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The process of embryonic mortality in seven initial laying strains during incubation*

Abstract

In five segments of incubation (within the 4th day, on the 7th, 14th, 20th days and in the stage of breaking through the shell) we studied the fertility of hatching eggs, the hatchability and embryonic mortality of seven initial laying strains (RIR – 1, RIR – 2, RIR – 3, RIW – 1, SU – 1, BPR – 1 and BPR – 2) in the course of three egg sets of individual pedigree hatching. The average hatchability of all the seven strains was 71.5%, the proportion of unfertilised eggs was 11.3% and embryonic mortality reached 17.2%. The embryonic mortality of all the seven strains culminated in two periods, i.e. within the 4th day of incubation (36.9% of the total embryonic mortality) and at the end of incubation (from the 15th to 20th day of incubation – 23.4% and during breaking through the shell – 18.1%). In terms of the inter-line differences, the embryonic mortality was the highest in three lines, which had a higher coefficient of inbreeding (Fx < 12.5%), i.e. RIR – 1 (20.9%), BPR – 2 (20.3%) and RIW – 1 (23.7%). All the three lines bear the recessive gene (k^+) on locus K, which is responsible for the rapid type of feathering using feathersexing. Within the 7th day of incubation the embryonic mortality was higher in both BPR lines (BPR – 1- 58.1%, BPR – 2 – 53.6% of the total embryonic mortality), while in the last trimester of incubation and in the period of breaking through the shell it was the lowest (BPR – 1 – 30.8%, BPR – 2 – 36.2% of the total embryonic mortality).

Key Words: hatching eggs, laying lines, fertilization, embryonic mortality, inbreeding, k^+ gene

Zusammenfassung

Titel der Arbeit: **Die embryonale Mortalität bei sieben Legehennenausgangslinien im Verlauf der Inkubation**

Untersucht wurden die Brutergebnisse in verschiedenen Zeitabschnitten zwischen dem 4. und 20. Tag der Bebrütungsdauer von Eiern folgender Legehennenausgangslinien: Rhode Island Red 1, 2, und 3, Rhode Island White, Sussex Light sowie Bar Plymouth Rock 1 und 2.

Die durchschnittlichen Schlupfergebnisse betrugen 71,5 %, der Anteil unbefruchteter Eier war 11,3 % und die embryonale Mortalität lag bei 17,2 %. Letztgenanntes Merkmal kulminierte bei zwei Zeitabschnitten und zwar bis zum vierten Tag der Inkubation und zum Ende der Brutdauer (15. bis 20. Tag sowie in der Schlupfphase). Die höchste embryonale Sterblichkeit war bei den drei Linien mit dem höchsten Inzuchtkoeffizienten (Fx > 12,5 %) zu verzeichnen. Bezogen auf die durchschnittliche embryonale Gesamtmortalität betrug sie bei den Rhode Island Red 1 = 20 %; Bar Plymouth 2 = 20,3 % und Rhode Island White 1 = 23,7 %. Diese Linien sind Träger des Gens (k^+) für schnelle Befiederung, das auch beim Autosexing eine bestimmte Rolle spielt. Bei den Bar Plymouth Rock 1 und 2 wurde erhöhte Embryonalmortalität besonders bis zum 7. Tag der Inkubation festgestellt, ab dem I5. Tag der Bebrütung und während der Schlupfphase war die embryonale Sterblichkeit besonders niedrig.

Schlüsselwörter: Legehennenlinien, künstliche Brut, Befruchtung, embryonale Mortalität, k^+ Gen

Introduction

The fertility of hatching eggs, embryonic mortality and hatchability can be listed among the important criteria of poultry fertility. The reproduction capacity expressed as the hatchability is influenced by many genetic and non-genetic factors, which are

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also responsible for embryonic mortality. Hatchability is a multi-factorial property and affected by a number of external factors, e.g. technology of hatching, age of the hen (CHRISTENSEN et al., 1996), nutrition and health condition. Sphere of influence are moreover some internal factors, such as genotyp of hatching chicks, the presence of lethal and semi-lethal factors, egg weight (SEWALEM and WILHELMSON, 1999) and the yolk : albumin ratio (MÁCHAL et al., 1992; HARTMANN et al., 2002), or the occurrence of double yolk eggs (FASENKO et al., 2000). The genetically determined metabolism of the parents is very important in terms of the quality of the hatching eggs. Genetic homeostasis, the phenomenon of super-dominance, the manifestation of some genes inducing certain abnormalities of the metabolism, or factors determining some other property, which to some extent modifies hatchability as well, could all be important factors of the differentiation of embryonic viability. It stands to reason that all these influences may interact and many times it is difficult to single out the individual components.

