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Technological and Economic Risk Analysis of laying hen breeding applying simulation

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**„What was expected, what we observed,
the lessons learned.”**

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ABSTRACT

In order to analyse risks and to choose from different decision-making strategies simulation models are often applied in several areas of animal breeding. We developed an improved Monte Carlo model for analysing laying hen breeding combined with Bayes' statistics. On the basis of data from a company breeding broiler parents, our paper examines the technological and economic risks of breeding a laying-hen stock with a simulation program developed by our team. During modelling we take individual cost elements and the most significant factors (different forage costs, price of sold eggs, unsuitable eggs, installing day-old chicks and old animals) affecting returns into consideration. The results can be presented in tables and graphs for both sexes as well. Specific production value, cost and revenue indicators can also be formed separately, thus the simulation allows the quantification of farming risks. Both the mathematical background of the program and its applicability in risk and economic analysis are presented.

Keywords: Monte Carlo, Risk analysis, Chicken production, Bayesian statistics, foraging

1 INTRODUCTION

Simulation models in various sectors of animal husbandry are regularly used to facilitate selection among various decision-making strategies and to analyze risks in production. Simulation models are presented as clusters of various assumptions in relation to the operation of the studied system, which are expressed by mathematical and logical correlations among the relevant objects of the system (WINSTON 2003). In animal husbandry, stochastic models are generally used as they include randomness (CSÁKI 1981). Among stochastic models, *Monte Carlo* models constitute a separate group as their model parameters are not necessarily of normal distribution. Models in animal husbandry are usually rather complicated, so the determination of their input parameters runs into difficulties (MÉSZÁROS 2005). Therefore, several models do not treat the uncertainties of input variables. This is not problematic when the operation of the given production system is to be analyzed, but it is a significant issue when the production system model is to be developed for decision support or for risk analysis (JORGENSEN 2000a). In these cases the model needs to include the total uncertainties and fluctuations of input parameters. "Decision-making in animal husbandry was treated for a long time as a toy against an unconscious adversary, nature. The Bayes' decision rule of maximum usefulness was applied as a selection criterion among probable activities. The key principle of the method is that we know the preliminary, "a priori" distribution of natural conditions (JORGENSEN 1999). The so-called Bayes-type statistical methods are also based on this principle. Several researchers apply *Bayes' statistics* in their simulation models to include their previous information into these models calculating the possibility of their modification as a result of several other factors (JORGENSEN 2000b; KRISTENSEN AND PEDERSEN 2003).

On the basis of data from a broiler parent breeding company in the North Great Plain region, our paper studies the technological and economic risks of breeding a laying-hen population by a simulation program based on the mathematical combination of Bayes' statistics and a Monte Carlo simulation, developed by our team. On one hand, the technological and economic risks of laying-hen breeding are influenced by body mass growth, mortality and egg production that are different for stocks kept in various or the same farms but bred in various time periods. On the other hand, we sought to form a lifelike simulation, so the program contains certain technological elements such as selection to maintain homogeneity or optimal forage supply.

2 MATERIAL AND METHODS

Businesses breeding broiler parents for meat production are predominant in each country (KALMÁR 2001) that can be characterized with highly-developed poultry breeding, as the production of broiler chickens in large quantities requires far more farm facilities and parents (HORN 2000). A basic requirement is to have stocks of equal lineage and age on farms simultaneously where their parents are bred and they can only be removed simultaneously as well (all in, all out), which was taken into consideration in our simulation model. Therefore we collected our primary data from one of the largest company keeping broiler parents in the North-Great Plain Region in relation to several years, stocks and various farms. The company owns building facilities for the breeding of a hen-laying stock of 200 thousand. The hybrid kept here is a genotype of Ross 308, with good development vigour and good, favourable feed conversion (ZOLTÁN AND HORVÁTH 1997). As to preserve continuous production, birds are kept in a rearing and two laying farms. The characteristic technological data of simulated farms are presented on Table 1.

