THE RATE OF SENESCENCE OF THE DOMESTIC FOWL AS MEASURED BY THE DECLINE IN EGG PRODUCTION WITH AGE.

By SAMUEL BRODY, EARL W. HENDERSON, AND H. L. KEMPSTER.

(*From the Agricultural Experiment Station, University of Missouri, Columbia.*)

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It is well known among poultrymen that egg production in the domestic fowl declines with age. Indeed, it is the general opinion that the decline is so rapid that after the age of 2, or at most 3 years, a hen is no longer a profitable egg producer, and should therefore be disposed of. The decline in egg production with age may be due to the gradual exhaustion of the oocytes, or to the decline in vigor of the organs or tissues which form the limiting factors in egg production, or to both. In either case, whether it be exhaustion of a limited substance on which the process depends, or whether it be the wearing out of a limiting organ, the process may be classed as senescence, and the course of egg production with age may be used as an index of the course of senescence of the limiting tissues or organs. If this reasoning is correct, then data on the course of decline of egg production with age should be suitable material for testing by one method the theory that senescence is a physicochemical process.

If senescence is a physicochemical process, then the course of senescence should follow the course of some chemical reaction, since it is a general principle of chemistry that in a system of chemical reactions which are interdependent, the slowest reaction determines the rate of the resulting process[1] and therefore senescence, while a complicated process, should roughly follow the course of a chemical reaction of a simple order (the slower the limiting reaction as compared to the other reactions in the system, the closer the agreement between the calculated and observed values). The data on egg production presented in

[1] Walker, J., *Proc. Roy. Soc. Edinburgh*, 1897–98, xxii, 22.

Table I and Fig. 1 were analyzed from this standpoint and they were found to follow the course of the equation

$$E_t = Ae^{-kt} \quad (1)$$

in which E_t is the egg production during any age, t, e is the base of natural logarithms, and A and K are constants. This equation indicates that each year's egg production is, regardless of age, the same per cent of the preceding year's production. Thus in Table I, if any value is

TABLE I.

The Decline in Egg Production with Age in the Domestic Fowl.

Age.	No. of birds included.	Egg production per year. (Nov. 1 to Nov. 1.)	
		Observed.*	Calculated.†
yrs.			
1	222	158	158.5
2	221	140	140.1
3	222	124	123.9
4	222	110	109.6
5	193	95	96.9
6	28	89	85.7
7	27	71	75.7
8	6	63	67.0

* The observed values are averages of two breeds and eight different groups of birds kept under different conditions of management. To save space in this general publication, the individual records, and their significance, are omitted,but they will probably be presented in a poultry journal.

† Calculated from the equation $y = 179.2e^{-0.123t}$ in which y is the yearly egg production at the age, t. The egg production during any year is 88 per cent of the preceding year's production.

divided by the preceding value, the quotient is always .88, that is each year's production is 88 per cent of the preceding year's production. In other words, the percentage decline of egg production with age is constant, or exponential, and the course of senescence of the limiting tissues or organs involved in egg production, may therefore be said to follow an exponential law.

This exponential law represented by equation (1) is the same as the law of monomolecular change in chemistry, thereby substantiating

the suggestion that "the natural duration of life would be in reality the time required to complete a chemical reaction or a series of chemical reactions resulting in the production of toxic compounds sufficient to kill or resulting in the destruction of necessary compounds."[2]

Equation (1) may also be used to throw some light concerning the particular factor that limits egg production. The total number of