CHRISTENSEN (2001) discovered that embryonic mortality did not occur randomly on all days of incubation. More embryos die in the first and third trimesters than in the second. The frequency of "early embryonic mortality" has been observed to increase between 2 and 4 days in the chicken. The physiological values of hatchability of the set eggs of commercial laying hybrids ranged between 85% and 93%. For instance MAULDIN (1989) discovered that the average hatchability of fertilised eggs from 18,500 flocks of broiler hens in the USA was 89.1%. The highest hatchability was observed in eggs from hens of the age between 34 and 42 weeks. FASENKO et al. (1992) were involved in investigations of the relation between the age of the hen and egg fertility and they studied the effect of the age of the hen and the sequence of the laid egg in the series on the fertility, hatchability, viability and embryonic development. In accordance with O'SULLIVAN et al. (1991) they reported that fertility and hatchability was significantly dependent on the age of the hen; older hens reduced both the fertility and hatchability. Embryonic mortality is also affected by inbred depression. BRAH et al. (1991) studied the effect of the coefficient of inbreeding on the incidence of embryonic mortality in Leghorn White hens. The mortality of embryos with inbreeding coefficients of 25%, 12.5% and 0% differed significantly, i.e. 24.8%, 22.8% and 9.5%, respectively. DUNNINGTON et al. (1990) discovered a positive heterosis effect in hybrids of hen lines of 29 generations selected for body mass for late embryonic mortality and hatchability from fertilised eggs. In their opinion long-lasting selection for body mass reduces the viability.

Material and Methods

The embryonic mortality of all seven initial laying lines of the Rhode Island Red (RIR), Rhode Island White (RIW), Sussex Light (SU) and Bar Plymouth Rock (BPR) breeds was analysed at the time of individual pedigree hatching in clinically healthy hens of the age between 53 and 56 weeks. A total number of 30,665 eggs from hens of all seven lines were set after artificial insemination. The hens of these seven lines were individually placed in the same laying house and fed the same feed ration *ad libitum*. After laying the eggs were stored in the same room under identical conditions. Incubation was carried out in the same setting and hatching compartments.

The hatchability, proportion of unfertilised eggs and embryonic mortality were evaluated in each of the initial laying lines (RIR – 1, RIR – 2, RIR – 3, RIW – 1, SU –

1, BPR – 1 and BPR – 2) in three segments of hatching. In order to estimate the day of incubation, when the embryo died, the shell of all not hatched eggs was broken and the embryo was examined visually. The day of the embryo's death was estimated according to the stage of development of the embryo on the basis of the "Timeline of the embryonic development of the chick" (HAMPL, 1987). The so-called "clear" eggs (i.e. actually unfertilised eggs and dead embryos at the beginning of development) were discarded after a week of incubation in the course of the first examination.
According to the stage of development the dead embryos were divided into five periods – within 4, 7, 14 and 20 days. Embryos already dead in the period of emergence from the broken shell formed a special group.

Results

Table 1 shows the proportion of unfertilised eggs, the embryonic mortality and hatchability in three successive periods and in total. The average hatchability in all three egg-sets from all seven lines of hens was 71.5%. The lowest average hatchability (68.6%) was observed in the course of the first hatching and the highest in the second (76.8%). The average proportion of unfertilised eggs was 11.3 %, the highest (14.0 %) has been observed in the 3rd hatching. The average embryonic mortality was 17.2 %, the highest happened in the first hatching (21.1 %), in the 2nd and 3rd hatching the embryonic mortality has been lover (12.6 % and 12.4 % respectively).

