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Effect of Fattening Period Duration on Meat Productivity of Domestic Quails from Different Productive Types

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Abstract
The aim of the present study was to investigate the effect of age and productive type on meat production in domestic quail. A total of 240 male and female quail of meat type (n=80), heavy dual-purpose (n=80) and light dual-purpose (n=80) type, sexed at 14 days of age, were fattened to 28, 35, and 42 days of age. Mortality (%), live weight (g), growth (g), feed consumption (g), feed conversion (kg/kg gain) were monitored during the fattening period. At 28-, 35-, and 42-days of age 9 male and 9 female birds from each productive type were slaughtered and the carcasses were analyzed. Live weight and carcass weight were seriously affected by the productive type and sex of the quail, especially at the end of the test period ($P < 0.001$). The amount of hand-boned meat from the most valuable parts of the carcass were affected by productive type $P < 0.001$) with statistically significant gender differences at the end of the test period ($P < 0.05$). The sex and productive type affected the meat yield which increased with slaughter age from 28 to 42 days ($P < 0.001$). With an increase in the slaughter age from 28 to 42 days, the inter-sex differences in slaughter yield increased ($P < 0.001$). Increased production costs (up to 75%) and lower efficiency of feed transformation (especially after 35 days of age) into finished products were observed with increasing fattening age in all three productive types. Meat production from a specialized meat-producing line is considered the most efficient and the least efficient - from the light egg-laying line. The study demonstrated that age and productive type have a serious impact on the fattening and meat-producing characteristics of quail and on the efficiency of quail meat production.

Introduction

Domestic quail (*Coturnix japonica domestica*) are descended from the wild Japanese quail and are one of the most recently domesticated birds (Chang *et al.*, 2007; Lukanov , 2019). Since the beginning of the domestication process, three main productive types have been developed in this farm bird - egg-laying, dual-purpose and meat-producing (Lukanov and Pavlova, 2020a). About 1.2-1.3 million tonnes of quail eggs and about 200,000-240,000 tonnes of quail meat are produced worldwide. This production is concentrated mainly in several countries - China, Spain, France, Italy, Brazil, the USA, and Japan (Minvielle, 1998; 2004; Bertechini, 2012; Lukanov , 2019). The main share of stock quail eggs produced come from egg-laying type quail with a weight slightly higher than that of their wild ancestors. -producing type quail areessential in the production of quail meat since their weight is more than 250% higher than that of wild Japanese quail (Lukanov and Pavlova, 2020a). The dual-purpose type of quail is used in some parts of the world as the primary type for table egg production because it lays larger eggs while maintaining a high egg-laying capacity, and surplus males can also be successfully used to obtain quail meat (Genchev, 2012). In Europe, dual-purpose and meat types of quail are reared industrially. A critical point in obtaining quail meat is the exact determination of the fattened birds' slaughter time. Apart from external factors, such as feeding and rearing conditions, the duration of fattening is influenced by the genotype and the intensity of

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selection applied in the quail population. The slaughter age can differ significantly depending on the productive type, growth intensity and meat quality of the quail (Afanasyev *et al.*, 2015; Gogaev *et al.*, 2016). The present study aimed to investigate the effect of age and productive type on meat production in domestic quail.

Material and methods

Experimental design

The study was conducted at the experiment station facilities of the Poultry Department, Faculty of Agriculture at Trakia University, Stara Zagora, Bulgaria. A total of 240 domestic quail belonging to different productive lines were included in the experiment: line WG - specialized meat production line; line GG - heavy dual-purpose type and line A - light dual-purpose type. During the experimental period, the three groups (four replications each) were fed a 3-phase feeding (Table 1) with combined feeds corresponding to the requirements of the domestic quail (Genchev, 2014). From 1 to 14 days of age, the birds were housed in cell batteries with 62 cm^2 of space per bird. The rearing conditions in the three groups were the same and strictly corresponded to the requirements of the species.

