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Mathematical models presenting the influence of the storage period on the qualities of turkey eggs

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Abstract

The purpose of this study is to analyze the impact of the storage period of turkey eggs prior to incubation on their hatching qualities and the changes in their constituent parts. Sensitive alterations are observed in indicators related to fertilization (91-97%), embryonic mortality (0-7 - days 90-95%; 8-14 days – 63-82%, 15 days – 71-91%), hatchability of fertile eggs (87-95%). It was found that the storage time does not significantly affect the egg weight as well as its component parts. Graphics and mathematical models were built during the processing and analysis process, presenting the impact of the storage period on the change of the respective indicators of eggs. Regression models have been built, presenting in an analytical form the established relations. The tools of IBM Statistics SPSS 24 were used.

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Introduction

The regression analysis is a method which presents the influence of certain factors (independent variables) on a single indicator (a dependent variable) in analytical form. For this purpose, mathematical models are built, which in themselves represent different functions (linear, square, cubic, etc.). This mathematical approach makes it possible to describe certain relations through mathematical means. This, in turn, is a tool for their in-depth research and analysis. Regression analysis is a widespread method of data processing in various fields of science. The livestock sector is no exception. There are many scientific developments based on regression models in the poultry sector (Bozlan *et al.,* 2008; Yuyan *et al.,* 2009 and Nwogu and Acha, 2014). The aim of Wolc *et al.* (2013) was to estimate various components for egg production over time in a commercial brown egg layer population using genomic relationship information. The results of this study show that random regression reduced animal models can be used in breeding programs using genomic information and can result in substantial improvements in the accuracy of selection for trajectory traits. Various types of regression analyses were used by Liebezeit *et al.* (2007). They modeled the relationship between egg flotation and age of a developing embryo for 24 species of shorebirds. They used regression analyses to estimate hatching date by modeling egg angle and float height, measured as continuous variables, against embryo age. For eggs early in incubation, they used linear regression analyses to predict hatching date from logit-transformed egg angles only. For late incubation, they used multiple regression analyses to predict hatching date from both egg angles and float heights. The storage of turkey eggs is an integral part of turkey breeding. It is known that increasing the storage period of egg hens reduces their hatchability (Fasenko *et al.,* 2001b; Tona *et al.,* 2004; Yassin *et al.,* 2008 and Hristakieva *et al.,* 2011), decreases the quality of chickens (Tona *et al.,* 2003) and increases the mortality after hatching (Yassin *et al.,* 2009). On average, each extra day of storage up to the seventh day of storage reduces hatchability by 0.2%, whereas this percentage increases to 0.5% after the seventh day of storage (Yassin *et al.,* 2008).

The aim of the present study is to investigate the influence of the duration of storage of turkey eggs prior to incubation on their hatching qualities and the changes in their constituent parts.

Materials and methods

Study site

The experiment was conducted in the breeding turkey farm at the Agricultural Institute - Stara Zagora.

Methods for obtaining the experimental data

For the test, turkey eggs at 38 weeks of age from the turkey line Layer light (LL) were used as the mother side for the production of turkey broilers. The turkeys were grown in boxes, in deep litter at a population density of 3 birds.m^{-2}, artificially inseminated twice a week in the afternoon with 0.025 ml fresh semen, undiluted. The turkeys were fed a standard ration containing metabolizable energy – 12.55 MJ/kg, crude protein – 18.10 %, calcium – 2.87%, available phosphorus – 0.49%. Average daily feed intake was 300 g. All the eggs from the daily yield from this line of turkeys were used, and only the deformed, broken and heavily contaminated eggs, which were not fit for incubation, were removed. The eggs were subjected to fumigation with formaldehyde vapors prior to storage. The eggs were divided into the following groups: eggs stored for 14 days, 10 days, 4 days and fresh eggs (no storage). The determination of the storage period was based on the practice where eggs need to be collected for incubation for different periods of time, depending on the demand for the commodity product – the one-day broiler turkeys. The weighing of the eggs was carried out individually on the day of receipt in order to calculate the mass loss during storage. The storage of the eggs during these periods took place in an egg-store with constant temperature and humidity, respectively 17 °C and 72%. On the incubation day, the eggs stored for 14, 10, 4 days and the fresh eggs were weighed again, divided into groups according to their weight: Group I – from 68 to 78 g, Group II - from 79 to 89 g, and Group III –