Table 1
Fertility, embryonic mortality and hatchability in pure original laying strains on the particular trays with eggs set pedigree hatching line (RIR- 1, RIR- 2, RIR- 3, RIW- 1, SU- 1, BPR- 1 and BPR- 2) (Anteil unbefruchteter Eier, embryonale Mortalität und Bruttauglichkeit bei Legehenenausgangslinien in den einzelnen Bruten)

	Unit	1st hatching	2nd hatching	3rd hatching	Total
Set eggs	pices	16702	6025	7938	30665
Unfertilized eggs	pices	1720	637	1110	3467
	%	**10.3**	**10.6**	**14.0**	**11.3**
Embryonic mortality	pices	3532	761	986	5279
	%	**21.1**	**12.6**	**12.4**	**17.2**
Hatched chicks	pices	11450	4627	5842	21919
Hatchability	%	**68.6**	**76.8**	**73.6**	**71.5**

Table 2
Set eggs, average egg weight, number of layed eggs to 250 days of age, unfertilized eggs, embryonic mortality a hatchability in pure original laying strains (RIR-1, RIR-2, RIR-3, RIW-1, SU-1, BPR-1, BPR-2) (Zahl gelegter und unbefruchteter Eier, die embryonale Mortalität und Bruttauglichkeit sowie Eigewichte und Legeleistung bis 250. Tag bei den Legehennenausgangslinien)

Line	Set eggs	Average egg weight	Number of layed eggs	Unfertilized eggs		Embryonic mortality		Hatched chicks	Hatchability
	pices	g	pieces	pices	%	pices	%	pices	%
RIR - 1	3928	59.93	76.55	258	**6.6**	821	**20.9**	2849	**72.5**
RIR - 2	1226	60.22	84.03	64	**5.2**	186	**15.2**	976	**79.6**
RIR - 3	4699	63.34	87.26	417	**8.8**	586	**12.5**	3696	**78.7**
RIW - 1	4587	62.62	91.07	697	**15.2**	1086	**23.7**	2804	**61.1**
SU - 1	6311	59.99	88.95	843	**13.4**	841	**13.3**	4627	**73.3**
BPR - 1	5390	58.40	79.01	812	**15.1**	841	**15.6**	3737	**69.3**
BPR - 2	4524	62.93	71.74	376	**8.3**	918	**20.3**	3230	**71.4**
Total	30665	/	/	3467	**11.3**	5279	**17.2**	21919	**71.5**

Table 2 gives the average egg weight, the average number of eggs to 250 days of age, number of unfertilised eggs, their percentage proportion of the total number of set eggs, embryonic mortality and hatchability in the individual lines. Considerable differences in the respective indicators were found between the individual lines. The lowest proportion of unfertilised eggs was discovered in line RIR – 2 (5.2%) and the highest in lines RIW – 1 and line BPR – 1 (15.2% and 15.1%, respectively). Embryonic mortality for the entire incubation was the lowest in line RIR – 3 (12.5%) and the highest in line RIW – 1 (23.7%). Line RIR –2 showed the highest hatchability (79.6%) and line RIW – 1 the lowest (61.1%). Relation between average egg weight and number of layed eggs and average embryonic mortality and hatchability wasn't findings.

Table 3
Embryonic mortality of the original laying strains in the segments of incubation (Embryonale Mortalität bei Legehennenausgangslinien in den Zeitabschnitten der Inkubation)