Table 1. Component (%) and nutritional composition of basal diet

Components	Starter (1 to 14 day)	Grower (14 to 21 day)	Finisher (>21 day)
Corn	29.2	35.5	38.8
Wheat	21	23.8	27
Soybean meal, 44% CP	34.6	25.8	20
Sunflower meal, 34% CP	8	8.5	9
Fish meal, 72% CP	2	1	0
Sunflower oil	0.62	0.91	1
Dicalcium phosphate	1.92	1.82	1.71
Chalk	1.52	1.48	1.43
Vitamin and mineral premix	0.6	0.6	0.5
NaCl	0.2	0.2	0.2
NaHCO3	0.1	0.1	0.1
Lysine, 98%	0.11	0.18	0.15
DL-methionine	0.14	0.12	0.11
	Nutritional composition		
Energy-Protein Ratio	110.27	134.28	156.31
Metabolizable Energy, kcal/kg	2646	2754	2820
Crude Protein, %	24.00	20.51	18.04
Crude Fibre, %	5.28	5.02	4.90
Calcium, %	1.20	1.10	1.00
Available Phosphorus, %	0.50	0.45	0.40
Lysine, %	1.30	1.10	0.91
Methionine, %	0.52	0.45	0.40
Methionine+Cysteine, %	0.92	0.81	0.73
Linoleic acid, %	1.30	1.62	1.75
Feed price, BGN/t*	764.08	672.13	591.48

*1BGN=0.51 EUR (2022)

The following indexes were monitored during the experimental period: mortality (%), live weight (g), growth (g), feed consumption (g), and feed conversion (kg/kg gain). Based on the differences in plumage color and patterns in both sexes, at 14 days of age the birds were separated by sex. Male and female quail were housed in separate cages, and further control for the study indexes was performed according to sex.

Health status and mortality were reported daily. The live weight control measurement was made weekly on an SV 2000 scale, and at 1 and 7 days of age the accuracy of its determination was 0.1 g, and at 14-, 21-, 28-, 35- and 42- days of age – 1 g. Daily measurements of the previous day's consumed and unconsumed feed were made for each sex with an accuracy of 0.1 g. Based on the consumption by each sex for one week and the realized weight gain, the feed conversion was calculated.

Slaughter analysis

At 28-, 35-, and 42-days of age after a 4-hour feed and 3-hour water withdrawal, birds were weighed with an accuracy of 1 g. Nine male and nine female birds from each productive type with a body weight closest to the gender-related body weight norm were selected and slaughtered. The carcasses were then analysed. Manipulations related to the slaughtering, processing, cutting, and deboning of the birds were done according to the protocol described by Genchev and Mihaylov (2008).

Table 2. Meat productivity of different productive types of domestic quail, depending on the gender and the length of the fattening period

Gender	Fattening period								
	1-28 days			1-35 days			1-42 days		
	WG	GG	A	WG	GG	A	WG	GG	A
Live weight, g									
♂:♀	NS	*	NS	***	***	***	***	***	***
♂	229.8±2.64c	206.8±2.28d	163.7±3.22e	258.8±1.83c	230.8±1.96d	174.2±4.08e	262.4±2.23c	241.3±3.12d	179.4±4.21e
♀	237.7±2.97c	214.5±2.37d	165.6±2.00e	280.7±1.96c	262.0±3.39d	192.6±3.37e	314.9±2.86c	294.9±4.57d	219.7±4.47e
Carcass weight, g									
♂:♀	*	NS	*	NS	***	NS	***	***	***
♂	134.1±1.59c	117.5±1.40d	83.7±1.78e	166.7±2.09c	137.9±1.07d	106.4±2.57e	156.0±2.82c	137.6±2.06d	102.8±2.24e
♀	139.1±1.75c	120.1±1.37d	88.9±1.19e	167.5±1.74c	152.9±2.18d	110.1±1.96e	174.8±2.73c	150.1±2.14d	120.0±2.33e
Hand-boned breast and leg meat, g									
♂:♀	*	NS	***	NS	***	NS	*	***	***
♂	89.3±0.72c	75.3±0.36d	48.8±0.77e	111.6±2.19c	90.3±0.45d	68.2±0.54e	105.9±1.86c	91.9±0.64d	66.00±0.36e
♀	92.3±1.19c	76.6±0.61d	53.9±0.58e	106.9±1.76c	96.7±0.94d	68.1±1.14e	114.7±3.83c	97.4±0.35d	77.2±1.01e
Abdominal fat, g									
♂:♀	NS	NS	***	**	NS	***	***	***	***
♂	0.77±0.15c	0.46±0.08f	0.24±0.01dg	1.47±0.32	2.07±0.19c	1.19±0.16d	1.76±0.35	2.18±0.10a	1.42±0.31b
♀	0.64±0.16	0.63±0.06c	0.35±0.03d	2.95±0.41a	1.86±0.10b	2.01±0.09b	3.98±0.36f	4.82±0.47c	2.71±0.22dg