from 90 to 103 g. In order to determine whether there are any changes in the constituent parts of the eggs, caused by their storage, the eggs were separated by 30 pieces from each group. The egg mass, shell mass and albumen and yolk mass were determined, using a scale with an accuracy of 0.01g. The height of the albumen in mm was measured with a micrometer Ames s-6428. The percentage of the components was calculated from the weight of the whole egg. The pH of the albumen was measured by means of a pH meter – Pocket pH ad 110pH. The incubation was done in Optima 59 incubator. A 7^{th} -day examination was performed to establish the number of non-fertilized eggs and embryonic mortality (E 0-7), and on the 14th day of the incubation, a second examination was performed and the dead embryos for this period were removed (E 8- 14). At the isolation on day 25, the loss of moisture of the eggs throughout the incubation was recorded.

Determination of the indicators

Egg weight loss during incubation to 25 d of incubation (%) = $(EW_1-EW_2)/EW_1*100$,

where: EW_1- egg weight prior to the incubation; EW_2- egg weight by the 25^{th} day of incubation before moving to the hatch.

On the day of the hatching of the turkeys their weight was determined and also the percentage of their weight from the weight of the whole egg. The percentage of the embryonic mortality from 0 day till 7 day, from 8 day till 14day and to the hatching (E 15 until hatching) was calculated, as well as the fertilization and hatchability of the fertilized eggs.

Embryonic mortality (%) = 100*(number dead embryons/ number set eggs for incubation)

Fertilization (%) = 100*(number fertilized eggs/ number set eggs for incubation)

Hatchability of the fertilized eggs (%) = 100*(number hatchling poults/number fertilized eggs).

Statistical analysis

The mathematical methods used in the work are the regression models. The regression models present in analytical form the relations between the studied variables. Thus, from a mathematical point of view, the impact of the storage period on the characteristics of turkey eggs could be analyzed in more detail. For the mathematical processing of the data, the software product IBM Statistics SPSS 24 was used (Meyers *et al.,* 2013 and McCormick *et al.,* 2017).

Results and discussion

Graphical representation of the influence of the storage period on the qualities of turkey eggs

The same can be said about the absolute and the relative weight of the turkeys from the three weight eggs groups. Overall, in terms of the weight loss, it was found that comparative resistance over time was observed for all indicators.

Table 1. Linear regression models presenting the impact of the storage period (x) on the weight loss (y) of the three weight eggs groups.

Group	Trait	Regression model	Sign.	Coeff. of determ. (%)
I group	Weight loss during the storage period(g)	y=0,0929x+75,836	*	97
	Weight loss during incubation(g)	y=0,1249x-0,2321	*	93
	Absolute weight of hatchlings(g)	y=0,02x+47,81	n.s.	4
	Relative weight of hatchlings(%)	y=-0,1103x+65,152	*	16
II group	Weight loss during the storage period(g)	y=-0,17x+83,628	*	83
	Weight loss during incubation(g)	y=0,1184x-0,0853	*	94
	Absolute weight of hatchlings(g)	y=0,033x+53,661	n.s.	3
	Relative weight of hatchlings(%)	y=0,1068x+62,72	*	32
III group	Weight loss during the storage period(g)	y=-0,2105x+95,319	*	54
	Weight loss during incubation(g)	y = 0,0928x + 0,0642	*	99
	Absolute weight of hatchlings(g)	y = 0,0238x + 58,853	n.s.	4
	Relative weight of hatchlings(%)	y = 0,1712x + 61,642	*	58

*the regression model is statistically significant at significance level $p<0.05$

n.s.the regression model isn't statistically significant at significance level $p<0.05$.

