ECONOMIC CONSEQUENCES OF ABERRATIONS IN THE PRODUCTION PROCESS IN AVIARY SYSTEMS FOR LAYING HENS

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Abstract: A simulation model has been developed that can be used to calculate the economic consequences of aberrations in the production process of laying hens that were housed in aviary systems. The model consists of a biological subsystem, a subsystem to model aberrations and an economic subsystem. The biological subsystem consists of separate mathematical curves to calculate daily the hen-day egg production, egg weight, cumulative mortality and feed consumption. A general concept that uses the parameters start of aberration, incubation time, duration of aberration, duration of recovery, maximum deviation and permanent deviation has been given to model aberrations in the production process. In the economic subsystem feed and egg prices are used to calculate the economic consequences af aberrations. For a flock of 20.000 hens, a feed price of 0,493 (Dfl/kg) and an egg price of 1,71 (Dfl/kg) an aberration in the water consumption at an age of 415 days resulted in a net production loss of 785 Dfl. A complex feed consumption aberration at an age of 203 days resulted in a permanent lower hen-day egg production of 4 % and a net loss of 25.422 Dfl.

Keywords: simulation model, egg production, aviary systems, mathematical curves

1. INTRODUCTION

In West-European countries most laying hens are housed in cage systems because they have strong advantages above alternative housing systems, especially in terms of economics, pollution control and working conditions (Appleby *et al.*, 1994). In terms of welfare aspects aviary housing systems are preferable (Blokhuis and Metz, 1995; Hansen, 1994). In aviary systems hens have a lot of space (approximately 1.000 cm^2 area per hen), have freedom to move through the house, they can scratch and dustbath in the litter and they can use laying nests and perches.

Production costs, labour requirements, the degree of management skill and the required veterinary supervision in aviary systems are all higher than in cage systems (Horne, 1991; Elson, 1992; Wit,1992). The decision support system LayVision has been developed to support the aviary farmer in his daily management which aims at controlling the critical success factor areas 1) feed consumption, 2) the ambient temperature in the house, and 3) to detect diseases in time (Lokhorst, 1995). LayVision contains amongst others an expert system to monitor the daily production process, and it contains mathematical curves that can be used as standard in the expert system. Non-linear mathematical curves are present for the description of the daily hen-day egg production, egg weight, feed consumption, water consumption, second-grade eggs, floor eggs, body weight, flock-uniformity and the cumulative mortality (Lokhorst, 1996).

Detection of aberrations is important, but there is also a need for information on the economic consequences of aberrations. It is unlikely to happen that experiments are set up in which the economic consequences of aberrations are determined. These experiment will be too expensive and hens can suffer. Simulation is a reasonable alternative. They can used to enlarge the understanding of the production process and to calculate the economic consequences of possible aberrations (Emmans,1989).

The aim of this study therefore was to develop a simulation model that must be able to calculate the economic consequences of aberrations in the production process of laying hens in aviary systems.

2. MODEL DESCRIPTION

The simulation model is subdivided into three subsystems: 1) the biological subsystem, 2) the aberrations subsystem, and 3) the economic subsystem.

2.1.Biological subsystem

Literature and plots of the data from six flocks were used by Lokhorst (1996) to draw up mathematical curves that describe the production process of laying hens in an aviary housing system. The variables hen-day egg production, egg weight, feed consumption, and cumulative mortality are of primary importance for the simulation model. Each mathematical curve is a function of age (t), where t represents the number of days in the production period which starts at an age of 141 days (Siplu, 1990). Cumulative mortality is based on the number of housed hens at the start of the production process and the other functions are based on the number of present hens.

2.1.1. Hen-day egg production The hen-day egg production is calculated as the number of eggs produced per day divided by the number of present hens. To model the daily hen-day egg production in an aviary system the next mathematical curve is used:

$$Y_{hen\_day\_egg\_prod} = \frac{100}{1 + a * r^{t}} - (b + c * t + d * t^{2})$$

The logistic part is described with parameters a and r, where a represents, together with parameter b, the percentage of lay at the start of the production period. Parameter r is responsible for the speed with which the top of the egg production is reached. The quadratic part with the parameters b, c, and d is responsible for the maximum hen-day egg production and the persistency. The quadratic equation results are subtracted from the asymptote of the logistic part, which represents the maximum percentage of 100 % for the hen-day egg production. The overall fitting results for the parameters a, r, b, c and d respectively were 5.274, 0.871, 7.506, -0.005 and 1.252E-4.

