Comparative study of fertility and hatchability of eggs from different hen genotypes

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Abstract

This study investigated the changes at the values of fertile eggs (%), hatchability of set eggs (%) and hatchability of fertile eggs (%) during the period 2009–2017 in five lines of hens. The changes of the values at these traits during different years were represented by mathematical models.

Regarding the values of fertile eggs (%) in the studied years from 2009 to 2017 varied at diferent extent in the five hen genotypes. It was found that in the studied years 2009–2017 fertility of eggs (%) has the highest coefficient of determination in line STR (76%), and in hatchability of set eggs (%) – in line GN (75%). In the different years from 2009 to 2017, the hatchability of fertile eggs (%) was statistically closest values at the eggs of line E (80%). Third-order polynomial regression models depicted the values of these parameters of the different years in the best way. They represented wave-like patterns of parameters' time course and instability in all lines of hens.

Key words*:* fertility of eggs, hatchability, reproductive performance, regression analysis, mathematical model.

Introduction

The fertility and hatchability of eggs are an important element of reproductive performance of poultry and of substantial economic significance. They are relevant for production of more chickens from a definite number of breeder hens within a period (Islam et al., 2002). The fertility of eggs is influenced by factors, directly associated with layer genotype (ovum) and its ability to combine with DNA of male chromosomes of the sire in order to create a beneficial medium for the development of the embryo (Brillard, 2003). Also, the fertility of eggs is strongly dependent on the amount and quality of rooster semen (McDaniel et al., 1995; Brillard, 2003), flock sex ratio (Alsobayel and Albadry, 2012); and flock age (Elibol and Brake, 2006).

Avigdor et al. (1986), Jayarajcin (1992) and Kumar et al. (2012) affirmed that the effects of hen breed and environment were among primary factors influencing egg hatchability. Peters (2000) and Peters et al. (2005) revealed that maternal genotype had a significant effect on fertility and hatchability. Abudabos (2010) found out a difference in the hatchability of eggs from two chicken genotypes (Ross; Cobb). According to Brillard (2003) the hatchability of the egg is a function of embryo's genotype, with contributions of both parents (father and mother). The environment is also relevant to eggs' hatchability and fertility (Banerjee, 1991, 1992; Elibol, 2000). A number of researchers (Kalita et al., 1985; Aggarwal, 1987; Farooq et al., 2003) demonstrated that environmental conditions had a substantial impact on egg incubation results.

For more detailed investigation and analysis of effects of various factors on hatchability traits of eggs, some authors (Jassim et al., 1996, Kuurman et al., 2001, 2003; Kuurman, 2002; Zakaria et al., 2009) proposed mathematical models using various mathematical statistical approaches. The mathematical model allows determining how changes in one or multiple factors could reflect on the changes in another variable. It is a means for theoretical research experiments, which, from economical point of view, are far more useful than practical approaches.

The aims of the present study were:

1. To establish the tendencies of change in the reproductive traits at five hen genotypes: fertility of eggs (%), hatchability of set eggs (%), hatchability of fertile eggs (%) from 2009 to 2017;

2. To present these traits at five hen genotypes in the different years by means of mathematical models.

Material and Methods

The present study was based on chicken egg incubation data from production of day-old hatchlings needed to replacement of breeder flocks in the pedigree farm of the Agricultural Institute – Stara Zagora, between 2009 and 2017. The poultry genotypes included in the study were line E, line GN, line Ss, line ChS, line STR. The birds were reared in panmixia, male to female ratio was 1 : 10, on wooden shavings litter at a housing density of 4–5 hens/1 m^2 and laying nests – 1 nest/4 hens. The hens were fed with standard diet for laying hens with metabolizable energy – 11.5 MJ/kg, crude protein – 18.1%, calcium – 3.8%, available phosphorus – 0.53%. Feed and water were supplied *ad libitum*.