The storage period of eggs does not significantly affect their constituent parts, either. This is evidenced by the fact that the values of the measured indicators do not change palpably over time. Their values are close to the original ones.

The change in the indicators is a matter of interest: fertilization (%), embryonic mortality (%) from 0 till 7days of incubation, embryonic mortality (%) from 8 till 14 days of incubation, embryonic mortality (%) from 15 days of incubation till hatched, hatchability of fertile eggsbecause of the movement found in their graphs.

Table 2. Regression models presenting the impact of the storage period (x) of three weight eggs on their fertilization, embryonic mortality and hatchability of fertile eggs (y) (%).

Trait	Group	Regression model	Sign.	Coeff. of determ.
Fertilized eggs (%)	I	$y=0,0613x^3-1,352x^2+6,2367x+87,5$	*	97
	II	$y=-0,013x^3+0,1293x^2-0,2333x+96$	*	93
	III	$y=-0,0143x^3+0,231x^2-1,4045x+93,75$	*	91
Embryonic mortality 0-7 days of incubation(%)	I	$y = -0,0082x^3 + 0,2027x^2 - 0,6795x + 8E-13$	*	90
	II	$y = 0,0379x^3 - 0,5837x^2 + 2,0488x + 2E-12$	*	95
	III	$y = 0,0087x^3 - 0,0487x^2 + 0,0564x + 1E-12$	*	91
Embryonic mortality 8-14 days of incubation (%)	I	$y = -0,0081x^3 + 0,2912x^2 - 2,8211x + 7,14$	*	82
	II	$y = 0,01x^3 - 0,1677x^2 + 0,5705x + 1,04$	*	62
	III	$y = 0,0186x^3 - 0,4647x^2 + 3,2271x + 7E-13$	*	83
Embryonic mortality 15 days of incubation to hatched(%)	I	$y = -0,0197x^3 + 0,3447x^2 - 1,8568x + 14,28$	*	88
	II	$y = 0,0129x^3 - 0,149x^2 + 0,3697x + 5,21$	*	71
	III	$y = 0,0365x^3 - 0,7165x^2 + 3,9496x + 2E-12$	*	91
Hatchability of fertile eggs (%)	I	$y = 0,036x^3 - 0,8392x^2 + 5,3589x + 78,57$	*	93
	II	$y = -0,0608x^3 + 0,9005x^2 - 2,989x + 93,75$	*	95
	III	$y = -0,0776x^3 + 1,564x^2 - 9,1815x + 100$	*	87

* the regression model is statistically significant at significance level $p<0.05$.

Although the storage period of eggs should not affect their fertilization, we have seen a tendency for a strong reduction up to the tenth day in the second and to the fifth day respectively in the third group (figure 1). Relative sustainability is then established. Some authors (Petek *et al.,* 2003 and Petek and Dikmen, 2004) reported lower fertilization of eggs stored more than 14 days prior to incubation.

Table 3. Linear regression models presenting the impact of the storage period (x) of turkey eggs on their constituent parts (y) (g).

Trait	Regression model	Sign.	Coeff. of determ.
Weight egg (g)	$y = -0,3453x + 86,377$	*	85
Weight egg-shell (g)	$y = -0,0008x + 7,6829$	n.s.	1
Weight yolk (g)	$y = 0,0374x + 25,798$	*	10
Weight albumen, (g)	$y = -0,4331x + 51,267$	*	90
pH of the albumen	$y = 0,0602x + 8,4188$	*	99
Height of the albumen (mm)	$y = -0,1493x + 8,1852$	*	94

* the regression model is statistically significant at significance level $p<0.05$

n.s. the regression model isn't statistically significant at significance level $p<0.05$.