Note: The difference between males and females is statistically significant in: * - $P < 0.05$; *** - $P < 0.001$.
Differences between the productive type within the same sex and the same length of the fattening period are statistically significant in: a;b - $P < 0.05$; f;g - $P < 0.01$; c;d;e - $P < 0.001$. NS - not significant.

The weight of the carcasses (without skin), viscera and cuts (breasts and legs – with bones and hand-boned) were measured with an accuracy of 0.001 g on an analytical scale Kern EMB 200-3 (KERN & SOHN GmbH).

Statistical analysis

The statistical processing of the obtained results was done using the statistical package IBM® SPSS® Statistics (V26) using the generalized linear model (Univariate GLM) procedure. The statistical comparison was made by the least significant difference (LSD) test at the 95% probability level. All data are reported as mean ± standard error of the mean (x±*SEM*). Statistical significance was established at $P < 0.05$.

Calculations to establish the relationship between individual traits, as well as the level of influence of the individual factors on the determination of these traits, were made according to the models described in detail by Merkurieva (1970).

Results

During the experimental period mortality of the three groups ranged from 2.7 to 4.1% over the 42 days.

Table 2 shows that with the extension of the fattening period from 28 to 42 days of age the live weight of the quail from the different experimental groups increased between 9.6 and 16.7% for males and between 32.5 and 37.5% for females ($P < 0.001$). In males, live weight increased intensively until 35 days of age after which it increased slightly (1.4-4.6%), and a proven difference was only found in birds from the GG line ($P < 0.01$). In a direct correlation between live weight, the weight gain shows the same regularities described above in terms of the breed type and the bird's slaughter age.

Like the live weight, quail productive type significantly affected carcass weight. Between 28 and 35 days of age the carcass weight increased on average from 17 to 27%. Regardless of gender or the length of the fattening period, the carcass weight from the WG meat line was significantly higher than that of the GG and A lines ($P < 0.001$). At 35 days of age, however, the differences between males and females were not as pronounced as at 42 days of age ($P < 0.001$).

An analogous dependence was also observed for the other quantitative trait—hand-boned meat from the breast and legs. The dispersion analysis showed that the amount of harvested meat from the valuable parts of the carcass was approximately 65% of the live weight of the birds. The study found that the nature of the relationship between the two traits was linear L = 0.03±0.05, and their dependence had a strong r-value (r = 0.787), which favors selection by body weight.

In both sexes, the slaughter yield varies within similar limits (from 54.3 to 66.6% for males and from 53.3 to 62.6% for females). As the age of the quail increased, the mean value for females decreased from 58.8-60.5% at 28 days of age to 55.1-58.2% at 42 days of age ($P < 0.001$). The decline in slaughter yield between 28 and 35 days of age is more noticeable (Figure 1). After 28 days of age, the slaughter yield in females was significantly lower than in males ($P < 0.01$), and no specific dependence on the productive type was observed. The impact of the age of slaughter factor was stronger – about 3% of the total variance of the trait ($P < 0.001$). Together, however, the two factors determined about 10% of the manifestation of slaughter yield ($P < 0.001$). Evaluating the effect of quail productive type on the investigated trait, we found that almost 11% of its manifestation was determined by the productive type of the birds ($P < 0.001$). Irrespective of the length of the fattening period, quail slaughter yield of the egg-laying type was lower (Figure 2), and the difference was more significant in the male sex ($P < 0.001$).