Setting of incubation eggs occurred in June–July every year, and flock age was 44 weeks every year. Incubation eggs were collected for 4 to 7 days from the production of the breeder flock, and submitted to fumigation and sorting. They were stored at 16–17 °C and humidity 72% in an egg storage facility. The number of hatching eggs varies from 400 to 860 in each of the studied years for the different genotypes of hens. Examination for removal of infertile eggs was performed on the 7th day, eggs with dead embryos were removed on the 13th day, and hatchlings were counted on the 21st day at hatching. Eggs were incubated in Optima incubators. Percent fertility and hatchability were determined by the following formula:

Fertility of eggs (%) = Total fertile eggs/ Total eggs set*100

Hatchability of set eggs (%) = Number of chick hatched/Total set eggs*100

Hatchability of fertile eggs (%) = Number of chick hatched/Total fertile eggs*100

The present study used different mathematical approaches for evaluation the following parameters at the different years: fertility of eggs (%), hatchability of set eggs (%), hatchability of fertile eggs (%) in mentioned above hen lines. Comparative analysis for the degree and direction of year effect in the five hen lines was made and the degree of stability of each parameter was assessed. Mathematical models describing the study parameters at different years with MS Excel 2010 software.

Results and Discussion

Fertility and hatchability of eggs are the most important determinants for producing more chicks from given number of breeding stock within a stipulated period (Sankhyan et al., 2015). Fertility and hatchability performance of eggs depend on the number of factors like genetic, physiological, social and environmental (Narahari et al., 1988). Table 1 presents data for fertility of eggs (%) of the five hen lines for the period 2009–2017. In the different years the values at this trait was approximately close in line E and line STR. In line Ss and line GN, period of decrease (2013–2014) and increase (2014–2015) were outlined, and the trends in both hen lines were in the same direction. Line ChS exhibited a more rapid decline in 2013 followed by substantial increase up to 2015, followed by a sharp decline of fertility up to 2017.

Fertility performance of eggs depends on genotypic factors in addition to other factors (Islam et al., 2002). Previous reports noted a fertility rate of 77% for local hens and 78%–82% for exotic hens (Essatu et al., 2011; Yimer, 2019), which were lower than the current finding. An exception is the fertility of eggs in 2017 on the line ChS, which has the lowest values for the study time – 75.64%. Fertility may be affected by various factors, including genetic factors, the general condition of the parents, mating rate, age, egg-storage duration and condition, weather conditions, and geographical location (Adu-Aboagye et al., 2020; Islam et al., 2002).

The mathematical models presenting fertility of eggs (%) in the five hen lines for 2009–2017 are given in Table 2. The year was the independent variable (x) and fertility of eggs – the dependent one (y).

It was found out fertility of eggs (%) was most significant in line STR (76%) followed by line ChS (59%) and line GN (35%) in the time 2009–2017. Year was not a factor with significant impact on fertility in the other two lines (Ss, E). During the years of the study there is an increase or decrease in the values of the studied parameters. This explains why models are presented with third-order polynomial regression models. There is no tendency for relative retention of the same values throughout the study period.

Many factors influence eggs' hatchability: storage term, temperature, relative humidity, ventilation, egg position, turning of egg, ovoscopy. Similarly, the feed used for layers' rations has also an impact on hatchability (Mussaddeq et al., 2002). Other factors relevant for eggs' hatchability are: egg size, age and quality of eggshell, feeding of hens etc (King'Ori. 2011).

Table 3 presents data from hatchability of set eggs for the period of interest (2009–2017).