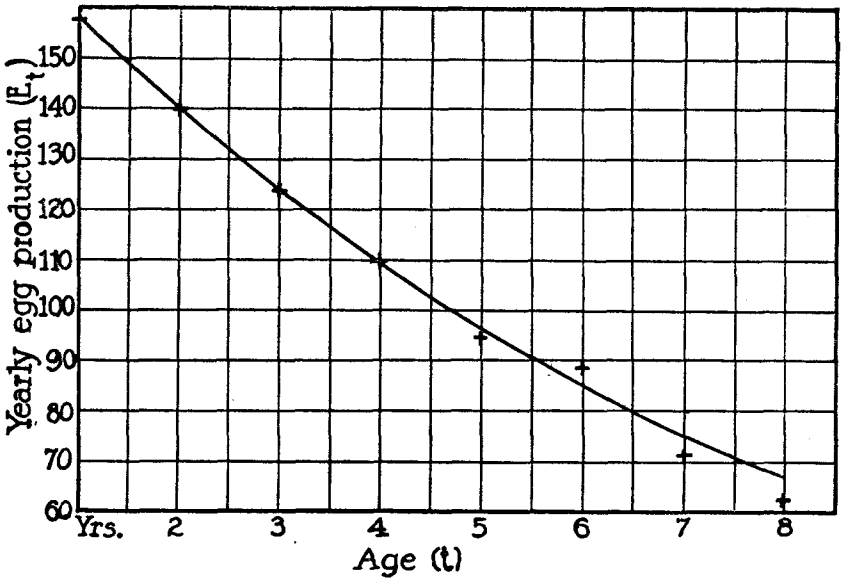

FIG. 1. The decline in egg production with age in the domestic fowl plotted from the averages in Table I. The smooth line represents the computed values; the crosses represent the observed values. The observed values during the 7th and 8th years are not reliable due to the small number of individuals represented in the averages.

eggs the average fowl in Table I would lay if she lived long enough to allow the senescence reaction represented by equation (1) to go to completion would be the total number of eggs laid from the time laying begins ($t = \frac{1}{2}$ year) to the time the senescence reaction is completed (t = infinity). This theoretical number of eggs can be found by

[2] Loeb, J., *Scient. Monthly*, 1919, ix, 578.

integrating equation (1) between the limits of $\frac{1}{2}$ year and infinity as follows:

$$E = \int_{\frac{1}{2}}^{\infty} Ae^{-kt}\,dt = \frac{a}{-k}\left[-e^{-kt}\right]_{\frac{1}{2}}^{\infty} = \frac{179.2}{0.123}\,e^{\frac{-0.123}{2}} = 1369$$

Now this total number of eggs, 1369, that the average hen in Table I can theoretically produce falls considerably below the number of oocytes found in the hen. Thus M. R. Curtis[3] found an average (in thirteen hens) of 1814 oocytes visible to the naked eye. There must be many more not so visible.[4] This rather low value obtained from the equation as compared to the actual count seems to indicate that it is not the number of oocytes in the hen that limits the course of egg production, but rather the decline in vigor of some limiting organ or organs.

SUMMARY.

Data are presented showing that the course of decline of egg production with age in the domestic fowl from the time laying begins up to and including 8 years follows an exponential law, that is, each year's egg production is a constant percentage of the preceding year's production (88 per cent in the group of fowl studied). Since the exponential law is the same as the law of monomolecular change in chemistry, and since the course of egg production with age may be taken as an index of the course of senescence of organs, or tissues limiting egg production, it is suggested that this exponential law of egg production substantiates the idea that senescence is a physicochemical process the course of which is limited by a chemical reaction. It is shown that the exhaustion of the oocytes is not likely to be the factor limiting the course of egg production.

There is a good deal of published data on egg production with age up to 4 years. We are not, however, acquainted with statistically significant data after this age. This scarcity of data after 4 years is due to the difficulty of keeping records of egg production after 4 years of birds whose "normal average expectation of life *at birth* is not substantially

[3] Curtis, M. R., Quoted by Pearl in *Maine Agric. Exp. Station, Bull. 205*, 1912.
[4] Pearl, R., *Maine Agric. Exp. Station, Bull. 205*, 1912.

more than 2 years."[5] The relatively large amount of data up to 8 years presented in this communication was made possible by combining data obtained at other places with the data obtained at this station. We take much pleasure in expressing our indebtedness to J. H. Bardsley, of the New Mexico Station, J. E. Daugherty, of the California Station, B. F. Kaupp, of the North Carolina Station, J. H. Martin, of the Kentucky Station, H. G. May, of the Rhode Island Station, and L. H. Schwartz, of the Purdue Station, for their cooperation in obtaining the data summarized in Table I.

We have also included in our averages the data given by E. D. Ball, G. Turpin, and Byron Alder in the Utah Agricultural Experiment Station Bulletins.[6]

[5] Pearl, R., The biology of death, Monograph on Experimental Biology, Philadelphia and London, 1922, 63.

[6] Ball, E. D., Turpin, G., and Alder, B., *Utah Agric. Exp. Station, Bull. 135*, 1914. Ball, E. D., Alder, B., and Egbert, A. D., *Utah Agric. Exp. Station, Bull. 148*, 1916.