Line		Age of dead embryos					
		Within 4 days	Within 7 days	Within 14 days	Within 20 days	Breaking through	Per cent total out of set eggs
RIR - 1	pieces	219	61	143	214	184	821
	%	**26.7**	**7.4**	**17.4**	**26.1**	**22.4**	**100.0**
RIR - 2	pieces	71	22	25	38	30	186
	%	**38.2**	**11.8**	**13.4**	**20.4**	**16.1**	**100.0**
RIR - 3	pieces	213	51	83	151	88	586
	%	**36.3**	**8.7**	**14.2**	**25.8**	**15.0**	**100.0**
RIW - 1	pieces	308	67	146	323	242	1086
	%	**28.4**	**6.2**	**13.4**	**29.7**	**22.3**	**100.0**
SU - 1	pieces	298	87	125	194	137	841
	%	**35.4**	**10.3**	**14.9**	**23.1**	**16.3**	**100.0**
BPR - 1	pieces	404	85	93	148	111	841
	%	**48.0**	**10.1**	**11.1**	**17.6**	**13.2**	**100.0**
BPR - 2	pieces	433	59	94	169	163	918
	%	**47.2**	**6.4**	**10.2**	**18.4**	**17.8**	**100.0**
Total	pieces	1946	432	709	1237	955	5279
	%	**36.9**	**8.2**	**13.4**	**23.4**	**18.1**	**100.0**

Embryonic mortality during incubation was not evenly distributed in time (Table 3) in the whole group and neither in the individual lines. The embryonic mortality of all the lines was the highest during the first trimester of incubation, i.e. 45.1% (within 4 days 36.9% and within 7 days another 8.2%). The embryonic mortality of all the lines was the lowest in the second trimester of incubation – within 14 days (13.4%). In the third trimester and in the period of breaking through the shell the embryonic mortality was again high, i.e. 41.5% (within 20 days it was 23.4% and in the period of breaking through the shell another 18.1%).

The breed and line had a relatively marked effect on the incidence and distribution of embryonic mortality in the respective segments of incubation (Fig.). Both lines of the BPR breed showed the highest embryonic mortality in the first trimester of incubation (9.1% and 10.9% from hatched eggs, respectively) and line RIR – 3 and SU – 1 showed the lowest (5.6% and 6.1% from set eggs, respectively). In the last week of

incubation the highest embryonic mortality, including embryos not hatched, was observed in line RIW – 1 (12.3% of set eggs) and the lowest in line BPR – 1 (4.8% of the set eggs).

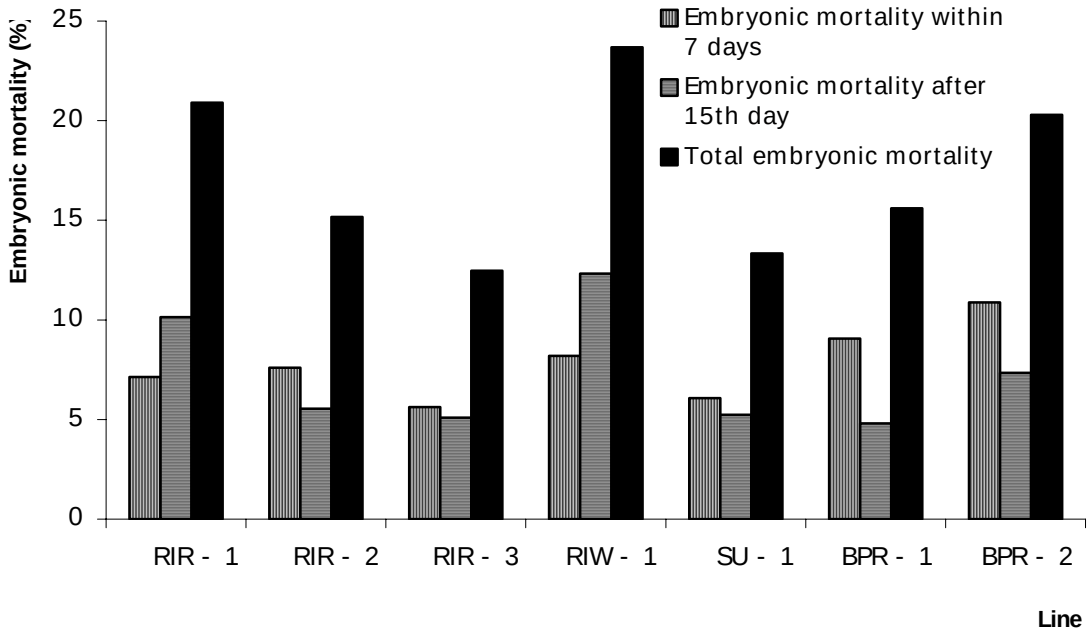

Figure: Embryonic mortality within the 7th day and after the 15th day of incubation in laying strains (Embryonale Mortalität der Legehennenausgangslinien bis 7 Tage und nach 15 Tagen der Inkubation)