2.1.2. Egg weight Egg weight is related asymptotically to age, which can easily be

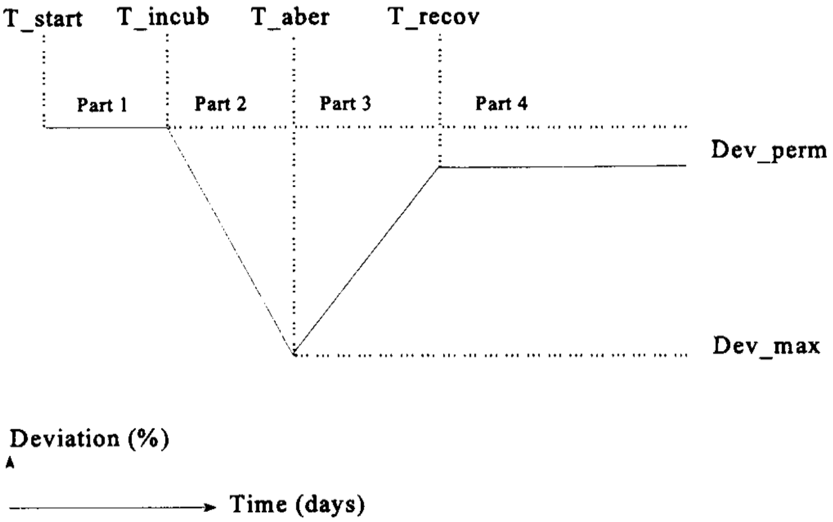


Figure 1 General concept for modelling aberrations in production variables.

described with the next restricted growth curve:

$$Y_{egg\_weight} = a + b * r^{t}$$

The parameter a in the formula expresses the horizontal asymptote of the maximum egg weight and a - b is the egg weight at the start of the production period. The overall fitting results for the parameters a, b and r respectively were 65.277, -21.938 and 0.981.

2.1.3. Feed consumption In the begin of the laying period feed consumption gradually increases, which can be represented by a restricted growth curve. After a while the feed consumption per flock shows different patterns. These pattern show a gradual increase or decrease or combinations, and these can be described with a second order polynome. The mathematical curve that describe the daily feed consumption is:

$$Y_{feed\_cons} = \frac{a}{1 + b * e^{-a * c * t}} + d * t + e * t^{2}$$

Parameter a represents the horizontal asymptote of the restricted growth curve. Parameter b represents, together with parameter a, the feed consumption at the start of the laying period ($Y_0 = a/(1+b)$) and parameter c, together with parameter a represents the speed of the increase in feed consumption in the restricted growth phase. Parameters d and e determine if feed consumption gradually increases or decreases during the rest of the laying period. The overall fitting results for the parameters a, b, c, d and e respectively were 121.513, 0.434, 4.027E-4, -0.028 and 1.617E-5.

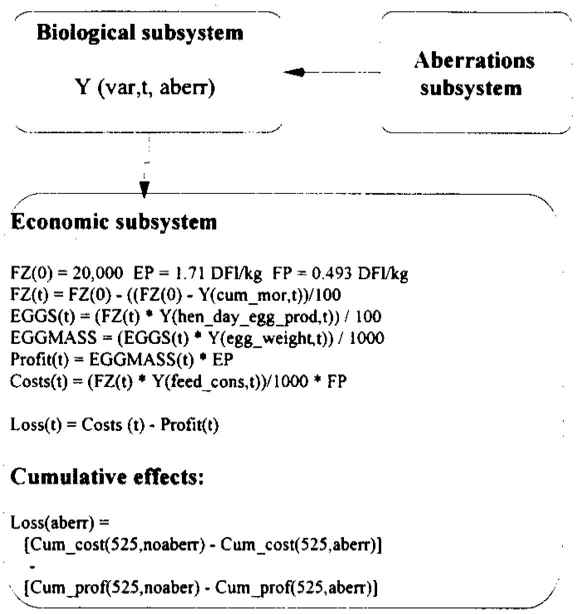
2.1.4. Cumulative mortality Cumulative mortality shows a quadratic increase in time . If the number of hens at the start of the production period is known, it is possible to calculate the number of hens present on a certain day. The mathematical curve that describes the cumulative mortality is:

$$Y_{cumulative\_mortality} = a * t + b * t^{2}$$

The parameters a and b respectively express the linear and quadratic increase in the mortality of the hens and their overall fits respectively were 7.563E-3 and 6.183E-6.