Table 1.: Summary figures of breeding technological elements

Name	Breeding young stock	Breeding laying hens
Method of breeding	Until the age of 20 weeks Surface of 2 x 9 x 1.000 m ² (2 blocks) Reception of 48.000 pieces of day-old chicks, in rotation Technology of deep-bedding /kept on the floor	Post-breeding of parents until the age of 24 weeks, then egg-laying until the age of 60 – 64 weeks 4 x 4 x 1.000 m ² (4 blocks) 5.500 pieces/hen-house Grated floor + area for scratching Nests for egg-laying placed along the walls on both sides
Drinking facilities	Nipple drinker of Monoflow	Nipple drinker of Zigity
Feeding facilities	Choretime C2 in 14 hen- houses, Minimax circular feeder in 4 hen-houses	The system of scratching chains with two circles of reverse direction, separate rooster feeder for roosters
Ventilation system	Transversal ventilation, 24 ventilators/building	Cowls on both sides + fans in the crest of the roof
Heating facilities	In 6 – 6 houses Dantherm furnaces with electric warm air insufflation, gas-infra in 3 – 3 hen-houses	-

2.1 Monte Carlo simulation

The Monte-Carlo method is a generally accepted method of modelling risks, which studies the probable outcome of an event characterized by any input parameters and described by well-known functions. The essence of the Monte-Carlo technique is, on the basis of probability distribution assigned to some uncertain factors, to randomly select values, which are used in each experiment of the simulation (RUSSEL AND TAYLOR 1998). Monte-Carlo methods are the statistical evaluations of numerical methods and their characteristics using the modelling of random quantities of mathematical solutions (SZOBOL 1981). The method is widely used to simulate the likely outcomes of various events and their probability when input parameters are uncertain. Our simulation model is a simplified mathematical implementation of a real poultry-breeding system that seeks to examine the behaviour of the original system under different varying conditions and circumstances. This model also allows us to compare the performance and profitability of various stocks and to evaluate decision alternatives. We applied a more improved variant of the Monte-Carlo technique. In the simpler version, by increasing the number of runs, the distribution of result variants can be given with arbitrary accuracy as follows (JORGENSEN 2000b):

$$\psi = E_{\pi}\{U(X)\} = \int U(x)\pi(x)dx, \quad (1)$$

where $X = \{\theta, \phi\}$ is the vector containing θ decision parameters and ϕ state parameters.

The most obvious example for decision rules is decision-making on culling. We can decide on the usage of certain fodders, the sex ratio of animals, and we can further include innumerable decision factors into our models depending on the models. The $U()$ function is the function of profitability (generally equal with income).). The $E_{\pi}()$ function is the expected value of $U()$ function in the case of some π probability distribution. During modelling, several hundreds of calculations are performed by randomly choosing one value out of input parameter values, i.e. $X = \{x^{(j)}\}$, where $x^{(j)}$ were taken from the

distribution of π . At the end of the simulation, an expected value is gained for the result variant to be determined, which can be calculated as follows (JORGENSEN 2000b):

$$\bar{\psi} = \frac{1}{k} \{U(x^{(1)}) + \dots + U(x^{(k)})\}, \quad (2)$$

where k is the number of simulation runs. In our simulation, we applied a more improved variant of the Monte-Carlo technique. Let $X = \{\theta, \phi\}$ be a vector containing θ decision parameters and ϕ state of nature parameters. We can decide on the usage of certain fodders, the sex ratio of animals, and we can further include innumerable decision factors depending on the model. The $U()$ function is the function of profitability. The $E_{\pi}()$ function is the expected value of $U()$ function in the case of some π probability distribution. the ϕ set of state parameters is further divided into two groups, $\phi = (\phi_0, \phi_s)$, where ϕ_0 are the initial values of simulation runs (states of nature) at the onset of calculations. For poultry breeding the states of nature parameters are average mass growth (ϕ_{01}), its variance (ϕ_{02}), survival rate (ϕ_{03}), the rate of fertile eggs (ϕ_{04}), and the percentage of egg production (ϕ_{05}). ϕ_s is a vector containing the state of nature parameter values modified in the simulation runs. Naturally, state parameters can change period from period, so $\phi_s = (\phi_1, \dots, \phi_T)$, where $1, \dots, T$ are indices marking periods. Thus the form of the simulation model results in formula (1) (JORGENSEN 2000B):

