Effect of the year and genotype on the reproductive performance of hen's lines

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Abstract

This study investigated the effect of the year on fertility (%), hatchability of eggs set (%) and hatchability of fertile eggs (%) for the period 2009–2017 in five lines of hens. The changes of these parameters during years were represented both graphically and by mathematical models. The most unstable line with respect to fertility of eggs (%) was Line ChS. It was found out that the effect of time on fertility was the greatest in Line StR (76%), while on hatchability of eggs set – in Line GN (75%). The strongest year effect on hatchability of fertile eggs was observed in Line E (80%). Third-order polynomial regression models depicted the effect of the year in the best way. They represented wave-like patterns of parameters' time course and instability in all lines of hens.

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

Introduction

The fertility and hatchability 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), Peters et al. (2005) and Peters et al. (2008) 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; Kuurman, 2002; Kuurman et al., 2003; 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 parameters: fertility (%), hatchability of set eggs (%), hatchability of fertile eggs (%) from 2009 to 2017;

2. To illustrate the effect of the year and genotype on these parameters 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 lines included in the study were line E, line GN, line Ss, line Chs, line StR. Hens were reared on wooden shavings litter at a housing density of 5–6 hens/1 m^2 and laying nests. The birds were fed standard feed for layer 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*. Insemination was natural mating, male to female ratio was 1 : 10.

Setting of incubation eggs for replacement of breeder flocks occurred in June–July every year, and flock age was 44 weeks. 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 incubation eggs from studied chicken lines varied from 400 to 860. 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.

The present study used different mathematical approaches for evaluation of year effect on the following parameters: fertility (%), hatchability of eggs set (%), hatchability of fertile eggs (%) in enumerated chicken lines. Graphs were plotted for better visualisation of changes with time. On the basis of graphs, comparative analysis for the degree and direction of year effect in the five lines was made and the degree of stability of each parameter was assessed. Mathematical models describing the effect of study year on respective parameters were built with MS Excel 2010 software.

Results and Discussion

The distribution of data analysed in this study, performed before the regression analysis was near to the normal one.

Table 1 presents data for fertility of eggs (%) of the five lines for the period 2009–2017. Fig. 1 depicts the change in this parameter with time. The time course of the trait was parallel 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 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. That is why, this line was evaluated as the most unstable with respect to eggs fertility (%).

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

It was found out that the effect of year on fertility (%) was most significant in Line StR (76%)

Table 1. Fertility (%) of the five investigated 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

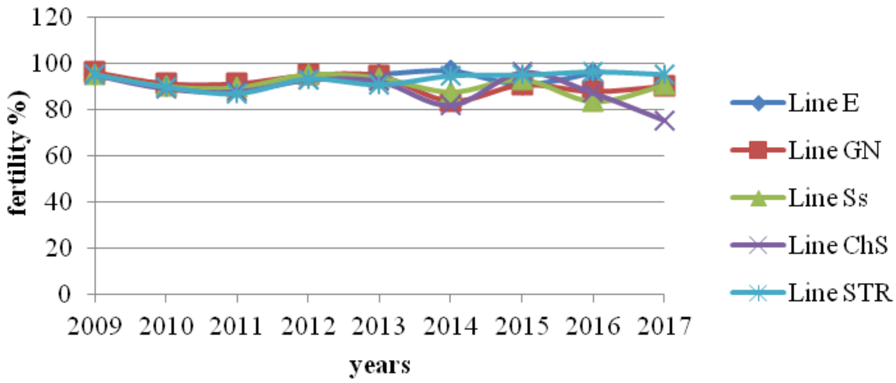

Fig. 1. The change in fertility (%) reported from 2009 to 2017

Table 2. Mathematical models representing fertility change (%) 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

followed by Line ChS (59%) and Line GN (35%). Year was not a factor with significant impact on fertility in the other two lines (Ss, E). As seen from Fig. 1, the year had positive or negative influence in the different years of study. This explains why models are presented with third-order polynomial regression models. No tendency for relative stability within the entire study period was outlined.

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 and Fig. 2 presents data from hatchability of eggs set for the period of interest (2009–2017).

The Line StR is characterised with high instability, observed as early as the beginning of

Table 3. Hatchability of eggs set (%) for the five 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