2.2. Aberrations subsystem

Aberrations can be of different types. Lokhorst (1995) described aberrations (eg. respiratory disorder, digestive disorder, high and fast mortality, major feed restriction and parasites) that can be detected by combining deviations in 10 quantitative production variables. In the biological subsystem each production variable was described separately,



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FZ(0) = 20,000  EP = 1.71 DFl/kg  FP = 0.493 DFl/kg
FZ(t) = FZ(0) - ((FZ(0) - Y(cum_mor,t))/100
EGGS(t) = (FZ(t) * Y(hen_day_egg_prod,t)) / 100
EGGMASS = (EGGS(t) * Y(egg_weight,t)) / 1000
Profit(t) = EGGMASS(t) * EP
Costs(t) = (FZ(t) * Y(feed_cons,t))/1000 * FP

Loss(t) = Costs (t) - Profit(t)

Loss(aberr) =
  [Cum_cost(525,noaberr) - Cum_cost(525,aberr)]
   -
  [Cum_prof(525,noaber) - Cum_prof(525,aberr)]
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Figure 2 Main components of the simulation model.

as if there are no relations between them. This was done to provide a simple model that can deliver standards that easily can be adapted to farm specific production circumstances. If the consequences of aberrations must be calculated, it would be convenient to model all types of aberrations in the same way. In figure 1 a concept is given for modelling aberrations.

A deviation can be subdivided in four parts that can be represented by 6 parameters. Part 1 describes the incubation period with the parameters T_start, that indicates the day the aberration begins, and T_incub(ation). In part 1 no deviation can be seen. In part 2 that runs from T-incub till T_aber(ration) the deviation increases till the maximum deviation (Dev_max). The recovery period is described in part 3. In part 3 that runs from T_aber till T-recov(ery) the deviation decreases till the original level or till a new stable level. If the original level from before the aberration occurred is not reached again a permanent deviation (Dev_perm) is present till the end of the production period (part 4). The deviations are expressed as a percentage from the expected production if no aberration was present.

2.3. Economic subsystem

In the economic subsystem the cumulative daily profits of the egg production and the cumulative daily feeding costs of a specific flock are calculated. Fixed costs, such as the price of the hens, are not incorporated in the calculation of the economic conseqeunces of an aberration. Figure 2 shows the main components that are used in the economic subsystem. The biological subsystem is used to calculate the flock specific technical results of the variables cumulative mortality, hen-day egg production, egg weight and feed consumption (Y(var,t,aberr)). Together with the flock size (FZ_0) at the start of the production period, the egg price (EP) and the feed price (FP) it is then possible to calculate the daily profits and costs.

To calculate the economic consequences of aberrations it is necessary to distinguish two groups, one with the aberration (Y(var, t,aberr)) and the other without the aberration (Y(var,t,noaberr)). The aberration influences the production results directly and so the profits and costs are also influenced by the aberration.

The daily profits and costs can be used to calculate the cumulated profits and costs, starting from the beginning of the production period. The end of the production period is set to the age of 525 days.

3. RESULTS AND DISCUSSION

3.1 Consequences for the production results

Literature that describes deviations is scarce. In the test data of Lokhorst (1996) two aberrations, a complex feed consumption aberration and a water consumption aberration, were known to be present. These two aberrations were analyzed and the aberrations were classified according the aberration concept of figure 1. The results for these two aberrations are shown in table 1.

At an age of 203 days feed consumption was 109 g per hen per day, which was already low for hens in full production, and it started to

Table 1 Complex feed consumption and a water consumption aberration.

Complex feed consumption aberration	T_start (age)	T_incub (days)	T_aber (days)	T_recov (days)	Dev_max (%)	Dev_perm (%)
water consumption	203	10	4	26	-14	0
feed consumption	203	0	14	9	-28	0
hen-day egg production	203	14	12	41	-18	-4
Water consumption aberration						
water consumption	415	0	5	5	-100	0
feed consumption	415	5	1	4	-45	0
hen-day egg production	415	6	2	7	-24	0
egg weight	415	6	3	2	-2	0
body weight	415	6	1	4	-6	0

decrease slowly till the age of 215 days. The next two days feed consumption fell down to 78 g per hen per day. In the meantime water consumption showed also a decrease from day 213 till day 217. Both feed consumption and water consumption recovered, although it took a couple of weeks. Hen-day egg production was also influenced and it never recovered till the original production level. It was very difficult to give one specific cause. Probably a combination of an IB-infection, a TRT infection, worms and the fact that the hens were quick in production with a low feed consumption, caused a low resistance of the hens.

At day 415 the water consumption of a flock starts to decrease slightly until at the middle of day 419 the water consumption completely stops. At day 421 this was repaired and the hens showed a catch up of this loss during the next 4 days. The aberration in the water consumption had also an effect on feed consumption, hen-day egg production and body weight. The effect on egg weight was small, but present. Other effects were not found. No permanent effects were seen but there was a loss of production for about 9 days.