The egg storage period has a strong impact also on E 0-7 for all three weight groups of eggs (figure 2). There is comparative sustainability from the beginning of the observation to the fifth day but then there were sharp changes in the behavior of this indicator in the different groups. In the first and third group a strong increase begins, which continues after the tenth day. In the second group there is a reduction period until the 10th day, after which a strong, sharp increase of the E 0-7 values was observed. Fasenko *et al.* (2001a) found higher embryonic mortality up to the 7th day of incubation in turkey eggs stored for 14 days than in eggs stored for 4 days. But this contradicts the finding by Bakst and Gupta (1997) that there are no differences between the embryonic development in eggs stored for 3, 7 or 14 days at 15 ° C.

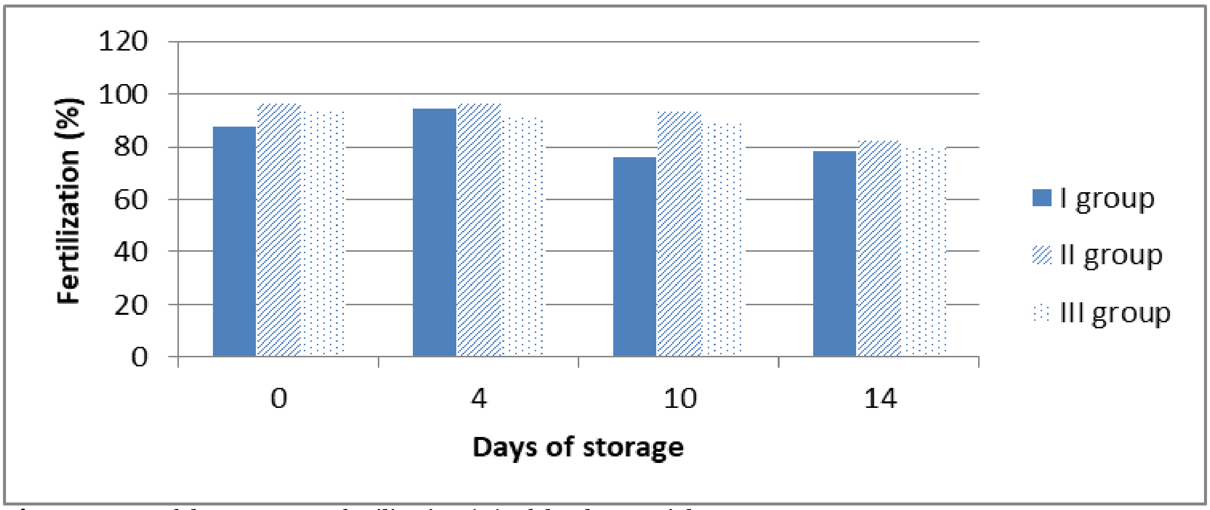

Fig. 1. Impact of the storage on fertilization (%) of the three weight eggs groups.

With regard to E 8-14, there was a sharp rise in the values in the third group as early as the first five days, followed by a slight decline to the tenth day and a comparative sustainability trend by the fifteenth day (figure 3). In the first group, the changes are opposite. We have a strong decline, followed by a smooth rise in E8-14 after the fifth day, which continues until the end of the period. Similar is the behavior in the second group.