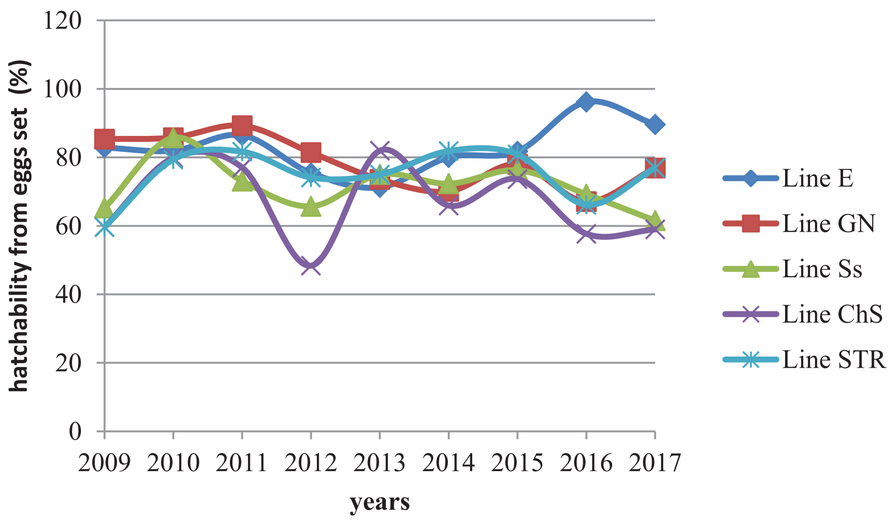

Fig. 2. The change in hatchability from eggs set (%) from 2009 to 2017

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 dynamics in Line Ss was 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. The graph illustrates the instability of this chicken line with regard to the studied trait. The most favourable years for Line GN were 2010 and 2017, while the worse ones were 2011 and 2012.

The year (x) effect on hatchability of eggs set % (y) is represented with mathematical models in Table 4.

The strongest effect of the year on hatchability of eggs set was found out in Line GN (75%). At a lesser extent, it has an effect on 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).

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 and their graphic representation in time – on Fig. 3.

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

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

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

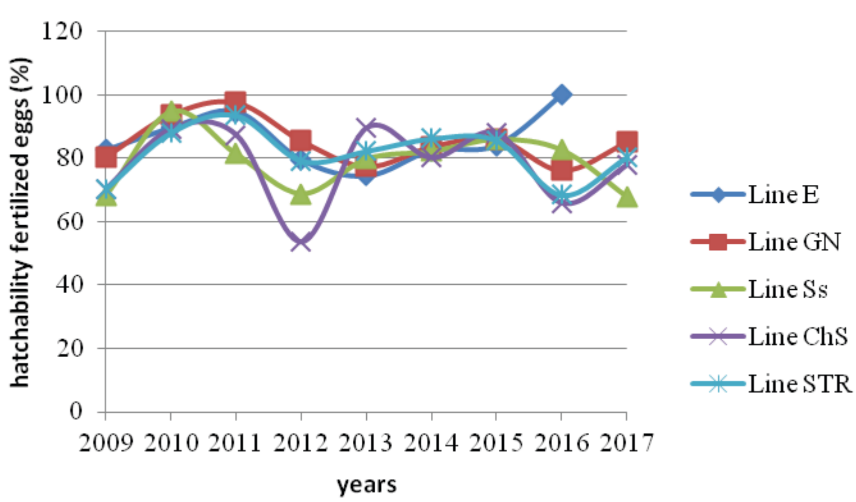

Fig. 3. The change in hatchability of fertile (%) eggs from 2009 to 2017

fect on hatchability. Considering hatchability of fertile eggs (%), the least stable line was ChS. The strongest increase was observed in 2013, and partly, in 2017.

In the five lines, the direction 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. This means that the effect of year on all lines was similar, except for 2013 for Line ChS and the end of the period for Line E. Instability of this trait in time explains why its dynamics is described with third-order polynoms. The strongest year effect (x) on hatchability of fertile eggs % (y) was observed in Line E (80%), but it was significantly weaker 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 lines, the year effect on fertility (%), hatchability of eggs set (%) and hatchability of fertile eggs (%) 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 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 lines exhibited instability of studied parameters with time. In general, the year effect was unidirectional in all lines, but at a various magnitude. The periods of increase and decrease of values of respective traits in the majority of lines were the same.

Regarding fertility of eggs (%), the least stable line was ChS; with regard to hatchability of eggs set (%): Line StR, Line SS, Line ChS. The hatchability of fertile eggs (%) showed great fluctuations in Line ChS, Line GN and Line E and lower fluctuations in the other two lines.

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.

References

Abudabos, A. (2010). The effect of broiler breeder strain and parent flock age on hatchability and fertile hatchability. *International Journal of Poultry Science*, *9*(3), 231-235.

Aggarwal, C. K. (1987). Effect of age of breeders and month of hatching on percent fertility in two lines of turkeys selected for high and low body weight: A note. *Indian J. Anim. Prod. Manag*, *3*, 157-158.

Alsobayel, A. A., & Albadry, M. A. (2012). Effect of age and sex ratio on fertility and hatchability of Baladi and Leghorn laying hens. *J. Anim. Plant Sci*, *22*(1), 15-19.

Avigdor, C., Zafrina, N., & Israel, N. (1986) Reproductive Performance of Broiler Lives Diversity Selected for Abnormal Fat. *Poultry Science*, *65*, 123-124.

Table 6. Mathematical models representing the change of 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 $p < 0.05$

Banerjee, G. C. (1991). A text book of animal husbandry 7th Edition. *Oxford and IBH Publishing Co. Pvt. Ltd.New Delhi- Bombay-Calcutta, P,* 747.