3.2 Economic consequences of aberrations

The economic consequences of the complex feed consumption and the water consumption aberration were calculated for a flock size of 20.000 hens, an egg price of 1,71 Dfl per kg of eggs and a feed price of 0,493 Dfl per kg (KWIN-Veehouderij, 1994). To simulate the expected production results the variables of the biological subsystem were used to calculate the cumulated egg profits and the cumulated feed costs till the end of the production period. The net economic loss of the water aberration was calculated as 785 Dfl. Egg profits were 2.004 Dfl lower, but feed costs were also 1.219 Dfl lower. The complex feed consumption aberration caused a decrease in egg profits of 29.070 Dfl and a decrease in feed costs of 3.648 Dfl, which resulted in a net loss of 25.422 Dfl.

Assumed that the effects of two aberrations on the production results were independent of age of the hens, the economic consequences of the two aberrations related to the start of the aberration are shown in figure 3. One can see that the economic loss of the complex feed consumption aberration depends on the start of the aberration and on the permanent effect of the hen-day egg production. If this aberration occurs at the end of the production period, it is even possible to have extra profits, instead of a loss. This can be explained by the lower feed consumption during the incubation time of 10 to 14 days. The economic loss of the aberration in the water consumption also depends on the start of the aberration and on the production results. The maximum loss is 892 Dfl and the

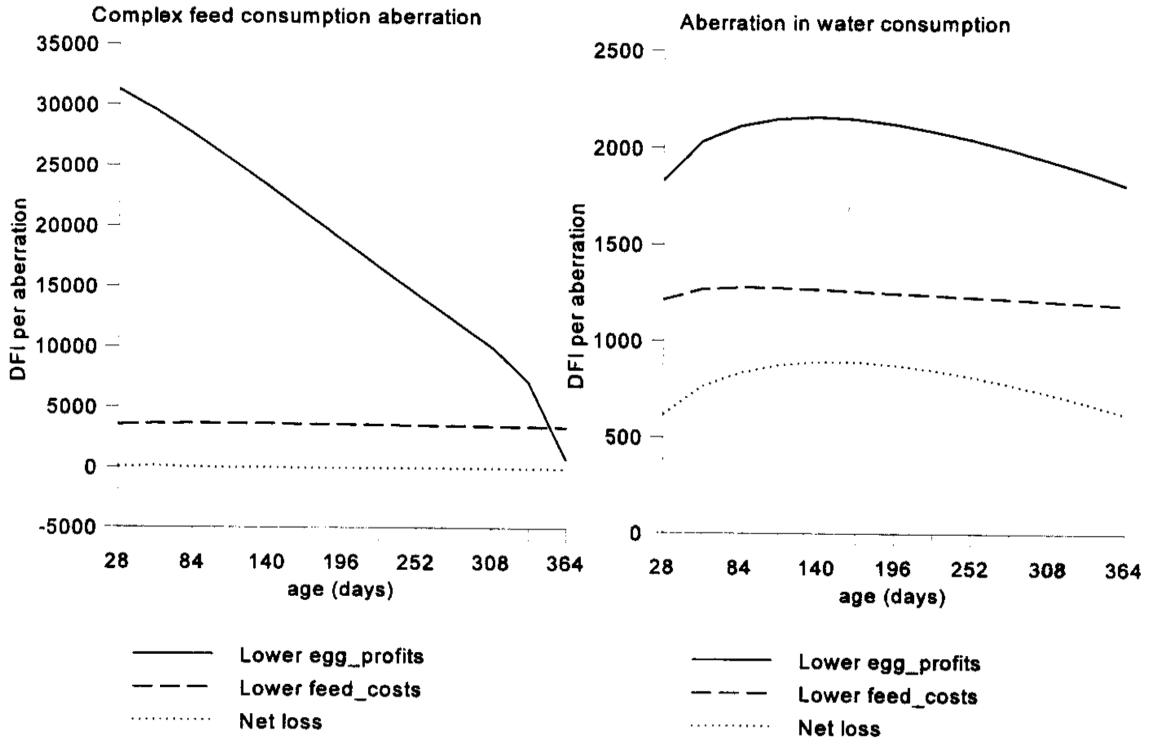

Figure 3 Relation between the simulated egg profits and feed costs of a complex feed consumption and a water consumption aberration and the age of the hens when the aberrations start.

minimum loss was 617 Dfl. It is clear from figure 3 that the economic loss can be severe throughout the whole production period, so detection of aberrations is important during the whole production period.

4. CONCLUSIONS

A simulation model has been constructed that consists of three parts, namely a biological subsystem, an aberrations subsystem and an economic subsystem. By altering the parameters of the mathematical curves of the biological subsystem and by altering the six parameters of the aberrations subsystem it is possible to simulate the consequences of aberrations under different production circumstances.

Results show that the economic effects of aberrations can be very high, which leads to the conclusion that it is important to detect aberrations in time during the whole production period, and that it can be profitable to invest in management tools that support the poultry farmers to detect in time aberrations in the production process.

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