production and processing of livestock products*. Odesa: Oldi+.

[15] Lebret, B., & Čandek-Potokar, M. (2021). Review: Pork quality attributes from farm to fork. Part I. Carcass and fresh meat. *Animal*, 16, article number 100402. doi: 10.1016/j.animal.2021.100402.

[16] Matsenko, M. (2020). Hematological indices and the rate of growth depending on duration of embryonic growth of pigs obtained by commercial cross-breeding. *Animal Science and Food Technology*, 11(2), 43-49.

[17] Mohammadabadi, M., Bordbar, F., Jensen, J., Du, M., & Guo, W. (2021). Genes regulating skeletal muscle development and growth in farm animals. *Animals*, 11, article number 835. doi: 10.3390/ani11030835.

[18] Muñoz, M., *et al.* (2018) Diversity across major and candidate genes in European local pig breeds. s*PLoS ONE*, 13(11), article number e0207475. doi: 10.1371/journal.pone.0207475.

[19] Mykhalko, O., Povod, M., Sokolenko, V., Verbelchuk, S., Shuplyk, V., Shcherbatiuk, N., Melnyk, V., & Zasukha, L. (2022). The influence of the castration method on meat cuts indicators of pig carcasses. *Scientific Papers. Series Management, Economic Engineering in Agriculture and Rural Development*, 22(3), 451-458.

[20] Order of the Ministry for Development of Economy, Trade and Agriculture of Ukraine No. 224 "On the Procedure for Carrying out Experiments and Experiments on Animals by Scientific Institutions". (2012, March). Retrieved from https://zakon.rada.gov.ua/laws/show/z0416-12#Text.

[21] Pan, Z., Li, Q., Wu, Y., Zhang, Y., Bo, Z., & Hao, Z. (2022). Identification of candidate genes that specifically regulate subcutaneous and intramuscular fat deposition using transcriptomic and proteomic profiles in Dingyuan pigs. *Scientific Reports*, 12, article number 2844. doi: 10.1038/s41598-022-06868-3.

[22] Panda, S., Gaur, G.K., Sahoo, N.R., Bharti, P.K., & Kar, J. (2020). Principal component analysis of morphometric and growth traits in crossbred piglets. *Indian Journal of Animal Sciences*, 90(8), 1168-1171.

[23] Provoratorov, H.V. (Ed.). (2007). *Feeding standards, diets, and nutritional value of feed for various types of farm animals*. Sumy: VDT "University Book" LLC.

[24] Ritchie, H., Rosado, P., & Roser, M. (2023). *Meat and dairy production*. Retrieved from https://ourworldindata.org/meat-production.

[25] Shaferivsky, B.S. (2021). The influence of breeding boars of specialized genotypes on the fattening characteristics of young pigs. *In Meat genotypes of pigs: Present and future: Materials of the international scientific and practical conference of scientific and pedagogical workers and young scientists* (pp. 46-48). Odesa: Odesa State Agrarian University.

[26] Shao, H., *et al.* (2008). Genetic architecture of complex traits: Large phenotypic effects and pervasive epistasis. *Proceedings of the National Academy of Sciences of the United States of America*, 105(50), 19910-19914. doi: 10.1073/pnas.0810388105.

[27] Vashchenko, P.A., Zhukorskyi, O.M., Saenko, A.M., Khokhlov, A.M., Usenko, S.O., Kryhina, N.V., Sukhno, T.V. & Tsereniuk, O.M. (2023). The influence of feeding level on the growth of pigs depending on their genotype. *Regulatory Mechanisms in Biosystems*, 14(1), 112-117. doi: 10.15421/022317.

[28] Voloshchuk, V.M. (Ed.). (2014). *Pig farming*. Kyiv: Agrarian Science.

[29] Voloshinov, V.V., Povod, M.G., Mykhalko, O.G., Usenko, S.O., Shaferivsky, B.S., Shostya, G.M., & Shpyna, I.G. (2024). Productive qualities and efficiency of fattening hybrid pigs of Danish and Canadian origin under industrial technology conditions. *Bulletin of Sumy National Agrarian University. Series: Animal Husbandry*, 1(56), 25-32. doi: 10.32782/bsnau.lvst.2024.1.4.

[30] Wusheng, Yu., Jørgen D.J. (2022). Sustainability implications of rising global pork demand. *Animal Frontiers*, 12(6), 56-60. doi: 10.1093/af/vfac070.

[31] Xie, X., Huang, C., Huang, Y., Zou, X., Zhou, R., Ai, H., Huang, L., & Ma, J. (2023). Genetic architecture for skeletal muscle glycolytic potential in Chinese Erhualian pigs revealed by a genome-wide association study using 1.4M SNP array. *Frontiers in Genetics*, 14, article number 1141411. doi: 10.3389/fgene.2023.1141411.

Дисперсійний та компонентний аналіз впливу генотипу на формування продуктивних ознак відгодівельних свиней

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Анотація. Актуальність роботи зумовлена необхідністю пошуку ефективних генетичних поєднань для підвищення продуктивності та забезпечення стабільності ростових процесів у тварин сучасних «комерційних генотипів». Метою дослідження було з'ясування ролі генотипу, як визначального чинника росту та розвитку свиней за допомогою однофакторного дисперсійного аналізу й аналізу головних компонент. В експерименті було використано 120 голів свиней на відгодівлі, піддослідний молодняк був розділений на три групи. І група: поєднання свиноматок великої білої та ландрас з кнурами породи дюрок канадської селекції (Genesus), ІІ група: поєднання свиноматок великої білої та ландрас з кнурами породи п'єтрен французької селекції (Axiom) і ІІІ група: поєднання свиноматок великої білої та ландрас з кнурами термінальної лінії «Maxter» селекції компанії «France Hybrides». Для оцінки використано живу масу свиней різних генотипів у віці 77-203 доби, абсолютні та середньодобові прирости в окремі вікові періоди, а також вік досягнення ними передзабійної живої маси 80, 100, 120 та 140 кг. За результатами дисперсійного аналізу встановлено достовірний вплив генотипу на всі досліджувані показники. Найбільший ефект фактору «генотип» відмічено для живої маси у віці 154 діб (43,27 %), абсолютних та середньодобових приростів у період 182-203 доби (44,97 %), а також віку досягнення живої маси 100 кг (44,72 %). Підтверджено, що свині І групи у ранні вікові періоди поступалися ровесникам інших груп, однак на пізніших етапах відгодівлі демонстрували достовірну перевагу за приростами та інтенсивністю росту. Тварини II та III груп характеризувалися подібними темпами росту та не відрізнялися статистично значущо між собою. Аналіз головних компонент дозволив виділити два етапи у процесі формування живої маси: перший (130-155 діб) та другий (180-205 діб), які визначаються різними механізмами росту та практично незалежні один від одного. Отримані результати підтверджують ключову роль генотипу у формуванні продуктивних ознак свиней та можуть бути використані при розробці селекційних програм і вдосконаленні систем відгодівлі

Ключові слова: селекція; породність; жива маса; прирости; головні компоненти