Banerjee, G. C. (1992). Poultry. 3rd ed., *Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, Calcutta,* 57.

Brillard, J. P. (2003). Practical aspects of fertility in poultry. *World's Poultry Science Journal*, *59*(4), 441-446.

Elibol, O. (2000). The problems due to seasonal changes in the hatchery. *Journal of Poultry Research (Turkey). 2,* 55-57.

Elibol, O. K. A. N., & Brake, J. (2006). Effect of flock age, cessation of egg turning, and turning frequency through the second week of incubation on hatchability of broiler hatching eggs. *Poultry Science*, *85*(8), 1498-1501.

Farooq, M., Javed, K., Durrani, F. R., Irfanullah, K., & Chand, N. (2003). Hatching performance of backyard hens in Peshawar, Pakistan. *Livestock Research for Rural Development*, *15*(9).

Islam, M. S., Howlider, M. A. R., Kabir, F., & Alam, J. (2002). Comparative assessment of fertility and hatchability of Barred Plymouth Rock, white leghorn, Rhode Island Red and White rock hen. *International Journal of Poultry Science*, *1*(4), 85-90.

Jassim, E. W., Grossman, M., Koops, W. J., & Luykx, R. A. J. (1996). Multiphasic analysis of embryonic mortality in chickens. *Poultry science*, *75*(4), 464-471.

Jayarajan, S. C. (1992**).** Effect of season and year on fertility and hatchability in white leghorn chickens of Meghalaya. *Indian Poult. Rev.*, 10, 41.

Kalita, D., Das, D., Goswami, R. N., Bora, H. N., & Dhar, W. (1985). Fertility and hatchability of White Leghorn and Rhode Island red breds of chickens in Meghalaya [India]. *Indian Veterinary Journal (India). 62*, 705-710.

King'Ori, A. M. (2011). Review of the factors that influence egg fertility and hatchability in poultry. *International Journal of poultry science*, *10*(6), 483-492.

Kumar, A., Das, K., Bharti, A., Kumar, R., & Kumar Singh A. (2012). Hatching performance in Black rock, Gramapriya and Vanaraja breeds of chicken. *Progressive Research 7 (Special),* 292-294.

Kuurman, W. W. (2002). *Mathematical modeling for hatchability of chicken eggs*. University of Illinois at Urbana-Champaign.

Kuurman, W. W., Bailey, B. A., Koops, W. J., & Grossman, M. (2001). Effect of hatch on the distribution for failure of an embryo to survive incubation. *Poultry science*, *80*(6), 710-717.

Kuurman, W. W., Bailey, B. A., Koops, W. J., & Grossman, M. (2003). A model for failure of a chicken embryo to survive incubation. *Poultry science*, *82*(2), 214-222.

McDaniel, C. D., Bramwell, R. K., Wilson, J. L., & Howarth Jr, B. (1995). Fertility of male and female broiler breeders following exposure to elevated ambient temperatures. *Poultry Science*, *74*(6), 1029-1038.

Mussaddeq, Y., Daud, S., & Akhtar, S. (2002). A study on the laying performance of cross (FAY+ RIR) chickens under different plans of feeding. *International Journal of Poultry Science*, *1*(6), 188-192.

Peters, S. O. (2000). Genetic variation in the reproductive performance of indigenous chicken and growth of pure and half bred progeny. *M. Agric thesis submitted to department of Animal Breeding and Genetics, University of Agriculture, Abeokuta, Nigeria*.

Peters, S. O., Ikeobi, C. O. N., Ozoje, M. O., & Adebambo, O. A. (2005). Modeling of growth in Savanna Chicken genotype. *Nig. J. of Animal. Production*, *32*, 40-47.

Sewalem, A., Lillipers, K., Johansson, K., & Wilhelmson, M. (1998) Genetic Trends of production and reproduction ,traits in white leghorn lines selected for production traits on reproductive adaptability. *Proceedings of the 18th World Poultry Congress Amsterdam,* 1998

Sreenivasaiah, P. V., & Joshi, H. B. (1987). Influence of hatching season on fertility and hatchability of fertile eggs in Japanese quails (Coturnix coturnix japonica). *Poultry Sci*, *20*, 25-28.

Wondmeneh, E., Dawud, I., & Adey, M. (2011). Comparative Evaluation of Fertility and Hatchability of Horro, Fayoumi, Lohmann Silver and Potchefstroom Koekoek Breeds of. *Asian Journal of Poultry Science*, *5*(3), 124-129.

Yassin, H. A. G. J., Velthuis, A. G., Boerjan, M., van Riel, J., & Huirne, R. B. (2008). Field study on broiler eggs hatchability. *Poultry Science*, *87*(11), 2408-2417.

Zakaria, A. H., Plumstead, P. W., Romero-Sanchez, H., Leksrisompong, N., & Brake, J. (2009). The effects of oviposition time on egg weight loss during storage and incubation, fertility, and hatchability of broiler hatching eggs. *Poultry Science*, *88*(12), 2712-2717.