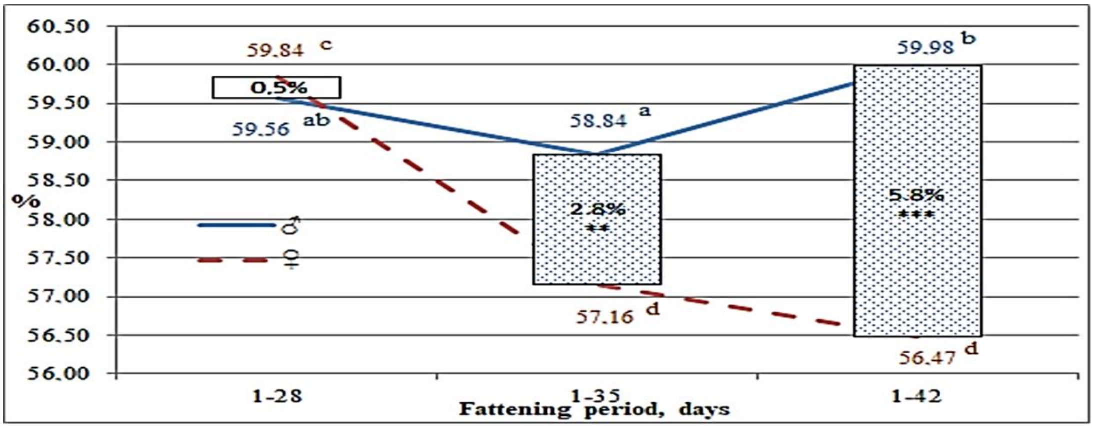

Figure 1. Domestic quail's The effect of gender and the length of the fattening period on slaughter yield of domestic quails.

<u>Note:</u> The difference between males and females is statistically significant in: ** - $P < 0.01$; *** - $P < 0.001$. The difference depending on the duration of fattening, marked in different letters, is statistically significant in: [a,b] - $P < 0.05$; [c,d] - $P < 0.001$.

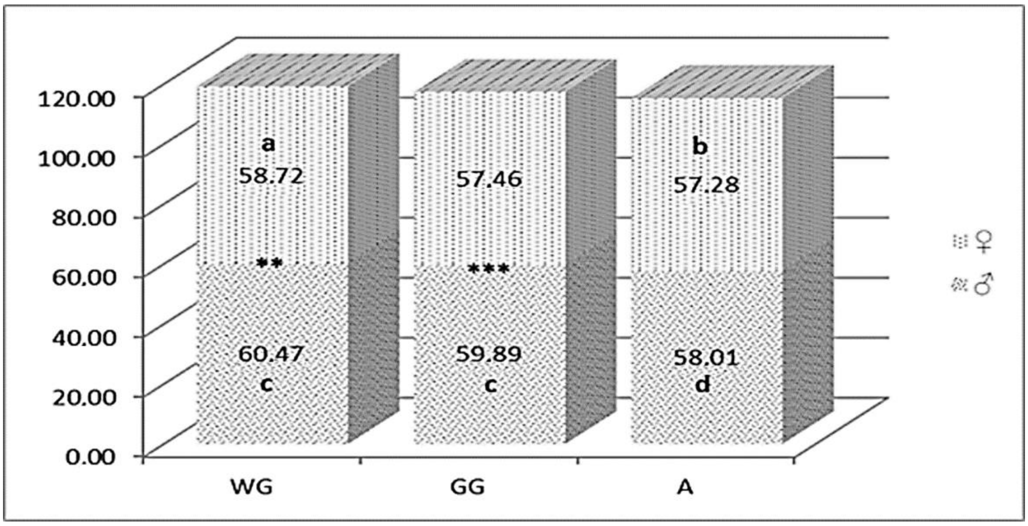

Figure 2. Slaughter yield of domestic quail of different productive type and gender, %.
Note: The difference between males and females is statistically significant in: ** - $P < 0.01$; *** - $P < 0.001$. The difference depending on the duration of fattening, marked in different letters, is statistically significant in: [a,b] - $P < 0.05$; [c,d] - $P < 0.001$.

After 28 days of age, the difference in meat obtained from the valuable parts was significant ($P < 0.01$) between the sexes, with the amount in the males being higher by 2.1-3.7% (Figure 3). Figure 4 presents the summarized results for the meat share in quail of different productive types.