Discussion

The line of the hen and the sequence of egg set also influence the hatchability of set eggs, the extent and the distribution of embryonic mortality in the course of incubation. The average hatchability of 30,665 eggs of all the seven initial laying strains (RIR – 1, RIR – 2, RIR – 3, RIW – 1, SU – 1, BPR – 1 and BPR – 2) in three successive settings was only 71.5%. This hatchability is considerably lower than is common in hatchings of parent sets or final hybrids (MAULDIN, 1989). Collecting the hatching eggs in intervals longer than one week and also the period of storage of the eggs, particularly in the first hatching, influences the overall lower hatchability of the initial strains, i.e. 68.6% (ALTABARI and KUNODI, 1989).

The proportion of unfertilised eggs increased in the individual egg sets (10.3%; 10.6%; and 14.0%) probably due to the great loading of the cocks of the respective lines in the period of pedigree hatching and following exhaustion, particularly of the cocks with a lower production of ejaculate, where the sperm was collected on a daily basis (MÁCHAL et al., 1996). The higher temperature inside the egg allows embryonic development to continue (WILSON, 1990), although very soon it stops definitely and the egg is then classified as one of the so-called unfertilised eggs and, in parallel, embryonic mortality increases (SCOTT and MacKENZIE, 1993). In the respective egg sets the embryonic mortality ranged between 12.4% and 21.1%, and in total was 17.2%. Embryonic mortality, however, is also affected by inbred depression (BRAH et al., 1991; INO, 1992), based on the inbreeding of initial strains and on changes in their metabolism.

In terms of genetic determination, differences were discovered in the hatchability and embryonic mortality of the respective breeds and lines. All the lines of the RIR breed showed the highest hatchability (72.5% to 79.6%), while the RIW and BPR showed the lowest (i.e. 61.1%; 69.3% and 71.4%, respectively). At the same time the line RIW – 1, which had the lowest hatchability, showed the highest embryonic mortality (23.7%).

Embryonic mortality during hatching was not evenly distributed in time in the whole set and neither in the respective lines. In all the seven initial strains embryonic mortality culminated in two segments of incubation – from the beginning to the 4th day of incubation the average was 36.9% of the entire embryonic mortality, from the 14th to the 20th day of incubation it was 23.4%, and during breaking through it was 18.1%.

On the basis of comparisons of the embryonic mortality of the individual lines it was discovered that embryonic mortality was the highest in line RIW – 1 (23.7%), RIR – 1 (20.9%) and BPR – 2 (20.3%), which had a higher Fx value (as high as 12.5%), than in the other lines where the maximum Fx value was 6.25% (BRAH et al., 1991). It is interesting that these three lines carry the recessive gene (k^+) on locus K, which is responsible for the rapid feathering using feathersexing, in contrast to the other lines where either the dominant gene K or both genes (K, k^+) are present on locus K.

In the course of hatching we observed a marked difference among the lines in terms of the distribution of the proportion of dead embryos during incubation. Embryonic mortality in the first trimester of incubation was the highest in both BPR lines (9.1% and 10.9% from hatched eggs, respectively), and the lowest in lines RIR – 3 and SU – 1 (5.6% and 6.1% from set eggs, respectively). The line RIW – 1 showed the highest embryonic mortality in the last week of incubation, including unhatched embryos (12.3% of set eggs), and BPR – 1 the lowest (4.8% of set eggs).

Characteristic of inbred lines is the course of and increase in embryonic mortality of all the seven lines. The first culmination of mortality (within the 4th day of incubation) is characteristic for the hatching of eggs of the domestic fowl (CHRISTENSEN, 2001), but can also be affected by the higher temperature in the setting compartments. The second culmination can be assigned to disorders of the transition from alantoid to lung respiration, and/or inadequate nutrition, particularly in the protein component of the mother with modified metabolism due to inbred depression.

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