$$\bar{\psi} = E_{\pi_0} \{E_{\pi_{s|0}} \{U(X)\}\} = \int \left\{ \int U(x) \frac{\pi(x)}{\pi_0(\phi_0)} d\{\theta, \phi_s\} \right\} \pi_0(\phi_0) d\phi_0, \quad (3)$$

where $E_{\pi_{s|0}} \{U(X)\}$ is the conditional expected value of a $U(X)$ function for a given, initial state of nature parameters. The conditional expected value is identical with the inner integral formula, which comes from Bayes' basic statistical correlations on the basis of formula (4):

$$\pi(x | \phi_0) = \frac{\pi(x)\pi(\phi_0 | x)}{\pi(\phi_0)}, \quad (4)$$

where ϕ_0 indicates the initial values of natural parameters. Practically, the simulation is the numerical implementation of this double integral formula. The method seeks to find the decision strategy and the probability distribution required for the maximum value of the above formula. At the initial point of the simulation we form an n pseudo-random $\phi_0^{(i)}$ variant from the distribution of $\pi_0(\phi_0)$ and then we perform k runs for each and every $\phi_0^{(i)}$, altogether $n*k$ runs. We get the value of $\bar{\psi}$ according to formula (5):

$$\bar{\psi} = \frac{1}{k} \{U(x^{(1)}) + \dots + U(x^{(k)})\}, \quad (5)$$

where $x^{(j)}$ were taken from the distribution of π . Then we calculate the average of $\bar{\psi}^{(i)}$ variants in the same way. We take the state of nature parameters of singular π_k distribution, which we call hyperdistribution and its parameters are hyperparameters. We applied a normal distribution for modelling the weekly mass growth during various weeks of life, and a normal hyperdistribution. This means that the average and variance of weekly mass is also normal. We accomplished an exponential log-rate survival model for estimating survival rates, and a Gamma hyperdistribution with $\alpha = (\text{survival rate})^{0.6}$; $\theta = (\text{survival rate})^{0.4}$ parameters. In case of egg production and the rate of fertile eggs we used a Beta hyperdistribution with $\alpha = 10 * \text{fertility}\%$ and $\beta = 1000 - 10 * \text{fertility}\%$ parameters. Distributions were chosen on the grounds of theoretical

and literary considerations (KRISTENSEN AND PEDERSEN 2003). On the grounds of standard data, function-like relations can be fitted among the body mass of hens and roosters and fodder consumption. The technological description of the Ross company specified the recommended doses of forage to reach the required body mass for certain weeks of life and the functions were prepared accordingly. As on various weeks of life various mixes are fed, fodder consumption was distributed into phases. For birds up to 18 weeks the following functions were formed:

For laying hen: $f_1(\text{testtömeg}) = e^{3.4803 + 0.000496 * \text{testtömeg}}$

For rooster: $f_2(\text{testtömeg}) = e^{3.71 + 0.000328 * \text{testtömeg}}$

The formula for calculating the elasticity function is: $E(f(x)) = \frac{x}{f(x)} \cdot f'(x)$

The above functions are significant in the optimization of foraging. If we form elasticity functions for the above functions, the birds' body mass under the standard mass can be detected and we can calculate the volume of extra fodder needed for the birds to reach their required body mass.