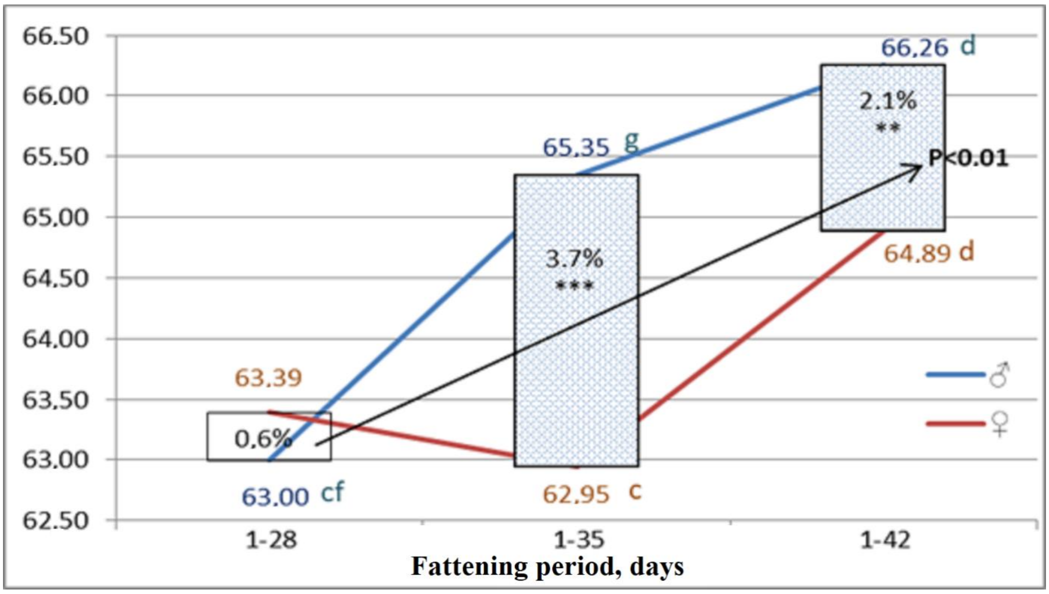

Figure 3. Share of hand-boned quail's breast and leg meat depending on the gender and the duration of fattening, %. The difference between males and females is statistically significant in: ** - $P < 0.01$; *** - $P < 0.001$. The difference depending on the duration of fattening, marked in different letters, is statistically significant in: [f,g] - $P < 0.01$; [c,d] - $P < 0.001$.

Analyzing the proportion of abdominal fat in relation to the weight of the carcass, we observed that regardless of the productive type of quail, it increased from 0.34-0.52% at 28 days of age to 1.7-2.4% at 42 days.

We can conclude from the results of the summarized research data (Table 3) that with an increase in the slaughter age of the birds, the cost of feeding quail increases by an average of 75% (for the different lines between 32.8 and 41.1% during the 28-35 day period and 23.2-29.8% during the 35-42 day period).

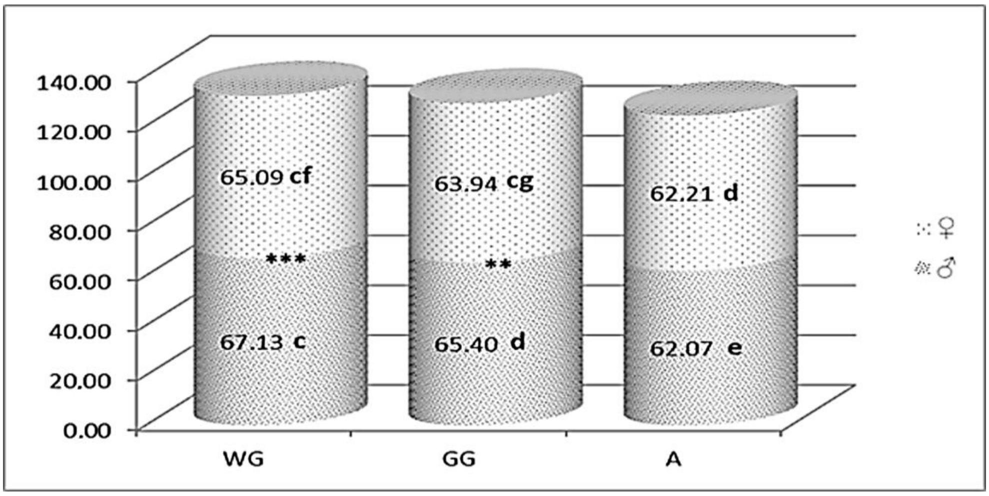

Figure 4. Share of hand-boned breast and leg meat depending on the quail's productive type, %.
The difference between males and females is statistically significant in: ** - $P < 0.01$; *** - $P < 0.001$. The difference depending on the quail's productive type, marked in different letters, is statistically significant in: ^{f,g} - $P < 0.01$; ^{c,d} - $P < 0.001$.