Table 1. Fertility of eggs (%) of the five hen lines from 2009 to 2017

Line / year	2009	2010	2011	2012	2013	2014	2015	2016	2017
Line E	95.60	91.48	91.26	94.86	95.58	96.92	91.25	96.18	96.78
Line GN	96.56	91.48	91.47	95.25	94.91	83.76	91.00	88.03	90.38
Line Ss	95.38	90.26	89.76	95.40	93.92	87.85	93.27	83.72	90.77
Line ChS	89.23	89.45	88.14	93.20	92.60	82.20	96.5	87.50	75.64
Line STR	95.38	90.03	87.29	93.53	91.07	94.91	95.23	96.62	95.46

Table 2. Mathematical models representing fertility of eggs (%) from 2009 to 2017

Line	Mathematical models	Coeff. Determ. (%)	Sign.
Line E	$y = -0.0923x^3 + 557.6x^2 - 10^6x + 8.10^8$	20	n.s.
Line GN	$y = 0.0397x^3 - 239.58x^2 + 482082x – 3.\ 10^8$	35	*
Line Ss	$y = 0.003x^3 - 18.127x^2 + 36549x – 2.10^7$	22	n.s.
Line ChS	$y = -0.2293x^3 + 1384.3x^2 – 3.\ 10^6x + 2.10^9$	59	*
Line STR	$y = -0.1352x^3 + 816.82x^2 – 2.10^6x + 1.10^9$	76	*

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

Table 3. Hatchability of set eggs (%) for the five hen lines from 2009 to 2017

Line/year	2009	2010	2011	2012	2013	2014	2015	2016	2017
Line E	82.88	81.96	86.45	75.43	71.25	80	81.75	96.18	89.6
Line GN	85.36	85.78	89.26	81.43	73.57	70.09	78	67.09	76.92
Line Ss	65.23	85.71	73.09	65.71	75.04	72.31	76.23	69.23	61.54
Line ChS	59.62	79.88	77.03	48.36	81.96	65.93	73.65	57.69	58.97
Line STR	59.62	79.39	81.67	74.12	75	81.86	80.86	66.15	76.92

The line STR is characterised with high variation at the values on hatchability of set eggs (%), observed as early as the beginning of the period and present until 2016. In line E, a relative stability was present up to 2015, while 2016 and 2017 at a lesser extent were years of strong increase, allowing assuming that favourable environmental conditions were present in these years. The variations at the values on these parameter in line Ss are characterised with peaks and drops. For this line, the worse year was 2011 and the most positive one: 2010. In the second half of the period, a relative stability was observed. In line ChS the period 2009–2014 exhibited considerable drops and peaks. The lowest hatchability of eggs set was registered in 2011, and the highest one – in 2013. There are several reports indicating that genotype, age of breeder hen and season has significant effect on fertility and hatchability traits (Elibol et al., 2002, Patra et al., 2016).

In Table 4 with mathematical models is represented change on hatchability of eggs set (%) at the different years.

The highest coefficients of determination on hatchability of set eggs was found out in line GN (75%). At a significantly lower, it has in line E (53%) and line STR (50%). Considering the low coefficients of determination in the other lines, the factors with substantial effects on this trait should be sought elsewhere. Mathematical models were third-order polynoms, indicative of the wave-like pattern of change of the trait during the period of the study. This is related to trait's instability in time in all studied lines. On the basis of models, no positive or negative effect of the year on hatchability of eggs set could be affirmed over the entire studied period (Table 4).

Fertility and hatchability are major parameters of reproductive Performance which are most sensitive to environmental and genetic influences (Sapp et al., 2004). Yeasmin et al., 2008 have investigated hatchability of eggs set in three hatcheries and reported best and worst years.

The results for 2009–2017 with respect to hatchability of fertile eggs are given in Table 5.