2.2 Calculating Costs and Incomes

The other goal of simulation was to analyse the cost, revenue and income conditions of meat type breeding egg production by a model structured on the basis of the production data of a given enterprise. Under given conditions, the model simulates the production costs of meat type breeding egg production, the distribution of its variable and constant costs, its production value, revenue and profitability. In our calculations, we investigated forage costs, constant and variable costs separately. Based on accounting records, forage costs included purchased feedingstuffs of industrial origin, purchased agricultural products, plant products and feedingstuffs from own sources. As a result of consultations with farm experts and economic executives, besides feedingstuff costs we totally included the costs of medicine, purchased day-old animals and examination fees in variable costs. In addition, we included 10% of lubricants, heating fuels, water, gas and electricity in this category. We received the constant costs by deducting variable costs from the total costs.

For the construction of our simulation model we calculated the following technological data: The sex ratio of the animal stock is optimal physiologically: 10:1 hen-rooster ratio. The length of the production cycle is 20+42 weeks (1.-20.-62 life week). The production of breeding eggs during a production cycle is 148 pieces/hen. The rate of breeding eggs is 86% on average. With these major technological indicators, taking prices into consideration, we calculated cost, revenue and income conditions presented in Table 2. It can be seen that production cost per one layer is about 6258 HUF, production cost is 6536 HUF, so the resulting income is about 278 HUF, which is 1.88 HUF per one breeding egg.

Table 2: Cost structure, production value and income of simulated breeding egg production

Name	for 1 layer (HUF)	For 1 breeding egg (HUF)
Material-type cost	4469.60	30.2
Personal type cost	1244.68	8.41
Depreciation	54.76	0.37
Auxiliary plant costs	112.48	0.76
Other direct costs	35.52	0.24
Sectoral general costs	340.40	2.3
Production cost	6257.44	42.28
Production cost	6535.68	44.16
Income	278.24	1.88

The data in the Table 2 show that 71% of the production costs is material type cost, of which 52% is feedingstuff cost and 40% is the purchase cost of point-of lay parents. On the basis of all these we can state that the keeping costs of parents are mostly determined by feedingstuff and point-of lay parent prices. The value of produced breeding egg accounts for 85% of production value, and out of by-products, the most significant is the value of culling hens (7,2%). So the volume of income depends on the price of breeding eggs and produced brooding eggs, the volume of which was changed according to technological parameters. The cost-related profitability of production under the given conditions is 4.45%. The net cost of breeding egg production is 42.28Ft/db HUF/piece.