Table 3. Productive indicators of quails from different productive types and genders subjected to various fattening periods

Parameters	Line*	Fattening period, days					
		1-28		1-35		1-42	
		♂	♀	♂	♀	♂	♀
Compound feed, kg/bird	WG	0.584	0.597	0.803	0.839	1.007	1.113
	GG	0.533	0.536	0.743	0.787	0.942	1.038
	A	0.454	0.436	0.619	0.624	0.770	0.820
Feed price, BGN*/bird	WG	0.393	0.401	0.522	0.544	0.643	0.706
	GG	0.336	0.360	0.460	0.508	0.578	0.657
	A	0.304	0.293	0.658	0.405	0.747	0.520
FCR**, kg/kg	WG	2.736	2.697	3.328	3.214	4.116	3.874
	GG	2.749	2.709	3.402	3.212	4.116	3.774
	A	3.008	2.895	3.973	3.523	4.786	4.185
1 kg quail' carcasses cost price, BGN*	WG	2.929	2.866	3.133	3.250	4.125	4.040
	GG	2.857	2.997	3.329	3.324	4.193	4.377
	A	3.629	3.298	6.152	3.372	7.268	4.334
1 kg quail's meat cost price, BGN*	WG	4.399	4.346	4.681	5.091	6.076	6.158
	GG	4.460	4.704	5.095	5.256	6.284	6.752
	A	6.223	5.449	9.6.49	5.941	11.329	6.735

*WG – heavy type; GG – heavy dial-purpose type; A – light dial-purpose type.
**FCR – Feed conversion ratio; 1BGN=0.51 EUR (2022).

Discussion

The scientific literature shows a large variation regarding farming quail mortality, with the strongest manifestation occurring in the first two weeks after the quail hatch (Sengul and Tas, 1997; Nanda *et al.*, 2015; Lukanov , 2022).

The productive type of quail plays a major role in forming the live weight trait. At all three ages, the difference between the live weight of the birds from the different lines was statistically significant ($P < 0.001$). Similar evidence is provided by Şeker *et al.* (2007) for light-type quail, Nasr *et al.* (2017) for different plumage color quail of dual-purpose type, and Ioniță *et al.* (2020) for heavy, meat-type quail. Lukanov (2022) reported the most significant increase in live weight in quail of dual-purpose and meat type until 28 days of age.

For slaughter at 42 days of age, male carcass weight was between 0.2 and 6.4% lower compared to results at 35 d. The opposite tendency was observed in female quail, but with a slight increase — 1.8-9%. In contrast to the present study, Abou-Kassem *et al.* (2019) reported an increase in carcass weight in male quail between 35 and 42 days of age by approximately 21.5%.

The amount of abdominal fat is highly correlated with the bird carcass's total fat content (Chambers, 1990). As quail age, the amount of abdominal fat also increases (Narinc *et al.*, 2014), with the most significant increase between 28 and 35 days of age, when in both sexes, it increases by 2 to 4 times. After 35 days of age, the increase in abdominal fat is weaker — about 19% in males and 35% in females. Evaluating the difference in the amount of abdominal fat between males and females, we can corroborate that it becomes most pronounced at 42 days of age, which is logical taking into consideration the already realized egg productivity of females and the role it plays in the large growth phase of the yolk follicle. There is a conflicting opinion in the scientific literature regarding gender differences in abdominal fat deposition. According to some authors, females accumulate more fat than males (Caron *et al.,* 1990; Genchev *et al.*, 2008; Raji *et al.*, 2015; Tufan and Bolacali, 2017), and according to others, the opposite is true (Sadjadi and Becker, 1980; Marks, 1990; Toelle *et al.*, 1991; Oğuz *et al.,* 1996; Tavaniello *et al.,* 2014). It was established that the selection for live weight reflected an increase in abdominal fat (Toelle *et al.,* 1991), respectively, in selected heavy dual-purpose and meat-type quail the share of abdominal fat was higher, and a similar tendency was observed in the present study.