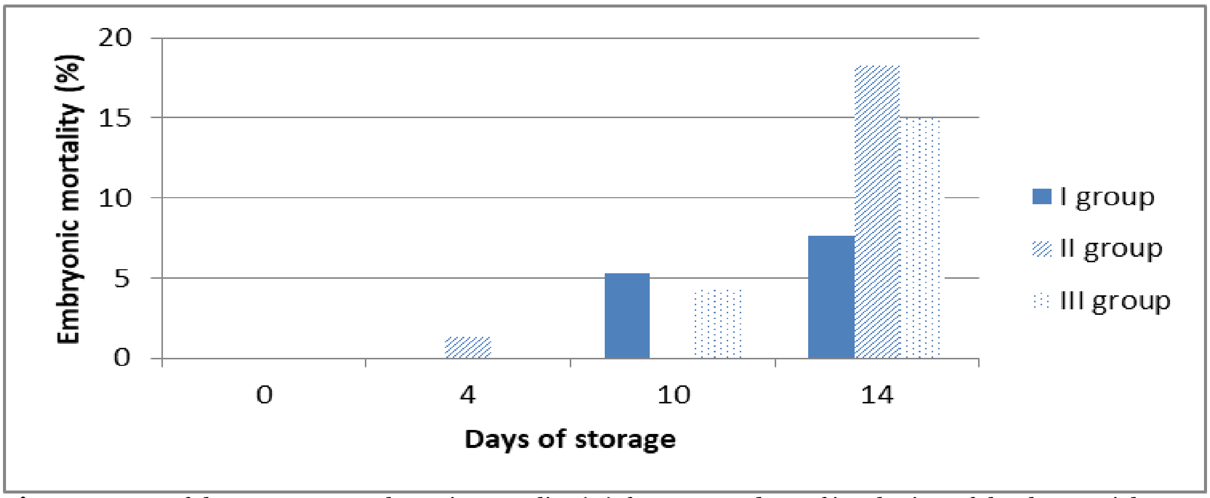

Fig. 2. Impact of the storage on embryonic mortality (%) from 0 to 7 days of incubation of the three weight eggs groups.

The storage period of the eggs has also a strong influence on the E 15 – hatched (figure 4). Until the tenth day, smooth peaks and drops occurred in the three groups. After the tenth day of storage, there were rapid increases in the second and the third group of the embryonic mortality from the 15th day of the incubation to hatching and strong reduction in first group , i.e. in the lightest eggs.

The change in the storage period of eggs prior to incubation results in a change in the values of the in hatchability of fertile eggs from the heavier eggs (second and third group) (figure 5). The hatchability of fertile eggs of the heaviest eggs (third group) no storage is 100% and 65% at 14 days storage.

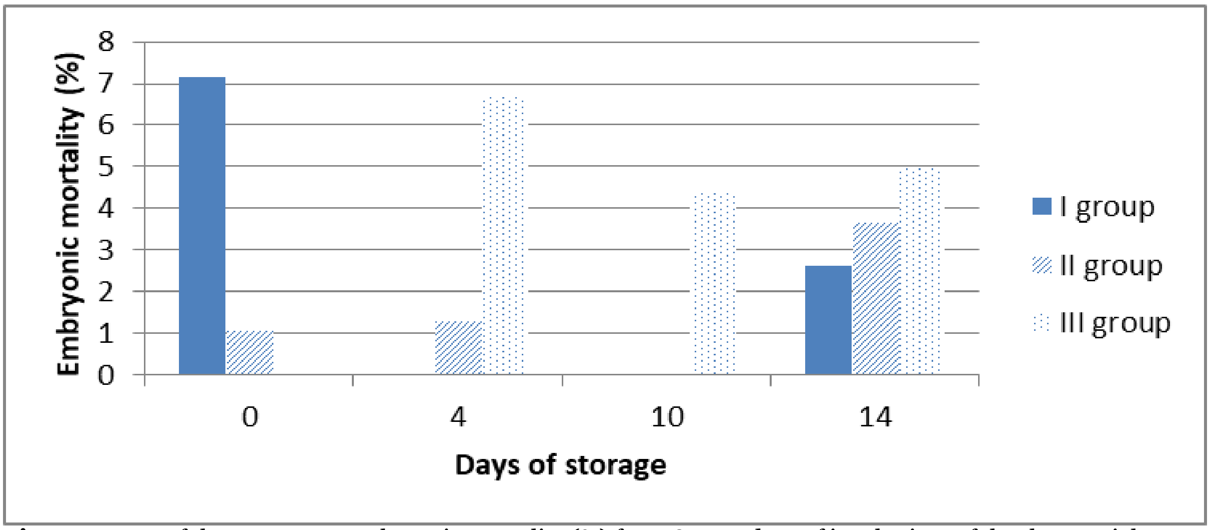

Fig. 3. Impact of the storage on embryonic mortality (%) from 8 to 14 days of incubation of the three weight eggs groups.