Islam et al. (2002) concluded that breed has an influence on fertility and hatchability of eggs, and

Table 4. Mathematical models representing the hatchability from set eggs (%) from 2009 to 2017

Line	Mathematical model	Coeff. Determ. (%)	Sign.
Line E	$y = 0.0122x^3 - 73.041x^2 + 145587x – 1.10^8$	53	*
Line GN	$y = 0.2198x^3 - 1327.1x^2 + 3.10^6x – 2.10^9$	75	*
Line Ss	$y = -0.0307x^3 + 185.2x^2 - 371925x + 2.\ 10^8$	26	n.s.
Line ChS	$y = 0.027x^3 - 163.42x^2 + 330052x – 2.\ 10^8$	14	n.s.
Line STR	$y = 0.2321x^3 - 1402.4x^2 + 3.10^6x – 2.10^9$	50	*

* *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*

Table 5. Hatchability of fertile eggs (%) for the five hen lines from 2009 to 2017

line/year	2009	2010	2011	2012	2013	2014	2015	2016	2017
Line E	82.68	89.6	94.69	79.52	74.54	82.54	84.12	100	95.63
Line GN	80.54	93.76	97.58	85.49	77.45	83.67	86.23	76.21	85.11
Line Ss	68.39	94.96	81.43	68.83	79.89	82.31	86.14	82.69	67.79
Line ChS	70.45	89.3	87.39	53.74	89.6	80.21	88	65.93	77.97
Line STR	70.45	88.18	93.56	79.25	82.35	86.25	85.62	68.47	80.43

that hatchability in White Leghorns was higher compared to that of White Rock, Rhode Island Red and Barred Plymouth rock eggs. Wonmeneh et al. (2011) showed that the breed has a great effect on hatchability. Considering hatchability of fertile eggs (%), the value at this parameters varied from 53.74% for 2012 to 89.60% for 2013 at line ChS. The strongest increase was observed in 2013, and partly, in 2017.

In the five hen lines, the values of change in this trait with time was the same, yet the magnitude of change was different. In general, periods of increase or decrease of hatchability of fertile eggs (%) were the same in all studied lines. Instability of this trait in time explains why its dynamics is described with third-order polynoms. The highest coefficients of determination on hatchability of fertile eggs (%) was observed in line E (80%), but it was significantly lower in line GN (47%) and line STR (45%) (Table 6). The wavy pattern of the time course of this trait was proved once again by the fact, the regression equations describing its behaviour were third-order polynoms.

It was demonstrated that for all hen genotypes, fertility of eggs (%), hatchability of eggs set (%) and hatchability of fertile eggs (%) in different years were depicted by third-order polynomial regression models. This is due to the wavy pattern of change e.g. instability of these traits with time. There was no clear tendency for either increase or decrease of any parameter in a specific line over the entire study period (2009–2017). That is why, categorical conclusion on the type of different year effect on studies parameters could not be made for any of lines. The regression equations showed theoretically the direction of mode of influence of year on these traits at a given time interval.

Conclusions

All studied hen genotypes exhibited varying values of studied traits at different years. In general, the different year was unidirectional in all hen genotypes, but at a various magnitude. The periods of increase and decrease of values of respective traits in the majority of hen lines were the same. Regarding the values to fertility of eggs (%) with the highest variation was line ChS; with regard to hatchability of set eggs (%) were eggs from line STR, line SS, line ChS. The hatchability of fertile eggs (%) showed great fluctuations at the values in line ChS, line GN and line E and lower fluctuations in the other two hen lines at different years. All obtained results could be subject of research aimed at increasing the stability of studied lines from one hand, and implementation of future selection practices on the other.

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Table 6. Mathematical models representing the hatchability of fertile eggs (%) from 2009 to 2017

Line	Mathematical model	Coeff. Determ. (%)	Sign.
Line E	$y = 0.6279x^3 - 3789.8x^2 + 8.10^6x – 5.10^9$	80	*
Line GN	$y = 0.2953x^3 - 1783.1x^2 + 4.\ 10^9x – 2.\ 10^9$	47	*
Line Ss	$y = -0.0884x^3 + 533.57x^2 – 1.\ 10^9x + 7.10^8$	14	n.s.
Line ChS	$y = 0.02x^3 -115.69x^2 +233387x -2.10^8$	2	n.s.
Line STR	$y = 0.2676x^3 - 1616.7x^2 + 3.10^6x – 2.\ 10^9$	45	*

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

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

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