Looking at the ratios between the quantitative traits analyzed above, we can say that regardless of the length of the fattening period, the average value of the slaughter yield (carcass without skin) is between 57.6 and 59.6%, which is comparable to the results published by Mahaparta *et al.* (2016), Bughio *et al.* (2020), Lukanov (2022). It should be noted that most studies of quail slaughter performance report slaughter yield per skinned carcass, where logically higher values would be expected.

Unlike Narinc *et al*. (2014) who found an increase in carcass weight associated with an increase in quail age from 4 weeks to 8 weeks, in the present study a similar tendency was observed only in females. The same authors found a decrease in slaughter yields with increasing slaughter age. Variance analysis showed that the independent influence of the gender factor on the manifestation of slaughter performance was very weak. As the slaughter age of the birds increased, the proportion of meat obtained from the valuable parts of the carcass also increased ($P < 0.01$). At 42 days of age, the values reached 64.3-66.8%, about 15% to 25% more than the results published by other authors (Wilkanowska and Kokoszynski, 2011; Gogaev *et al.*, 2016).

Analysis of the effect of the slaughter age and quail productive type showed that these two factors are the basis of the manifestation of the meat share from the valuable parts of the carcass trait—51.4% of the total variance of the trait ($P < 0.001$). Detailed analysis showed that the effect of the productive type factor was dominant—27.6% of the total variance of the trait compared to 7.4% for the slaughter age factor ($P < 0.001$).

Ioniță *et al.* (2020) reported a similar trend of deterioration in the efficiency of quail meat production with an increase in the slaughter age of meat-type quail. The increase in the values of some important meat characteristics such as carcass weight, the weight of carcass parts, meat quality and composition, lead some authors to recommend an optimal slaughter age of 5-6 weeks of age (Şeker *et al*., 2007; Narinc *et al.,* 2014; Abou-Kassem *et al.,* 2019), which also corresponds to the age of realization of meat-type quail in most production systems – 40-45 days (Jahan *et al.*, 2020). Considering the production efficiency of quail meat Lukanov *et al.* (2021) recommend ***an*** optimal slaughter age of meat quail of 28-35 days. A more detailed approach to optimizing slaughter age, considering the sex of quail, can be found in the studies conducted by Lukanov and Genchev (2018) and Lukanov and Pavlova (2020b). The strong deterioration of feed conversion, especially evident after 35 days of age, also increases the cost of obtaining 1 kg of the grill, and for quail of different productive types, cost increases between 10% in the WG line and 42% in the A line. The tendency of increasing cost for producing 1 kg of hand-boned meat is similar—12-34%. For both traits, the production efficiency of heavier-type birds (lines WG and GG) deteriorated more significantly after 35 days of age. Regardless of the slaughter age of the birds, the production of grill and hand-boned meat is seen to be the most efficient from the specialized meat-producing line WG and the least efficient from the light egg-laying line A. The differences are especially large compared to the WG line after 28 days of age, when the cost of producing 1 kg of grill increases by more than 42%, and 1 kg of hand-boned meat by more than 48%.

Conclusion

In the current study, the productive type of quail significantly affected live weight and carcass weight. The slaughter yield in the female sex decreased with age ($P < 0.001$), and the decline was more noticeable between 28 and 35 days of age. The study proved that the manifestation of the quail slaughter yield is determined at 11% of the productive type of the birds ($P < 0.001$).

The amount of harvested meat from the valuable parts of the carcass was mainly influenced by the live weight of the birds, and the relationship between the two traits had a linear character with a strong dependence between them (r=0.787 at $P < 0.001$). The age of slaughter and productive type factors were the basis of the manifestation of the meat share from the valuable parts of the carcass (over 51%), with the influence of the productive type factor being dominant (over 27%) ($P < 0.001$).

As the slaughter age of quail increased from 28 to 42 days, the total cost of feeding the birds raised by an average of 75%. The strong deterioration of feed conversion, especially pronounced after 35 days of age, increased the cost of obtaining 1 kg of grill and 1 kg of hand-boned meat. Regardless of the slaughter age of the quail, the production of grilled and hand-boned meat was most efficient from the specialized meat-producing line WG, but light egg-laying line A wasthe least efficient from.

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