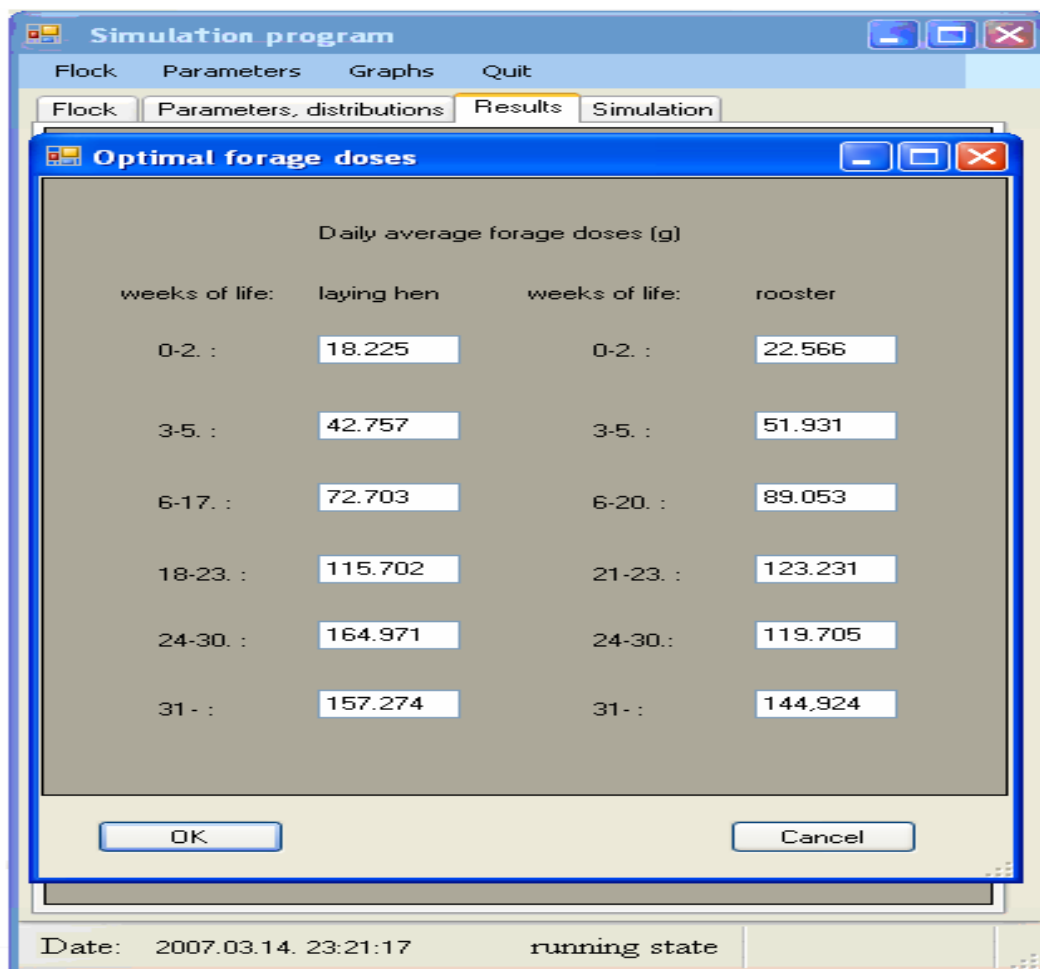
3 INTRODUCTION OF RESULTS

Raw data were originated from the computer system of the studied company. After we have received these data we broke them down according to stock, age and farm, we produced the suitable hyperdistributions in relation to mass growth and we estimated hyperparameters as well. Regarding mortality, we estimated the expected rate of survival for each week of life for the studied population in each farm. We calculated the rates of egg production and fertilization on the basis of primary data as well. The type of stock, sex ratio, the number of egg storing days and the type of the farm were the decision variants of the simulation model. The development of body mass is controlled by the regulation of fodder volumes. The determination of fodder doses is based on their correlation with the expected mass. Fodder doses are specified by elasticity functions. Certain birds' resistance against diseases and their competitiveness for feed are different, so the relative standard deviation of body mass grows with increasing stocks. The reasons may include chick quality, fodder distribution, fodder quality, temperature, vapour content, vaccination and diseases. As homogeneity is as important as reaching the expected body weight, we also included this technological element in our simulation program. To preserve homogeneity until egg production, the stock is selected into 2-3 groups at the age of 28-35 (week 4-5), when the relative standard deviation of body mass is between 10-14% (Anonym, 2007).

First the relative standard deviation of the total stock should be calculated and then group sizes are determined to reach equal stocking density in various groups. The mass limit of certain groups is calculated in a way that relative standard deviation should not exceed 8% in each group. During selection, the program arranges each bird into a group which corresponds to its body mass. Birds which are at the body mass limit value get into a lower group. After selection, the program treats the case when birds of light body mass have

their average weight at least 100 g below technological body weight. Then the program marks a new curve in parallel with the technological one until day 105., so that birds could reach the required body mass by day 140. The aim in the case of heavy weight birds is to reach the expected body weight by their age of 9 weeks. If they remain overweight, the program marks a parallel curve above the technological one and does not shift their body mass back to the technological curve. After week 10 there is no selection, and birds cannot get from one group to another. Birds in various body mass groups are fed differently. Surplus feed doses are fed to recover birds below the expected body mass to the required one. The simulation program was run at the sex ratio of 5:1 for 500 birds and 62 weeks of life in 50 replications in the case of a given farm (the number of simulation replications was 5, the number of the different states of nature was 10).