Analytical presentation of the influence of the storage period on the qualities of turkey eggs
Using the tools provided by IBM Statistics SPSS 24 (Gaur and Gaur, 2009 and Chinna *et al.,* 2012), data distribution normality check was performed.

The measured values of the indicators associated both with the weight loss and with the changes in egg components have a near-normal distribution (verified by P-P Plot and comparison with the normal line). This is a must for applying linear regression analysis. Secondary and third degree polynomial regression models were found to be statistically significant. For each of these, the following checks were made: the determination coefficient (approximate or equal to one) was calculated, the distribution of the regression residues was close to normal (by building a histogram).

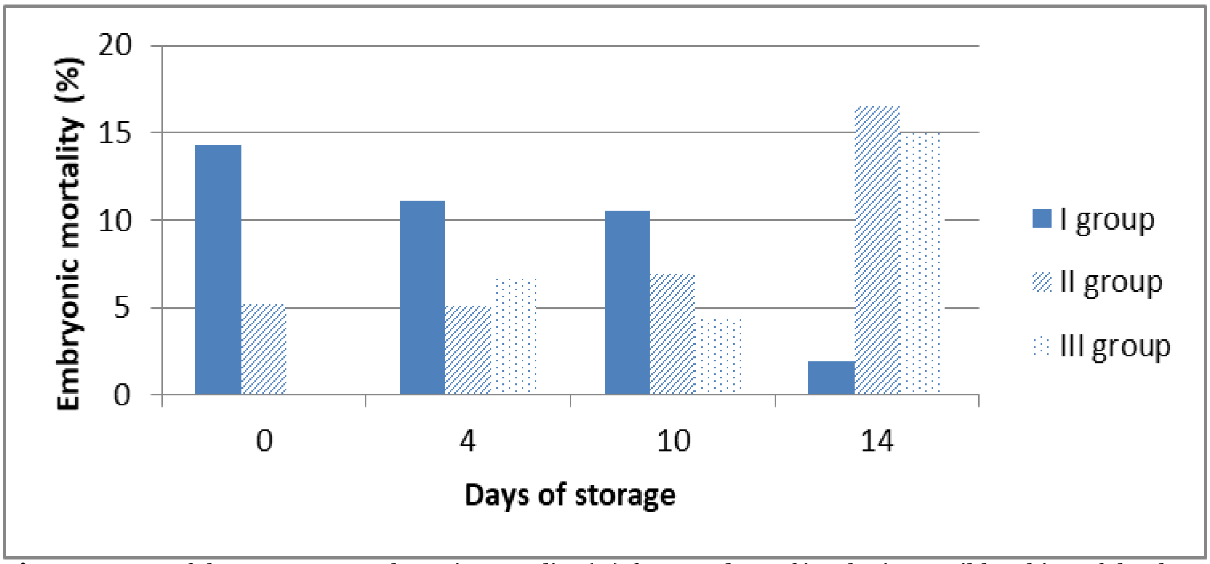

Fig. 4. Impact of the storage on embryonic mortality (%) from 15 days of incubation until hatching of the three weight eggs groups.

Tables 1-3 show the regression models presenting in an analytical form the relation between the storage period of three weight turkey eggs on the one hand and respectively the weight loss (Table 1), fertilization (%), embryonic mortality (%) and hatchability (%) (Table 2) and the egg components and some albumen traits (Table 3). They most accurately describe the impact of the storage period on the different characteristics of the eggs.

These regression models present the changes in the weight loss, fertility, embryo mortality, hatchability and constituent parts of egg turkeys during storage.

In Tables 1 to 3 are given the coefficients of the determination which show the degree of the influence on the period of storage above corresponding indicators. They provide information on how much of the variation of each indicator is explained by a change in storage time.