Figure 2: Optimal daily average forage doses in grams

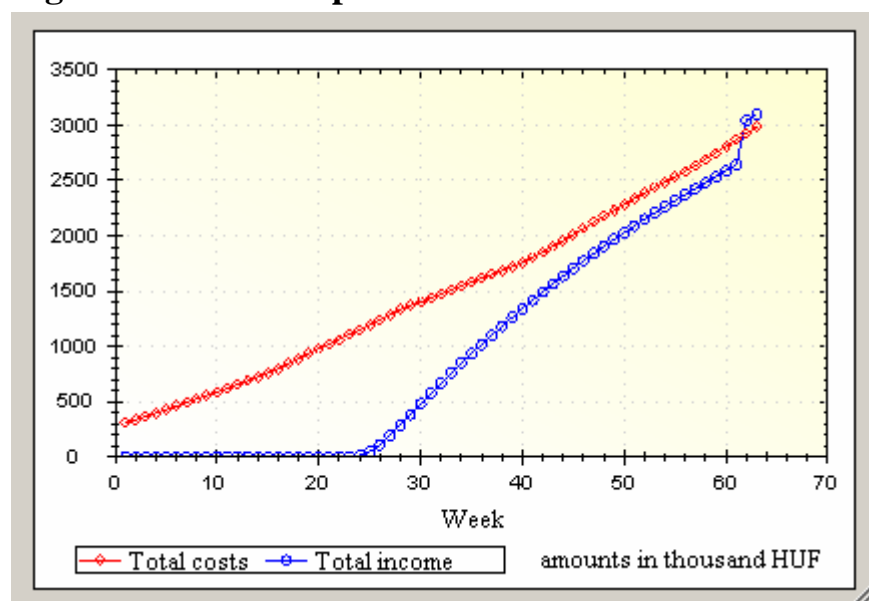


Source: Own calculations based on our own simulation program

Time intervals may differ during feeding various fodder mixes (Figure 2.). The volume of average daily feed can be calculated for these periods, which can be used for the calculation of total fodder consumption.

Figure 3. shows the development of the simulated total costs and income of an animal stock during 62 weeks. It can be clearly seen that in the early phase of production (keeping on rearing farms) only costs emerge, as there is no revenue from egg production.

Figure 3 Development of the total costs and income of stock in certain life weeks



Source: own calculation

A few weeks after resettling the birds to the laying farm, depending on the light program, the production of the stock gets started. Then egg production outstandingly accelerates up to week 60, and the stock is partially sold from this time. The program sells all the laying hens by week 62. It can be observed that the production value curve crosses the total cost curve only after selling the stock. This means that income occurs in breeding egg production at this time. Besides the above type of figure, the program prepares graphs mostly on the basis of production indicators.

4 CONCLUSIONS

Several simulation models neglect the uncertainties of input variables. In our model we applied a more improved variant of the Monte-Carlo technique instead of a simpler version in order to compare the performance and profitability of various stocks and to evaluate decision alternatives with better accuracy. By using simulation techniques in production before bringing practical decisions, the occurrence probability of natural states can be examined, which can later influence experts in solving actual problems. The application of our model can facilitate corporate decision –makers in the implementation of more efficient production without risking their existing resources and in reducing the uncertainties of agricultural production in general. For example we can calculate the volume of average daily feed for given periods, which can be used for the calculation of total fodder consumption. The development of the simulated total costs and income of an animal stock during 62 weeks proves that in the early phase of production only costs emerge, and the production value curve crosses the total cost curve only after selling the stock in the last week. This means that income occurs in breeding egg production at this time. The production cost is 6536 HUF (about 6258 HUF per one layer), the resulting income is about 278 HUF, which is 1.88 HUF per one breeding egg. The cost-related profitability of production under the given conditions is 4.45%.

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