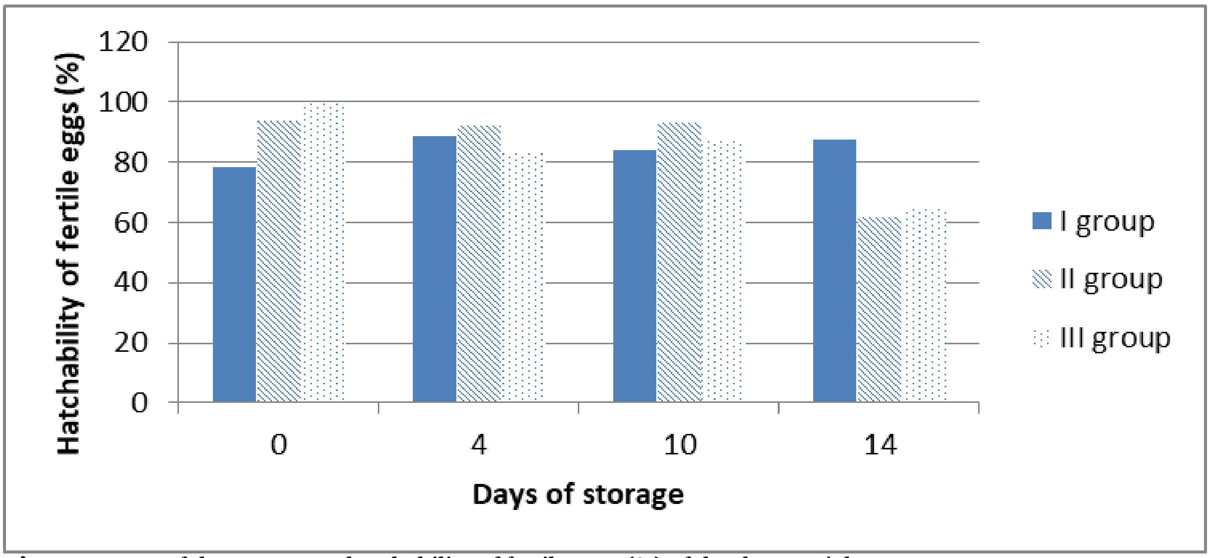

Fig. 5. Impact of the storage on hatchability of fertile eggs (%) of the three weight eggs groups.

After compiling the regression models, it has been shown that increasing of the storage period has a beneficial effect on some of the traits under consideration, and on others - there is a negative effect.

In the first-group eggs ,the increased storage period had a positive effect on the absolute mass of the turkeys. On the other hand, however, it leads to an increase in mass loss during storage and incubation as well as a decrease in the relative weight of the turkeys (Table 1).

The longer the eggs in the second group are stored, the more it reduces the loss of mass during storage, in addition it is increasing during the incubation.

It appears that the turkeys in this group has term that has a positive effect over the absolute and the relative mass of the hatched turkeys.

In Table 2 are shown the determination coefficients which prove the high degree of impact of egg storage period on fertility(%), embryo mortality(%) and hatchability(%).

As a result of the research, the degree and direction of influence of the storage period of the eggs and their constituent parts was determined (Table 3).

The effect of the storage period on the weight yolk and the pH of the albumin is positive. Increasing storage time, however, has a negative impact on its remaining components: weight shell, weight albumen and height of the albumen.

From the regression models in Table 3, it was found that by increasing the storage of the egg, it reduced the egg weight, the shell and the albumen as well as the height of the albumen, but increased the weight yolk and the pH value of the albumen.

However, the changes analyzed above are not sensitive, given that the coefficient before the independent variable are close to zero.

Conclusion

Following the studies and analyzes that have been carried out it has been found that the change in the storage period of turkey eggs has the greatest impact on their fertilization, embryonic mortality and hatchability. The changes in the rest of the indicators are insignificant, even in some of them the values are close to the initial ones. After building regression models, the functional relations between the egg storage period and the corresponding indicators were obtained. Some of them are linear functions, others are polynomial regression models of second or third degree. Each of these mathematical models could serve as a basis for future studies of the impact of the storage period on certain indicators, especially those related to the time factor.

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